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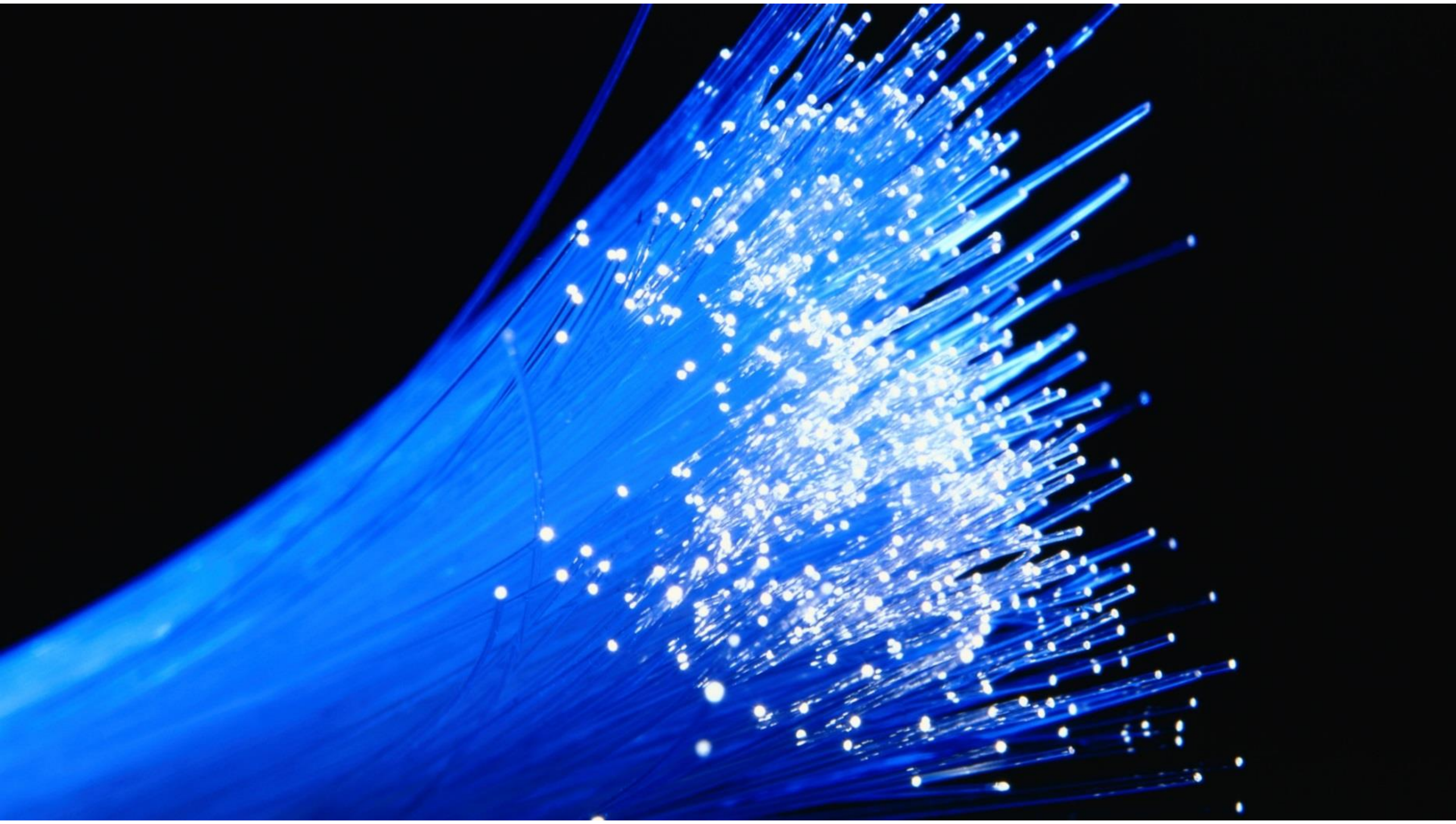

FTTP Deployment Cost & Financial Projections

Prepared for the Holland Board of Public Works
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Draft

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1 Executive Summary

1.1 Background and Objectives

The Holland Board of Public Works (HBPW) owns and operates a fiber optic network that includes infrastructure throughout parts of its service area, encompassing the City of Holland and surrounding communities. The HBPW currently serves commercial customers over fiber with three different service offerings: dark fiber leases, point-to-point bandwidth direct to customers, and "open access" bandwidth for Internet Service Providers (ISP) to sell services to customers.

The HBPW is interested in potentially expanding its successful fiber operation in two ways: First, using its existing fiber as a foundation, it seeks to deploy an expanded fiber-to-the-premises (FTTP) network throughout its service area to reach more customers. Second, it seeks to act as an ISP and sell services directly to customers—while also maintaining its open access approach, and promoting competition in the local broadband market by continuing to lower the barriers to entry for competitive ISPs.

Through this planned expansion, the HBPW seeks to increase the availability and affordability of 1 Gbps ("gigabit") service—and, in the long term, to future-proof its network so that it will continue to meet the community's broadband needs.

The HBPW hired CTC Technology & Energy (CTC) to evaluate the HBPW's existing infrastructure, analyze various financial models for an FTTP expansion, and develop a cost estimate for outside plant (OSP) construction.

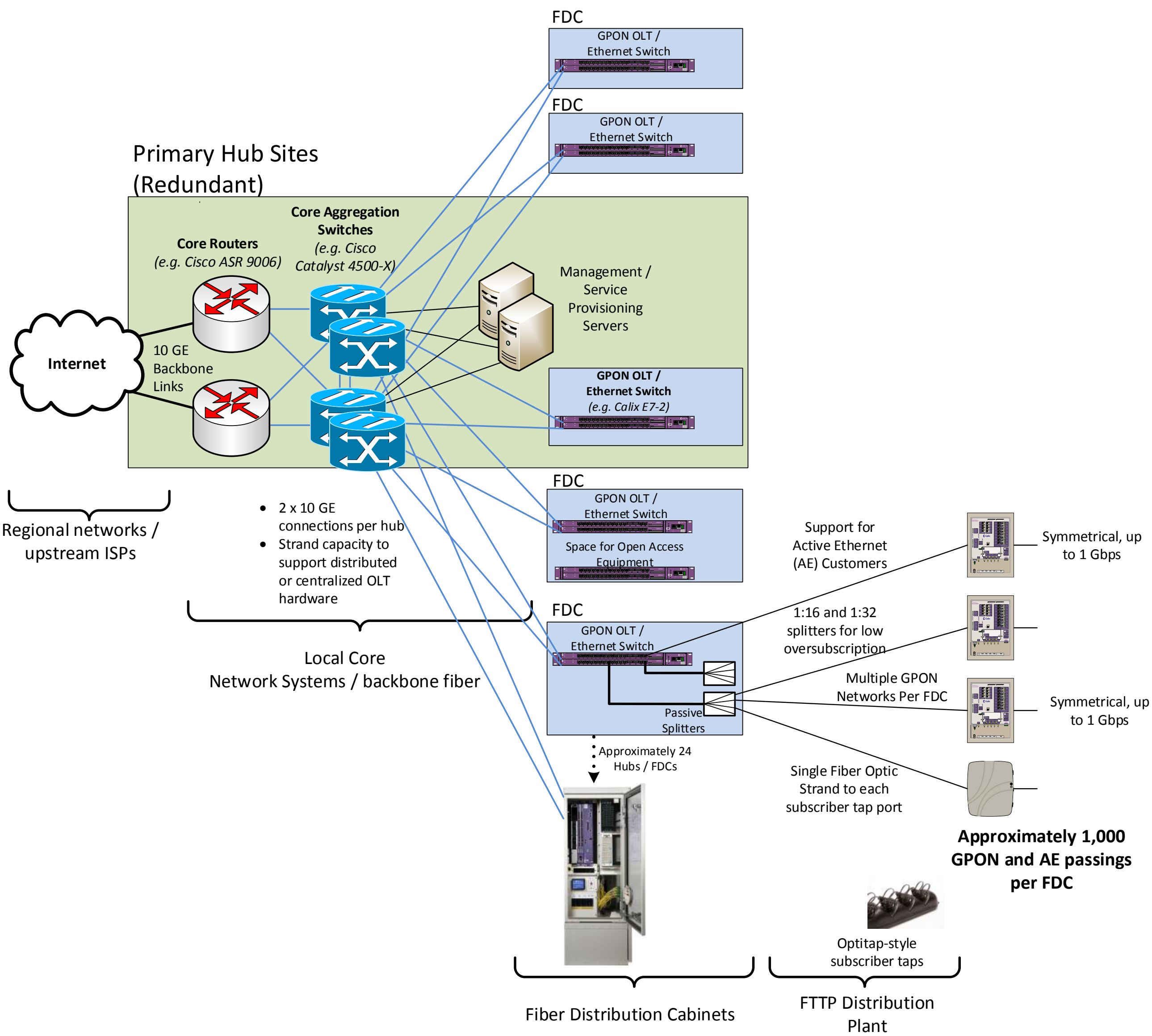
1.2 Candidate FTTP Design

The recommended design is a hierarchical data network with different attributes at each layer, targeting a balance of critical scalability and flexibility, both in terms of the initial network deployment and the network's capability to accommodate the increased demands of future applications and technologies. The design criteria driving this hierarchical FTTP data network are capacity, availability, physical path diversity, scalability, flexibility, and security.

Extensively leveraging the existing HBPW fiber plant, the recommended design entails a backbone network interconnecting approximately 24 hub locations over approximately 45 miles of physically diverse routes. The backbone includes core network electronics of sufficient capacity and scalability to support the demands of residential and business FTTP services throughout the HBPW electric service footprint. The backbone design seeks to deliver high-capacity, resilient data transport to network nodes located within close physical proximity to all target customers, enabling the HBPW to offer nearly any level of business and residential services.

The recommended network architecture (Figure 1) places active distribution network switches, Active Ethernet access switches, and Gigabit Passive Optical Network (GPON) Optical Line Terminal (OLT) hardware in hardened shelters and equipment cabinets equipped with backup power and other environmental support systems, aggregating customer connections over multiple, fully redundant 10 Gigabit Ethernet uplinks.

Figure 1: High-Level FTTP Architecture



The recommended fiber topology provides dedicated "home run" fiber strands from each potential customer to these hub locations, allowing growth in capacity demand to be met by reducing GPON split ratios and/or providing dedicated Active Ethernet connections to certain customers, while supporting any conceivable future access network technology that may emerge. By emphasizing scalability in the longer lasting, underlying physical fiber infrastructure, the HBPW can adopt a more conservative, pay-as-you-grow approach to future network electronics upgrades.

The design model and assumptions employed for cost estimation yield the following totals for certain key metrics:

Table 1: Summary of Design Model Metrics

Physical Plant	
Total passings	28,854
Average Passing density	61 passings per route mile
Total hubs	4
Total FDCs	20
Total backbone routes (new and existing)	45.5 miles
Total new backbone routes	2.2
Total distribution plant path	472
Total distribution cable placement	1,091 miles
Estimated aerial / underground plant	55% aerial / 45% underground
Total new pole attachments	10,604 poles
Network Electronics	
Total GPON interfaces	928 (14,848 customers at 1:16 split or 29,696 customers at 1:32 split)
Total Active Ethernet (1 GE) interfaces	464
Aggregate Access Capacity	2,773 Gbps downstream 1,618 Gbps upstream
Aggregate Distribution Network capacity (OLT to Distribution Layer)	480 Gbps
Aggregate core capacity (Distribution Layer to Core)	80 Gbps
Maximum oversubscription	1:361

1.3 Financial Overview

The base case financial analysis we present in this report reflects the revenue needed to cover the cost of serving the HBPW's entire service area, including the City of Holland and remote areas. The total capital costs (roughly $47.5 million, inclusive of OSP construction and network electronics—not including customer service drops and customer premises equipment), and the ongoing operating costs described in Section 5 are the cost to meet the HBPW's goal of providing ubiquitous fiber services.

In the base case analysis we assume that the HBPW offers three retail services, at prices that compare favorably to similar services in other cities:

- A 1 Gbps residential service at $80 per month,
- A 1 Gbps small commercial service at $85 per month, and
- A 1 Gbps medium commercial service at $220 per month (including service-level agreement)

We also assume that the HBPW will offer two wholesale transport services:

- A 1 Gbps residential service at $62 per month, and
- A 1 Gbps small commercial service at $66 per month

We assume a 39.6 percent take rate for both residential and business customers—and that for each sector, 90 percent will choose 1 Gbps retail service and 10 percent will choose 1 Gbps wholesale transport. (For the business sector, we further assume that 5 percent of businesses will obtain the higher-level retail service, 85 percent will opt for the lower-level retail service.)

The financial analysis for this base case scenario is as follows:

Table 2: Base Case Financial Analysis with 39.6 Percent Take Rate

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,996,344	$ 10,996,344	$ 10,996,344	$ 10,996,344
Total Cash Expenses	(2,251,000)	(3,790,970)	(3,790,970)	(3,790,970)	(3,790,970)
Depreciation	(1,893,940)	(5,864,230)	(3,777,560)	(3,716,080)	(3,678,700)
Interest Expense	(1,800,000)	(2,427,220)	(1,563,910)	(766,120)	(129,110)
Taxes	-	-	-	-	-
Net Income	$ (3,047,858)	$ (1,086,076)	$ 1,863,904	$ 2,723,174	$ 3,397,564
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,708,492	$ 529,080	$ (232,240)	$ 5,951,130	$ 16,035,400
Depreciation Reserve	-	2,024,620	2,506,540	1,545,840	3,012,200
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,758,492	$ 4,803,700	$ 4,524,300	$ 9,746,970	$ 21,297,600

The base case scenario also assumes issuance of $62.2 million of debt (combination of loans and bonds). The complete model is provided in Appendix C.

This analysis does not indicate whether obtaining this required take rate is realistic; rather, it reflects the take rate necessary to maintain a positive cash flow, considering all other assumptions in the model. That said, while we did not conduct market research or test the reasonableness of a 39.6 percent take rate, results from other municipalities do suggest that this take rate is possible—although the take rate is dependent on local conditions and the success of the marketing program. For most municipal systems, obtaining a 35 percent take rate is quite realistic, while obtaining and maintaining a 40 percent take rate requires an extremely effective marketing program.

We note that most municipal examples are based on a “me-too” triple-play of services that are similar to the incumbent offerings and often compete on price. The proposed HBPW offering is a data-only service that is substantially more robust than other data products available in the area. To date we are aware of two municipal utilities that offer a similar line-up. The first, in Sebewaing, Michigan, is approaching a 60 percent take rate. In Sebewaing’s case, however, the utility faced little competition (DSL and cable modem service in Sebewaing is spotty and unreliable). The second example is Longmont, Colorado. Longmont started offering services a few months ago, and is doing a phased deployment. In neighborhoods where it has deployed, it has seen take rates in the 40 percent range with a $50 per month residential data product.

Given the size of the required capital investment, the HBPW could approach a network deployment in a phased manner. For example, the HBPW could start in the City, and do early deployment where take rates are highest (i.e., building out in neighborhoods where a certain percentage of residents have committed to buying service). Such an approach would lead to ubiquity but, in the short term, would help the HBPW to manage its capital costs and risks.

The phased approach presented in the financial model completes the build in a three-year period—an approach that is quite different to the customer-by-customer way in which the HPBW has grown the existing fiber network. That type of organic growth is not realistic with a residential FTTP build, for a number of reasons. First, FTTP needs to be deployed in clusters of neighborhoods to maintain reasonable fiber construction costs. Second, there would be political pressure if the FTTP build did not deliver ubiquitous coverage in a reasonable deployment period. Extending out the deployment period would likely upset residents who do not have coverage and may create the appearance that the HBPW is red-lining neighborhoods.

1.4 Recommendations

The HBPW’s planned FTTP enterprise will likely struggle if it attempts to compete with incumbent providers by offering services similar to existing packages (a “me-to” product offering). Instead, it is important 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. Our analysis suggests that a ubiquitous 1 Gbps service may enable the HBPW to directly serve customers with an exceptional “niche” offering, and avoid competing with “me too” services.

A 1 Gbps service that is expandable to 10 Gbps and beyond may be the differentiator that the HBPW needs to stand out. By focusing on an extremely powerful data-only offering and communicating with users about the potential advantages of a high-performance, unfettered data product, the HBPW may spark the shift in the market it needs to be successful. The goal is to focus on *unbundling*, and effectively encouraging consumers to leverage the data service to its fullest capacity—by not emulating traditional providers and focusing on television lineup as a selling feature.[1]

A 1 Gbps service offering can significantly disrupt the market by enabling over-the-top (OTT) content and enabling consumers to make more flexible choices about the services they subscribe to, and the providers they select. This enables choice and competition in the market.[2]

The general next steps—which are dependent on the business model pursued—include:

1. Complete required due diligence under the State of Michigan Metro Act
2. Determine whether the HBPW pursues a FTTP business and, if so, determine which model (retail vs. public-private partnership)
3. Refine business plan and select suppliers/partners
    a. Retail model – key suppliers include help desk, peering, bandwidth
    b. Partnership
        i. Conduct RFI/RFP to solicit and assess interest
        ii. Select partner; define responsibilities, terms, and conditions
4. Begin detailed design
    a. Select engineer for detailed design
    b. Prepare bid documentation
        i. Electronics
        ii. OSP
5. Obtain required authorizations

The cost estimate for initial legal and consulting support is $250,000. The estimate for engineering for the OSP is $6.18 million (see Table 12 for additional details).

[1] 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, or “me too” services.
[2] Note that this analysis recommends an initial offering of 1 Gbps service. Over time, incumbents may work to challenge the HBPW’s FTTP offering, and the HBPW will have to respond by evaluating its offering and potential changes it should make at that time.

2 Assessment of Local Broadband Market

To support our financial analysis of an FTTP expansion of the HBPW's fiber network, we assessed the current market for residential, small business, and enterprise services within the City of Holland (a primary subset of the HBPW's service area that can be correlated to Census information and other available market data) . In the sections below, we identify the speeds and pricing for a range of available services; this competitive assessment informs our recommendations for potential HBPW retail offerings (see Section 5).

2.1 Residential and Small Business Services

Residential and small business customers in the Holland area have access to a range of services, though individual service options are dependent on location. Table 3 lists some of the service providers in the area and the range of advertised download speeds for each type of service that is available in at least some part of HBPW service area.

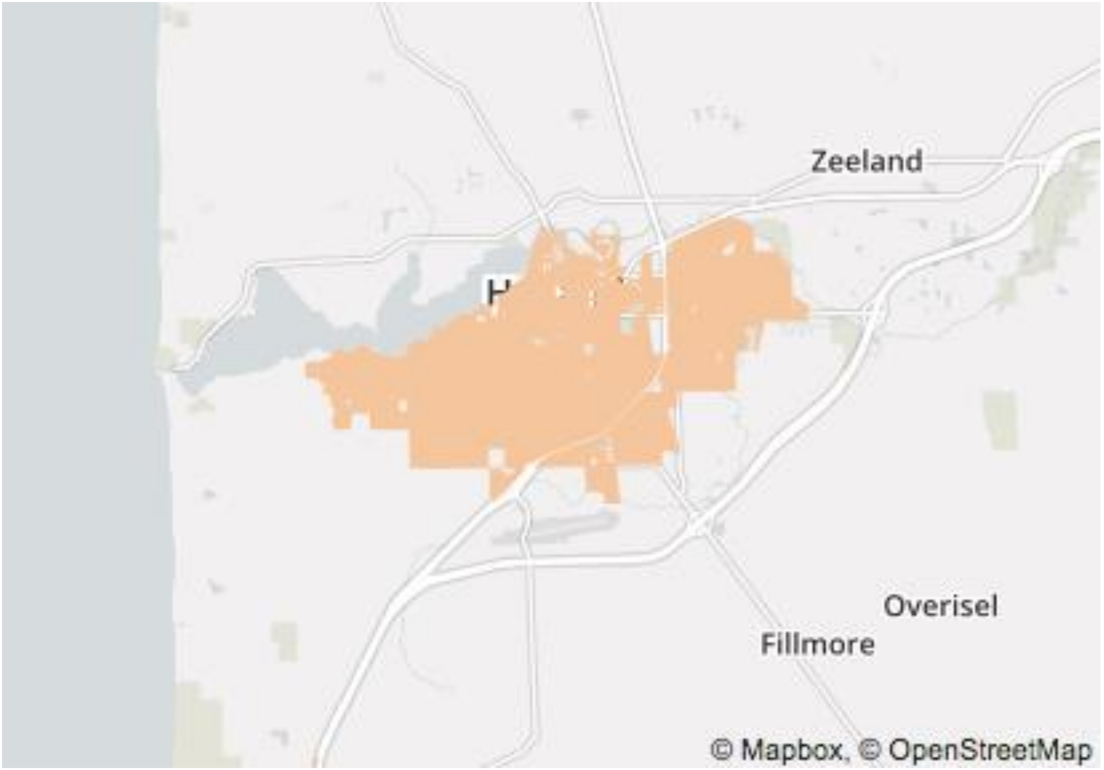
Table 3: Overview of Residential and Small Business Data Services in Holland

Service Type	Provider	Advertised Download Speed Range
Cable	Comcast	10 Mbps – 2 Gbps
DSL	AT&T	3 Mbps – 24 Mbps
	MegaPath	1.5 Mbps – 6 Mbps
Satellite	HughesNet	10 Mbps – 15 Mbps
3G/4G/Wireless Internet Service Provider	Verizon	5 Mbps – 12 Mbps
Fixed Wireless	Michwave	2 Mbps – 10 Mbps
Fiber	HBPW	1 Mbps – 50 Mbps

2.1.1 Cable

Comcast service is available in much of the City of Holland, as well as some of the surrounding areas, as shown in Figure 2 below.

Figure 2: Comcast Service Area[3]



Comcast currently offers Internet service with download speeds from 10 Mbps to 2 Gbps starting at $29.99 per month in some locations in Holland (see Table 4). Promotional rates are available for the first year, after which the rates increase. Discounted prices are available if Internet service is bundled with another service like voice or TV.[4]

[3] National Broadband Map, Comcast Corporation, http://www.broadbandmap.gov/about-provider/comcast-corporation/nationwide/, accessed February 2016.
[4] http://www.xfinity.com/locations/internet-service/michigan/holland.html, accessed January 2016.

Table 4: Comcast Residential Internet—Internet Only

Package	Internet Speed	Monthly Regular Price	Monthly Promo Rate
Performance Starter	Up to 10 Mbps download	$49.95	$19.99
Performance	Up to 20 Mbps download	$66.95	$39.99
Blast!	Up to 75 Mbps download	$91.95	$49.99
Extreme 150	Up to 150 Mbps download	$129.95	$99.99
XI Gigabit Pro	Up to 2 Gbps download	$299.95	-

Comcast advertises its 2 Gbps Gigabit Pro service as available in Holland, but it is only available in locations less than one-third of a mile from Comcast's existing fiber network, and is subject to a $500 activation fee and a $500 installation fee.[5]

On the small business side, Comcast offers multiple options with download speeds ranging from 16 Mbps to 150 Mbps (Table 5).[6] Bundling with voice reduces the cost by $30 to $40 per month.

[5] Todd Ogasawara, "Comcast begins rolling out DOCSIS 3.1-based gigabit home Internet, Extreme Tech, December 29, 2015, http://www.extremetech.com/extreme/220025-comcast-begins-rolling-out-docsis-3-1-based-gigabit-home-internet, accessed February 2016.
[6] http://business.comcast.com/internet/business-internet/plans-pricing, accessed January 2016.

Table 5: Comcast Small Business Internet—Internet Only

Package	Internet Speed (Download/Upload)	Monthly Price
Starter	Up to 16 Mbps /3 Mbps	$69.95
Deluxe 50	Up to 50 Mbps / 10 Mbps	$109.95
Deluxe 75	Up to 75 Mbps /15 Mbps	$149.95
Deluxe 100	Up to 100 Mbps /20 Mbps	$199.95
Deluxe 150	Up to 150 Mbps /20 Mbps	$249.95
Deluxe 250	Up to 250 Mbps /25 Mbps	$349.95

Comcast currently is in the process of upgrading its entire network from Data Over Cable Service Interface Specification (DOCSIS) 3.0 to DOCSIS 3.1. DOCSIS 3.1 uses channel bonding and orthogonal frequency division multiplexing (OFDM) to use available spectrum in the network more efficiently. This upgrade to DOCSIS 3.1 will provide only limited increases in available data capacity initially—approximately 25 percent more compared to DOCSIS 3.0 using the same system capacity—but coupled with more extensive physical upgrades and reconfiguration of the network, will allow the company to reserve a larger portion of the network for data traffic and deliver download speeds of up to 10 Gbps.

Comcast has already transitioned portions of its network in Philadelphia to DOCSIS 3.1, and has announced plans to transition its network in Atlanta, Nashville, Chicago, Detroit and Miami by the end of 2016. The company predicts that its DOCSIS 3.1 enabled gigabit service will be available across "virtually" all of its territory in the next two to three years.[7]

Unlike Comcast's fiber-based Gigabit Pro offering, which requires fiber to be installed all the way to the customer premises, the DOCSIS 3.1-based gigabit service can be delivered over the

[7] Jon Brodkin, "Comcast 2Gbps fiber available to 18 million homes, gigabit cable coming soon," *Ars Technica*, February 2, 2016, http://arstechnica.com/business/2016/02/comcast-2gbps-fiber-available-to-18m-homes-gigabit-cable-coming-soon/, accessed February 2016.

company's existing hybrid fiber-coaxial (HFC) network, with minimal new construction. Comcast has not yet announced pricing for its gigabit service.[8]

2.1.2 DSL

AT&T offers DSL service for residential customers in Holland, starting at as $30 per month for standalone DSL service up to 3 Mbps (download) with a 12-month commitment. Additional options up to 45 Mbps are available as indicated in Table 6.[9]

Table 6: AT&T Residential Internet—Internet Only

Internet Speed	Monthly Regular Price	Monthly Promo Rate
Up to 3 Mbps download	$42	$30
Up to 6 Mbps download	$52	$35
Up to 18 Mbps download	$62	$45
Up to 45 Mbps download	$82	$65

AT&T offers DSL-based small business services starting at $60 per month for up to 6 Mbps download/ 1.5 Mbps upload speeds. Additional options up to 24 Mbps are available (Table 7).[10]

Table 7: AT&T Business Internet—Internet Only

Internet Speed	Monthly Price
Up to 6 Mbps download	$60
Up to 12 Mbps download	$70
Up to 18 Mbps download	$80
Up to 24 Mbps download	$90

[8] Sean Buckley, "Comcast's 1Gbps drive could shake up AT&T, Verizon broadband plan," Fierce Telecom, February 10, 2016, http://www.fiercetelecom.com/story/comcasts-1-gbps-drive-could-shake-att-verizon-broadband-plans/2016-02-10, accessed February 2016.
[9] https://www.att.com/shop/u-verse/offers.html, accessed January 2016.
[10] https://www.att.com/smallbusiness/content/shop/internet-phone-tv/internet.page, accessed January 2016.

MegaPath is an Internet service provider (ISP) that offers DSL service to residential customers with a maximum speed of up to 6 Mbps download and 768 Kbps upload. MegaPath also uses a blend of technologies to offer small businesses service in some parts of Holland with a range of speeds[11] up to 100 Mbps download and 20 Mbps upload.

Frontier is another ISP that offers 6 Mbps DSL service to residential customers in Holland at an unbundled price of $34.99 per month.[12] I2K also offers retail DSL service, which it provides over Frontier and AT&T lines.[13]

2.1.3 HBPW Fiber

The HBPW provides point-to-point transport for some residential and business customers. Using this connection, small business customers can receive service ranging from 5 Mbps to 50 Mbps from ISPs that are connected to the HBPW fiber network, including 123Net, Iserv, Sirus, Comlink, and Lynx Network Group. Small business customers must pay a one-time setup fee of $550, engineering and construction fees in some locations, and a monthly rate to both the HBPW and the ISP.[14]

Currently, Iserv is the only connected ISP offering service to residential customers over the HBPW fiber network; Iserv's service range from 1 Mbps to 5 Mbps. Residential customers must pay a one-time fee of $200 (or $5 per month for four years), in addition to the Internet connection rates of both HBPW and the ISP. Iserv currently offers residential customers a 1 Mbps symmetrical connection for $30 per month and a 5 Mbps symmetrical connection for $50.[15]

2.1.4 Satellite

Satellite Internet access is available across the entire HBPW service area as well.

HughesNet has seven packages available, of which four packages are for Internet services to small businesses. The Select 100 package provides speeds of up to 10 Mbps download and 1 Mbps upload for $79.99 per month, with a 20 GB per month "Business Period" (8 a.m. to 6 p.m.) data allowance and an additional 10 GB anytime allowance, for a total monthly data allowance of 30 GB. The Select 200 and 300 packages provide speeds up to 10 Mbps download and 2 Mbps upload, and offer a higher data allowance during business hours. The Select 400 costs $159.99

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[11] https://www.megapath.com/services/, accessed January 2016
[12] http://internet.frontier.com/plans-pricing.html, accessed January 2016
[13] http://www.i2kdsl.com/pricing.htm, accessed January 2016
[14] https://www.hollandbpw.com/about-us/broadband/broadband-rates#business-broadband-rates, accessed January 2016
[15] Prices based on report of a current Iserv residential customer, reported to HBPW staff member, January 2016.

per month, offers up to 15 Mbps download and 2 Mbps upload speed, and provides a 50 GB per month data allowance during business hours, and a 10 GB per month anytime allowance for a total monthly data allowance of 60 GB. The three residential packages offer similar speeds and data allowances, and cost between $59.99 and $129.99. All of these packages require a two-year agreement.[16]

Exede also offers satellite Internet access, with three packages available in the Holland area. All packages provide up to 12 Mbps download and up to 3 Mbps upload, with a 10 GB data allowance costing $59.99 per month, an 18 GB data allowance costing $99.99, and a 30 GB data allowance costing $149.99 per month.[17] Parent company ViaSat recently announced plans to launch new satellites that will enable higher tiers of service, up to 100 Mbps. However, the launch is not expected until 2019.[18]

DISH offers satellite Internet access as well, with prices starting at $49.99 per month for up to 10 Mbps download with a 5 GB data allowance. The top service level costs $79.99 per month for up to 10 Mbps download with a 15 GB data allowance. Both packages are subject to a $10 per month equipment rental fee, and can be packaged with TV and phone service at reduced prices.[19]

2.1.5 Wireless

Verizon Wireless offers two 4G LTE data packages with multiple choices for data allowances and pricing, depending on the desired mobility and equipment chosen. LTE-Installed is a data-only 4G LTE service with Wi-Fi connectivity for up to 20 devices and wired Ethernet for up to four devices. Available download speeds are 5 Mbps to 12 Mbps; upload speeds are 2 Mbps to 5 Mbps. Monthly prices range from $60 for a 10 GB data allowance to $120 for a 30 GB data allowance. Overages are charged at $10 per additional GB. A two-year contract is required, with a $350 early termination fee. Verizon offers a $10 monthly deduction for every month completed in the contract.[20] Verizon's Ellipsis JetPack provides a mobile solution, with download speeds of 5 Mbps to 12 Mbps and upload speeds of 2 Mbps to 5 Mbps. Prices for the 12 options of data allowances range from $20 per month for a 2 GB data allowance to $710 per month for 100 GB of data, in addition to a monthly line access charge of $20. The device is $0.99 with a two-year contract. There is a $35 activation fee.[21]

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[16] http://business.hughesnet.com/plans-and-pricing/internet-service, accessed January 2016.
[17] http://www.exede.com/services-pricing/?zip=49423, accessed January 2016.
[18] Mike Freeman, "ViaSat taking satellite broadband global," *The San Diego Tribune*, February 9, 2016, http://www.sandiegouniontribune.com/news/2016/feb/09/viasat-spacex-eutelsat-boeing-satellite-internet/, accessed February 2016.
[19] http://www.dish-systems.com/products/dishnet/, accessed January 2016.
[20] https://www.verizonwireless.com/b2c/lte-internet-installed/ accessed January 2016.
[21] https://www.verizonwireless.com/b2c/lte-internet-installed/, accessed January 2016.

Sprint offers 4G LTE wireless data in Holland. The three data packages offered range from a 100 MB per month data allowance for $15 per month, to a 6 GB per month data allowance for $50 per month, to a 12 GB per month data allowance for $80 per month. Each MB over the limit is billed at a cost of $.05. A two-year contract is required, as well as an activation fee of $36 and equipment charges for three different types of devices. There is an early termination fee of $200.

AT&T also provides 4G LTE wireless data service in the area, but only offers one package type with a 5 GB per month download allowance for $50 per month. There is a fee of $10 per 1 GB over the limit. There are also equipment charges, with or without a contract, and an activation fee.

Of the cellular wireless providers in the area, the least expensive wireless data option offered is from T-Mobile, at $20 per month with a limit of 1 GB per month. T-Mobile offers additional capabilities and increasing data limits at incremental costs in a total of six packages, up to $70 per month for up to 11 GB of data. Depending on current promotions, the $35 activation fee is sometimes waived.

Michwave is a Western Michigan-based fixed-wireless ISP with coverage in the eastern and southern outskirts of Holland. Michwave's packages range from Standard, which provides download speeds of up to 2 Mbps to 3 Mbps for $55 per month, to Super, which provides download speeds of up to 10 Mbps for $90 per month. Installation costs between $150 and $650, depending on the length of the contract.[22]

2.2 Enterprise Market

This section provides an overview of competitive providers of dark fiber and lit services for enterprise customers in the City of Holland.

The HBPW's existing fiber network has already had a major impact on the availability and price of enterprise data transport services in the City. Many of the service providers we identified during the course of our research interconnect with the HBPW fiber network. The HBPW network has improved available service offerings and lowered the cost of new construction necessary for enterprise-grade data transport services.

During the course of our research, we identified 11 service providers in the Holland area that offer a range of enterprise services, from point-to-point connectivity to direct Internet access (DIA), with speeds that range from 1 Mbps to 100 Gbps. Individual providers tailor these services to customers' requirements (e.g., speed, class of service). Greater proximity to the provider's existing network infrastructure, or to the HBPW's existing fiber network, result in lower service

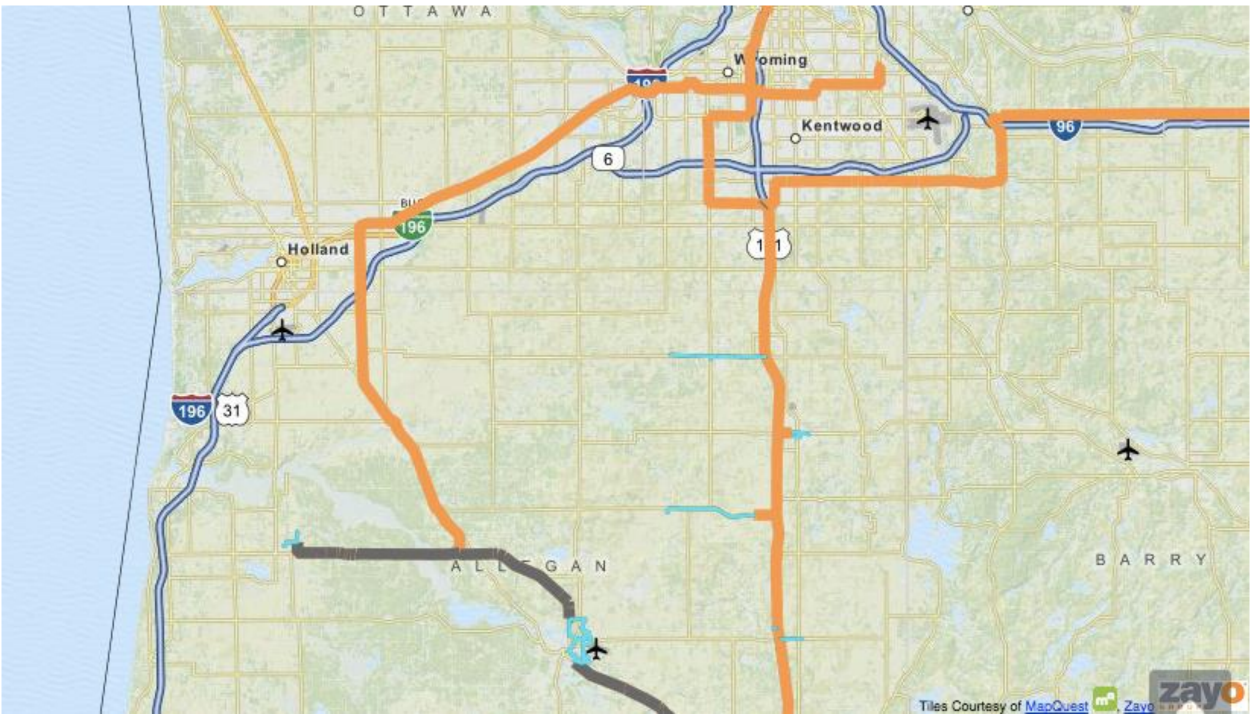
[22] http://www.michwave.com/index.php/prices2, accessed January 2016.

pricing. Providers prefer to offer transport services between locations on their network ("on-net") and provision Multiprotocol Label Switching (MPLS) based services for connecting locations that are "off-net."

2.2.1 Dark Fiber Services

The HBPW leases excess capacity on its existing fiber network for dark fiber services at a rate of $.0105 per foot per strand. We did not identify any other dark fiber available for lease in the Holland area, although Zayo's fiber network does pass to the east and south of Holland, as seen in Figure 3.

Figure 3: Zayo Fiber Routes[23]



Zayo claims to have proven expertise in deploying major new dark fiber networks and offers multiple financing options, including leases and Indefeasible Right of Use (IRU) agreements. Zayo's pricing varies significantly depending on whether the building to be connected is On-Net or not; if the location is Off-Net, construction and splicing costs would apply.[24] Currently Zayo has no On-Net locations within the HBPW service area.

2.2.2 Lit Services

Many service providers offer enterprise-grade, Ethernet-based services in Holland. Bandwidths range from 1 Mbps to 100 Gbps. Ethernet service can be classified into three types: Ethernet

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[23] http://www.zayo.com/solutions/global-network/, accessed January 2016.
[24] http://zayofibersolutions.com/why-dark-fiber, accessed January 2016.

Private Line (EPL or E-Line), Ethernet Virtual Private Line (EVPL), and ELAN. These may be known by different names among different providers.

EPL is a dedicated, point-to-point high-bandwidth Layer 2 private line between two customer locations. EVPL service is similar to EPL but is not dedicated between two locations. Instead, it provides the ability to multiplex multiple services from different customer locations from one point on the provider's network (multiple virtual connections) to another point on the network. ELAN is a multipoint-to-multipoint connectivity service that enables customers to connect physically distributed locations across a Metropolitan Area Network (MAN) as if they are on the same Local Area Network (LAN).

Internet services over Ethernet are typically classified under two categories: Dedicated Internet Access (DIA) and MPLS IP Virtual Private Networks (IP-VPN). MPLS-based networks can provide dedicated capacity and guaranteed performance levels for real-time applications such as voice and video and are typically priced higher.

The carriers that provide these services in the Holland include the six carriers that interconnect with the HBPW fiber network (123Net, Iserv, Sirus, Comlink, Merit Network, and Lynx Network Group) as well as AT&T, Comcast, EarthLink, MegaPath, Windstream Communications, XO Communications, and Zayo. Prices depend on the bandwidth, location, and network configuration; whether the service is protected or unprotected; and whether the service has a switched or mesh structure.

Iserv offers a range of Internet services using both its own cable network and the HBPW fiber network. Over its cable network, Iserv offers Internet access with download speeds up to 150 Mbps and upload speeds up to 20 Mbps for $355 per month. Using the HBPW fiber network, Iserv offers speeds up to 2 Gbps. The minimum 10 Mbps symmetrical service costs $415 per month, and a 100 Mbps symmetrical service costs $1,950, plus a $550 installation fee and additional construction and engineering fees based on location.[25]

123Net also uses the HBPW fiber network to provide enterprise services to Holland businesses. It offers symmetrical Internet access at $1,299 per month for 200 Mbps, $1,499 for 500 Mbps, and $2,199 for 1 Gbps. All prices are based on a 60-month contract and are subject to additional construction and engineering fees based on location.[26]

AT&T has four different types of Ethernet products—GigaMAN, DecaMAN, Opt-E-MAN, and Metro Ethernet. GigaMAN provides a native-rate interconnection of 1 Gbps between customer end points. It is a dedicated point-to-point, fiber optic-based service between customer locations,

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[25] Prices based on a quote for a new business customer in January 2016.
[26] Prices based on a quote for a new business customer in January 2016.

which includes the supply of the GigE Network Terminating Equipment (NTE) at the customer premises. DecaMAN connects the end points at 10 Gbps and is transmitted in native Ethernet format similar to GigaMAN, only 10 times faster. Opt-E-MAN service provides a switched Ethernet service within a metropolitan area. It supports bandwidths ranging from 1 Mbps to 1,000 Mbps, and configurations such as point-to-point, point-to-multipoint, and multipoint-to-multipoint. Metro Ethernet service provides various transport capabilities ranging from 2 Mbps through 1 Gbps while meeting IEEE 802.3 standards.[27]

Comcast provides EPL services, which enable customers to connect their customer premises equipment (CPE) using a lower-cost Ethernet interface, as well as using any Virtual Local Area Networks (VLAN) or Ethernet control protocol across the service without coordination with Comcast. EPL service is offered with 10 Mbps, 100 Mbps, 1 Gbps, or 10 Gbps Ethernet User-to-Network Interfaces (UNI) and is available in speed increments from 1 Mbps to 10 Gbps.[28]

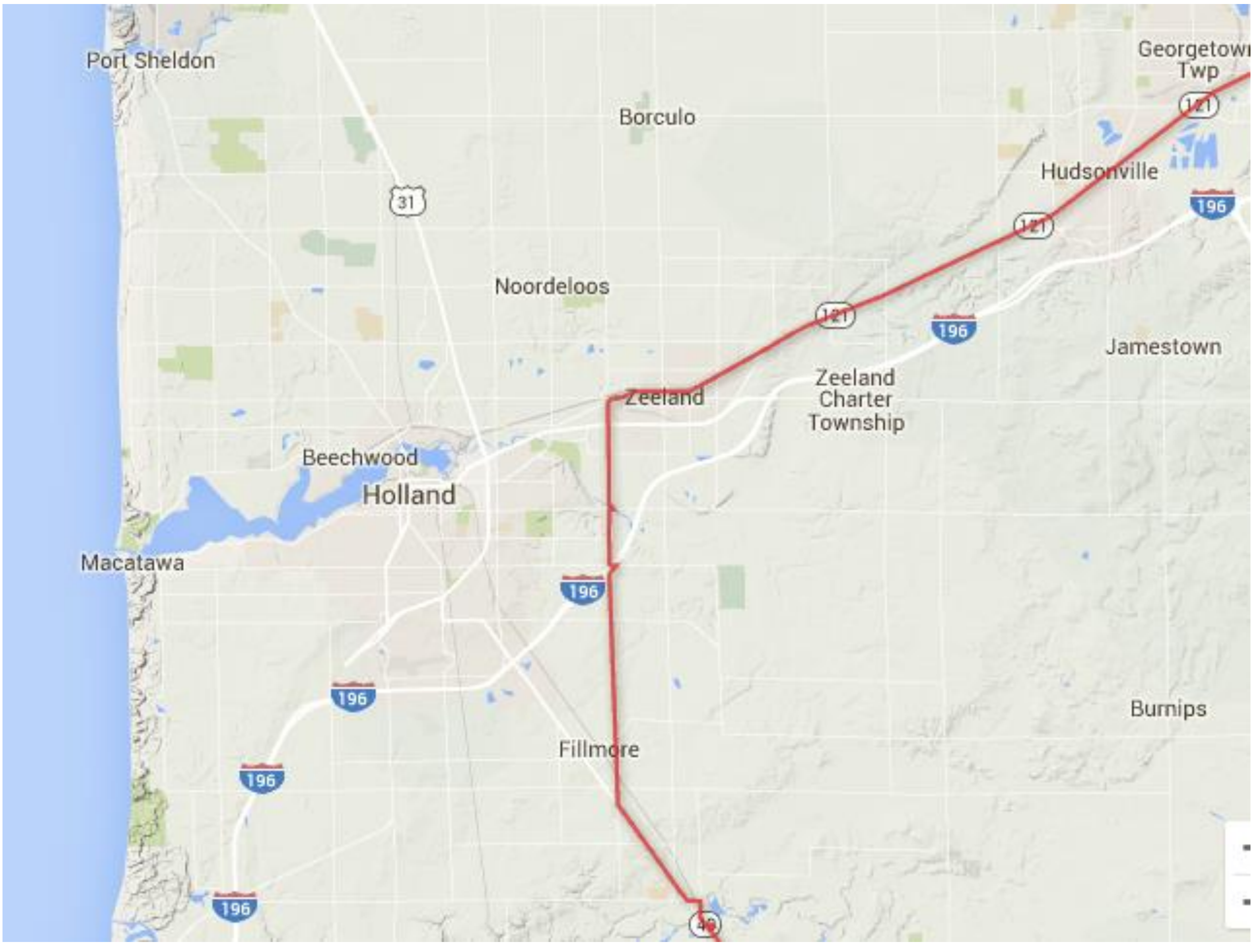
EarthLink offers both MPLS and Ethernet services in Holland. A 100 Mbps Ethernet connection costs $1,550 per month and a 1 Gbps connection costs $6,000 per month. Additional construction fees apply; those vary by location.

MegaPath offers a range of enterprise services in the Holland area with advertised symmetrical speeds up to 1 Gbps. A 1 Gbps Ethernet connection costs $9,898 per month, with a one-time installation fee of $1,334.[29] MegaPath also has lower-cost cable service available with a maximum speed of up to 100 Mbps.[30]

Windstream Communications has a nationwide presence serving major metropolitan areas—including Holland, where it offers DIA services with speeds up to 1 Gbps.[31] However, like Zayo's network, Windstream's network only passes the eastern edge of the City, as seen in Figure 4 below. The further a location is from Windstream's existing network, the higher new construction fees will be.

[27] http://www.business.att.com/service_overview.jsp?repoid=Product&repoitem=w_ethernet&serv=w_ethernet&serv_port=w_data&serv_fam=w_local_data&state=California&segment=whole, accessed January 2016.
[28] http://business.comcast.com/ethernet/products/ethernet-private-line-technical-specifications, accessed January 2016.
[29] Price based on a new business quote obtained January 2016.
[30] https://www.megapath.com/services/, accessed January 2016.
[31] http://www.windstreambusiness.com/shop/products/mi/holland, accessed January 2016

Figure 4 Windstream Fiber Network[32]



XO Communications offers carrier Ethernet and DIA services at multiple bandwidth options, from 3 Mbps to 100 Gbps, over its Tier 1 IP network.[33] Although XO Communication prohibits publishing its pricing data, we have shared relevant pricing data with HBPW staff.

[32] http://www.windstreambusiness.com/network-data-centers-map, accessed February 2016.
[33] http://www.xo.com/carrier/transport/ethernet/, accessed January 2016.

3 FTTP Objectives

As part of our analysis of business models the HBPW might want to pursue, we evaluated the HBPW's goal of ubiquitous service, as well as certain other common broadband objectives that many communities prioritize, and how these may affect the HBPW's decision-making process. Choosing which goals to prioritize can be challenging; we sought to provide the HBPW with information to empower decisions about its connectivity needs that will have ongoing positive outcomes.

3.1 Common Community Broadband Objectives

Competition and consumer choice are only two of several objectives that may drive a community's pursuit of a publicly owned fiber optic network. Many public entities share certain objectives when it comes to considering investment in a community broadband network. Examples of these common goals are as follows:

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

Each of these is understandable in the context of what is best for a community, though they do not necessarily all align with one another. In fact, some common objectives that communities prioritize when planning their networks actually conflict with one another. In light of this, communities benefit from careful consideration of which objectives they deem most important to adequately meet their needs.

As an example, risk aversion is top priority for some communities—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 is in direct conflict with the goal of building the network throughout an entire community—and that ubiquity may be the most important objective for another community.

Each community must balance its needs so that it can achieve its goals without sacrificing important objectives. Our analysis does not advise the HBPW on which objective(s) it should prioritize; rather, we describe common objectives and explain their roles in communities, how they interact with each other, and some of the potential advantages and disadvantages of each.

We illustrate in Table 8 below the intersection of common objectives. As the key at the top of the table shows, objectives may have no impact, they may be in alignment, they might conflict, or they may be inapplicable.

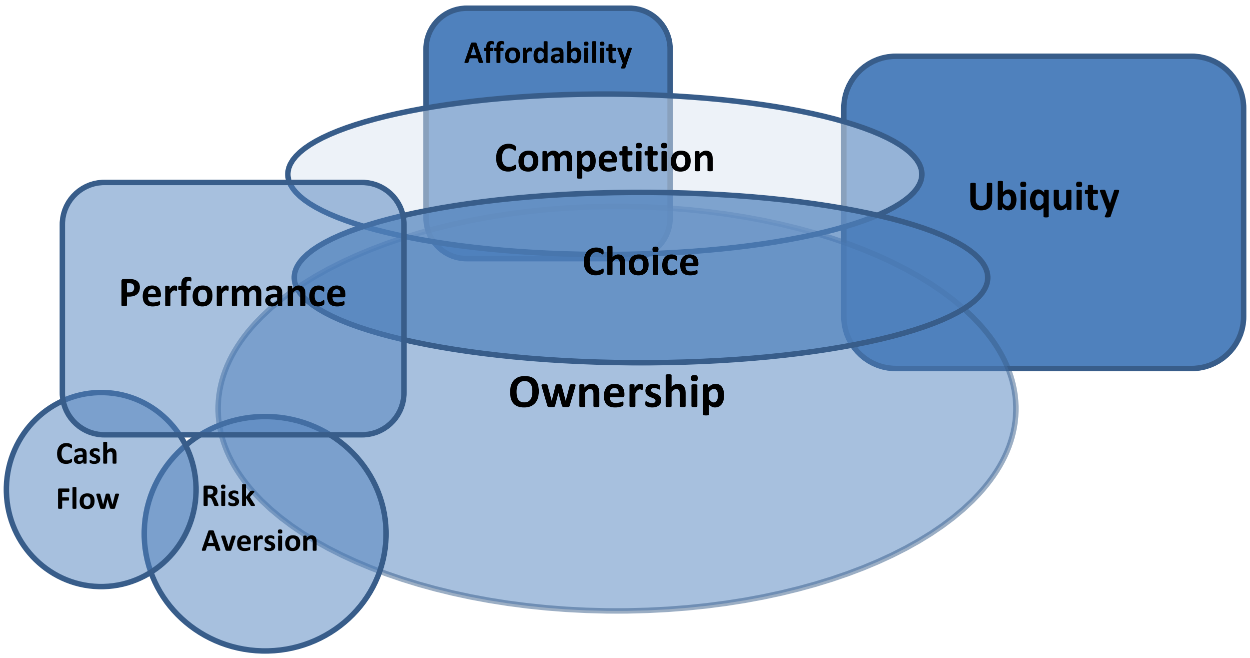
Table 8: Common Goal Alignment

A: Align	**C:** Conflict	**NI:** No Impact	**NA:** Not Applicable

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

In the sections below, we further explain this table and how the objectives listed here interact with one another (i.e., how prioritizing one objective may impact another). Figure 5 below shows a visualization of Table 8 to illustrate the relationship between objectives.

Figure 5: Interactions between Objectives



There are numerous possible outcomes associated with different objectives, and the HBPW has to determine what it believes will best serve its unique needs and have the greatest impact on its community. This analysis does not seek to urge the HBPW in any particular direction, but we do make recommendations about some of the objectives that may well serve any public network.

For example, performance is an objective that either interacts favorably or not at all with other objectives, and prioritizing performance can have a significant positive impact on the FTTP network's viability by setting it apart from incumbent providers. Thus, there are no real disadvantages to making performance a top priority for the FTTP network because doing so does not have to be at the exclusion of any other objectives. Further, some objectives can and should be pursued in parallel.

3.2 Ubiquity

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 structure in the community—is a key objective. From Connecticut to Minnesota to Oregon, communities (and community organizations) large and small have prioritized ubiquity as a primary goal in their broadband pursuits.[34]

This is a respectable objective for any community, and it makes sense that leaders want to bring service to the entire community—but immediate, communitywide build-out often entails significant risk and cost. The financial risk alone is significant, and in order to make the model sustainable, the service may have to be priced out of some consumers' reach.

Overall risk aversion conflicts directly with the notion of a full-scale community build-out, as the HBPW will likely face stringent construction deadlines and much higher capital costs than it would if it were to undergo a phased build-out. The need for outside funding is likely also higher with a ubiquitous network build, which greatly increases the HBPW's risk.

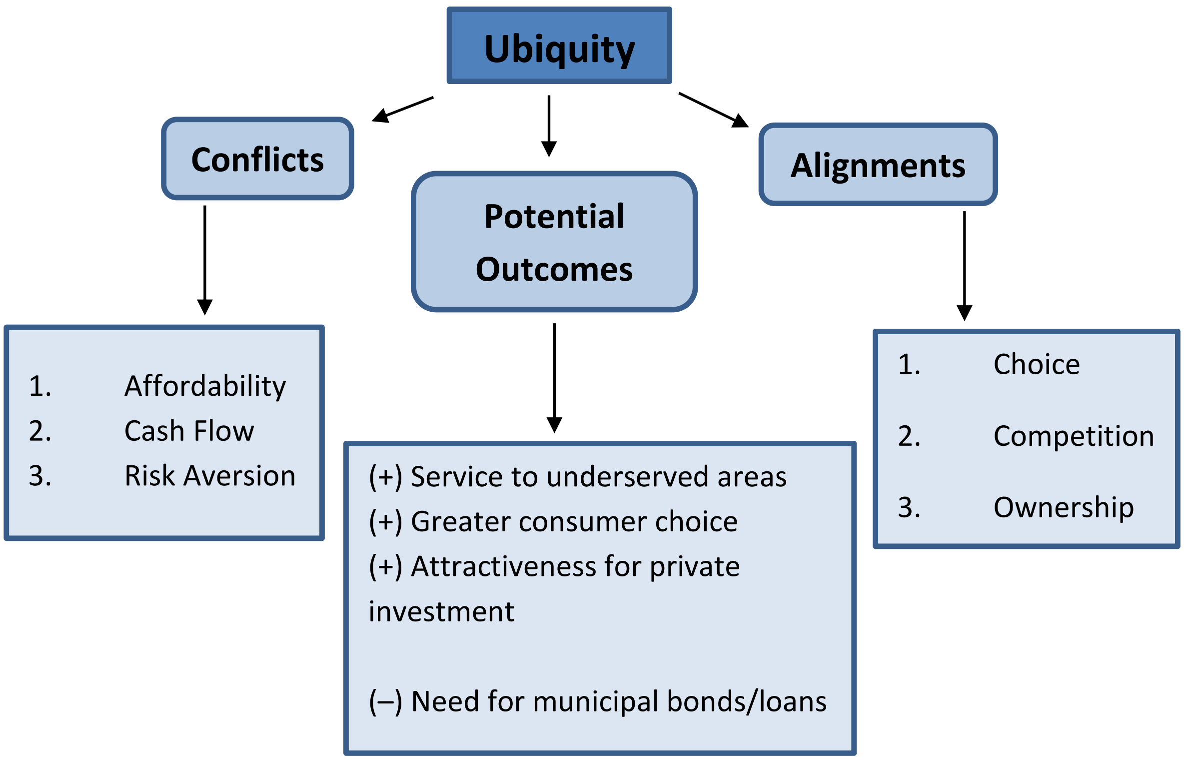
Because the HBPW will likely need to procure financing from an outside source, and due to the high capital investment necessary for large-scale construction, it is likely that the HBPW will be forced to raise monthly service fees. This would reduce the affordability of the HBPW's FTTP service and to some degree would defeat the purpose of ubiquitous build-out. If the service reaches the entire community but is priced too high for many residents and businesses to afford, the HBPW would fail to meet its goal of providing access to its citizens—because the service would essentially be inaccessible.

Cash flow is another objective that conflicts with ubiquity. The HBPW likely will not expect to make a profit on the FTTP network, but it is important for the entity to become able to financially sustain itself, including operating costs and any debt service payments. This is often referred to as "cash flow" or "breakeven." The higher cost of building out to every structure in the HBPW service area means that the point at which the FTTP network is able to cash flow will come much later than if the HBPW slowly built out and began generating subscriber revenue earlier in the build-out process.

Figure 6 shows conflicts, alignments, and potential outcomes associated with prioritizing ubiquity.

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

Figure 6: Ubiquity Alignments, Conflicts, and Potential Outcomes



3.3 Consumer Choice

As we noted, localities often pursue open access as a means to increase consumer choice, and 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.

An overarching goal of developing an open access network is to level the provider playing field to reduce monopolistic and oligopolistic practices by incumbents, and to give consumers greater choice in service providers.

Most other objectives that a community decides to pursue will interact favorably with consumer choice. A ubiquitous network that fosters open access, boosts competition, and reaches all parts of the community enhances consumer choice on a number of levels. In addition to gaining access to residential services that may have previously been unavailable, consumers often 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 is an important component in access that 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 better access to basic human services like healthcare and education.

Risk aversion could negatively impact consumer choice. If the HBPW 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 HBPW 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. If the HBPW chooses to seek partnership, this could be negotiated.[35]

3.4 Competition in the Market

Fostering competition in the market is generally the second component of an open access pursuit. That is, communities 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 major reason communities 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.

The key for most objectives is to determine whether they are primary, how they may conflict with others, and how best to pursue whatever a community deems is its most important goal(s). We believe that competition both upholds and is upheld by all other potential primary objectives—it aligns with, does not impact, or is not impacted by other common community objectives.

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 HBPW's network, but also in the form of incumbent providers lowering prices and enhancing services in response to improved services by other providers.[36] This also speaks to competition vis-à-vis affordability and network performance: the

[35] The Urbana-Champaign Big Broadband (UC2B) public network negotiated a similar partnership with a private entity.
[36] http://www.cnet.com/news/googles-fiber-effect-fuel-for-a-broadband-explosion/, accessed April 2015.

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 to a public provider. A major challenge faced by networks built and operated by public institutions is opposition from existing, private-sector providers, as we previously noted. There are a number of reasons for this, some of which are related to perception while others relate to the market itself. Criticisms will range from allegations of cross-subsidization of expenses, using general or other funds for debt service coverage, to questioning the need or demand for public based connectivity services.

An important risk that the HBPW should keep in mind is the potential for litigation from objectors ranging from incumbent providers to watchdog groups. Lafayette's LUS was sued by incumbent providers the same year it proposed creation of a separate utility for fiber-to-the-home-and-business,[37] and the Tennessee Cable Telecommunications Association filed a lawsuit against EPB.[38] These are only two examples of the litigation that public sector entrants to the market have faced from incumbent providers and others.

3.5 Ownership and Control of Assets

Retaining ownership of outside plant (OSP) assets is important to mitigate risk; owning assets is an important way for communities to retain some control of the network. This includes a scenario wherein a community pursues partnership with a private provider—a good way to balance risk and reward is for the HBPW to maintain ownership and control of the 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 to what degree the HBPW chooses to exert control. Maintaining a fiber optic network can be costly, particularly if the HBPW 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 cash flow.

[37] http://lusfiber.com/index.php/about-lus-fiber/historical-timeline.
[38] http://www.chattanoogan.com/2007/9/21/113785/Cable-Group-Files-Suit-To-Try-To-Block.aspx.

Other objectives either interact favorably or not at all with ownership and control of the assets. If the HBPW retains complete control of the assets, it can make determinations about which provider(s), if any, can offer services over the network. It can regulate which service providers offer services and to what degree, thus allowing for considerable quality control. For example, if a locality offers dark fiber agreements to multiple ISPs, it can determine specific metrics that guide the providers' service.

Similarly, the HBPW 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 HBPW may also be able to govern price points to support consumer affordability and service speeds to enhance performance. And because the HBPW owns the network itself, it is in control of performance at that level.

3.6 Performance

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

Prioritizing performance in a municipal retail offering is not only advantageous, we believe it is necessary to make the offering stand out among existing broadband providers. Market entry is generally a major challenge for municipal 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 HBPW's FTTP enterprise will likely struggle and has a greater potential for failure if it attempts to compete with incumbent providers by offering services similar to existing packages. Instead, it is important 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. Our analysis suggests that a 1 Gbps niche service may enable the HBPW to directly serve customers with an exceptional offering, or will enable a private partnership to enter the market and avoid competing with "me too" services.

A 1 Gbps service that is expandable to 10 Gbps and beyond may be the differentiator that the HBPW needs to stand out. By focusing on an extremely powerful data-only offering and communicating with users about the potential advantages of a high-performance, unfettered data product, the HBPW may spark the shift in the market it needs to be successful. The goal is to focus on *unbundling*, and effectively encouraging consumers to leverage the data service to its fullest capacity—by not emulating traditional providers and focusing on television lineup as a selling feature.[39]

Performance interacts favorably or not at all with other objectives, which is shown in the visual breakdown in Figure 6. 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.

As we noted, a 1 Gbps service offering can significantly disrupt the market by enabling OTT content and enabling consumers to make more flexible choices about the services they subscribe to, and the providers they select. This enables choice and competition in the market.[40]

As we noted, if the HBPW retains ownership of its assets, it also has better control over performance. The HBPW—whether acting as the retail provider or overseeing a private entity who is serving end user customers—can command the 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 HBPW minimizes its risk by entering the market with a premium 1 Gbps high performance network. The HBPW can set itself apart from other providers by offering a high-speed data product that incumbents cannot.[41] 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, or telecommute to their job, or pursue an advanced degree.

3.7 Affordability

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

There are areas in Holland 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

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[39] 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, or "me too" services.

[40] Note that this analysis recommends an initial offering of 1 Gbps service. Over time, incumbents may work to challenge the HBPW's FTTP offering, and the HBPW will have to respond by evaluating its offering and potential changes it should make at that time.

[41] It is important to note that products like AT&T's GigaPower and Comcast's Gigabit Pro do not set their advertised 1 Gbps and 2 Gbps service as a baseline, which is what we have suggested to the HBPW. Rather, these products offer a 10 Mbps to 100 Mbps baseline with the potential to offer 1 Gbps to 2 Gbps service as occasional exceptions. The HBPW, on the other hand, may be able to provide service up to 10 Gbps and beyond with 1 Gbps as its baseline.

most likely to recover their cost to build. While the HBPW is fortunate that it 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 benefit for the City in forms like enhanced quality of life and economic benefit. Further, the HBPW could work with local government 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. Bringing ultra-high speed affordable access to portions of the community that may have previously had little to no access to any connectivity may significantly enhance the quality of life, thus often raising a community’s overall desirability.

As we previously noted, prioritizing ubiquity may come at the exclusion of affordability for some consumers unless the HBPW is able to offset costs in some other way. It could negotiate an agreement with one or more private partners that includes sensitivity to the need for affordable, accessible services in all parts of the community. Similarly, the HBPW may decide that it is politically palatable to subsidize services for certain portions of the community.

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

If the HBPW decides to subsidize services, it may find that it becomes more difficult to prioritize risk aversion and cash flow. The more debt and responsibility the HBPW takes on, the higher its risk and the longer it will take for the FTTP network to be cash-flow positive. Similarly, even if the HBPW 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 HBPW to determine its priorities, and to strike a balance so that one objective is not achieved entirely at the exclusion of another.

3.8 Risk Aversion

Risk aversion is important, and 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 HBPW’s top objective. The “slow and steady” approach is not without merits, but it also does not necessarily give a community a competitive edge. Decreased speed to market—or building out slowly—gives competitors too much time to respond to the HBPW’s approach.

Figure 7 shows a risk and reward matrix that highlights the HBPW'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 build-to-demand model.[42] This approach signs up a community by neighborhood (known as "fiberhoods" in the Google Fiber model) and once a neighborhood has reached a certain threshold, fiber will be built there.

Figure 7: Risk and Reward Matrix

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

If the HBPW 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 HBPW has to 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 HBPW 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,

[42] http://www.wsj.com/articles/google-fuels-internet-access-plus-debate-1408731700

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 HBPW 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. As we previously noted, the HBPW's speed to market is critical to secure its potential competitive edge and take full advantage of its unique niche service offering. Further, affordability becomes more difficult to achieve because the HBPW must align service fees to support self-sustaining operations. This means the monthly service will be priced higher to avoid City subsidy.

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

3.9 Cash Flow

Becoming cash flow positive is a common 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. Net income then deducts interest, taxes, and depreciation. It is also important to note that when EBITDA becomes positive, the business is not necessarily cash flow positive. This is because EBITDA does not include interest on debt, service payments, or capital replenishments. The complete financial analysis needs to include both an income statement (EBITDA and net income) and a cash flow statement.

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 HBPW elects to retain ownership of all network electronics, including customer premises equipment (CPE). Depreciation costs are significant, and it is important to reserve funds for equipment and infrastructure replacement. Typically, last mile access network hardware 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 considered to be 20 years or more, our financial analyses do not account for its replacement.

Another element of ownership in the context of cash flow is the need for network maintenance and locating costs. Because the HBPW already owns a fiber network and has experience with locating, these additional costs will likely be incremental and less significant than a startup enterprise. Yet 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.

4 FTTP Network Requirements

The HBPW recognizes the importance of deploying a robust, scalable FTTP infrastructure that can support a wide range of applications and services.

This section describes many of the applications and services that the HBPW's FTTP expansion will need to support, as well as the general requirements of the FTTP network design. We present the proposed design in Section 5.

4.1 User Applications and Services

The HBPW's FTTP network must be able to support "triple play" services—high-quality data, video, and voice—that residential customers have grown accustomed to having in their homes, although this does not mean that the HBPW will be the entity that *directly* provides telephone or cable television services. As Internet technology has improved and network speeds have increased, voice and video services have become available as applications delivered by hundreds of providers over an Internet Protocol (IP) data network connection.

The HBPW can enable residential and small business customers to purchase voice, video, and other over-the-top (OTT)[43] services by providing them with unfettered,[44] reliable, high-speed Internet access with connections at a minimum of 1 Gbps.[45] In other words, the HBPW would become an IP data network provider, either directly or through partnership(s), and would enable its citizens to purchase services—without the HBPW taking a gatekeeper role.

Additionally, the HBPW would continue its "open access" operations, making the network available on a wholesale basis to any qualified provider to offer a data service bundled with Voice-over-Internet Protocol (VoIP),[46] cloud storage, or other services. The fiber connection will also support customer-selected applications such as telemedicine, VoIP, the Internet of Things (IoT), video streaming, home security monitoring, and cloud services.

4.1.1 Internet Access

Internet access is the fundamental service that most residents and small business owners will expect from a fiber connection, and is the prerequisite service for all of the applications described

[43] "Over-the-top" (OTT) content is delivered over the Internet by a third-party application or service. The ISP does not provide the content (typically video and voice) but provides the Internet connection over which the content is delivered.
[44] Meaning that access to websites offering OTT services is not blocked, restricted, or rate-limited.
[45] Rate is a best-effort basis, not a guaranteed speed. Further, it is important to note that with the proposed architecture the HBPW would provide a 1 Gbps baseline service and 10 Gbps and beyond on a case-by-case basis. The baseline can be increased to 10 Gbps and beyond by upgrading the network electronics
[46] Telephony (voice) service delivered over an IP data network

below. The HBPW's FTTP network will also include one or more peering connections with upstream ISPs, reducing wholesale Internet costs and improving service delivery.

As described in detail below, the FTTP network will support a baseline service level (e.g., 1 Gbps) suitable for residential and small business customers. It will also be capable of supporting higher residential speeds—10 Gbps and beyond—and a range of business and enterprise services.[47]

4.1.2 IP Telephony (VoIP) and Video Conferencing

As noted above, VoIP is a voice telephony service delivered over an IP data network.[48] In the context of an FTTP access network, VoIP generally refers to an IP-based alternative to Plain Old Telephone Service (POTS) over dedicated copper wiring from a Local Exchange Carrier (LEC). With VoIP, both the live audio (voice) and the call control (signaling) portions of the call are provided through the IP network. Numerous third parties offer this type of full-service VoIP, which includes a transparent gateway to and from the Public Switched Telephone Network (PSTN).

Because VoIP runs over a shared IP network instead of a dedicated pair of copper wires from the LEC, extra design and engineering are necessary to ensure consistent performance. This is how the VoIP services delivered by Comcast (which provides Quality of Service, or QoS, on its network underneath the VoIP services) typically have the same sound and feel as traditional wireline voice calls. In contrast, VoIP services without QoS (such as Skype) will have varied performance, depending on the consistency of the Internet connection. For voice and other real-time services such as video conferencing, network QoS essentially guarantees the perceivable quality of the audio or video transmission.

From a networking perspective, IP-based video conferencing services are fundamentally similar to VoIP. While IP video conferencing is currently less common as a residential application, small and medium-sized businesses in the FTTP domain can be assured that QoS for IP-video conferencing can also be supported, as with VoIP.

4.1.3 Streaming Video

The variety of online video available through service providers like YouTube, Netflix, Hulu, HBO Go, and others continues to attract users and challenge cable providers' traditional business models. These are all examples of OTT[49] video available over the Internet to users at home or on mobile devices like a smartphone or tablet.

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[47] Network can support faster connection speeds and other guaranteed service levels to some portion of end users.
[48] In this context, voice services are delivered over a data connection.
[49] OTT refers to voice, video, and other services provided by a third-party over the Internet rather than through a service provider's own dedicated network. OTT is also known as "value added" service.

Traditional cable television providers (also known as linear multi-channel video services) can also deliver content over a fiber connection rather than through a separate coaxial cable connection to users' homes.

All of these video services can be supported by the HBPW's FTTP network—as will be locally produced content from the Media Center and public service videos or documentaries filmed by high school students, which can be streamed to residents directly from a school, library, or government building that is on the network. The avenues through which consumers can access content are broadening while the process becomes simpler.

Because of the migration of video to IP format, we do not see a need for the FTTP network to support the Radio Frequency (RF) based video cable television service, an earlier technology used by some providers to carry analog and digital television in native form on a fiber system.

Early municipal providers like Lafayette Utilities System (LUS) and Chattanooga's Electric Power Board (EPB) found that a data product alone was not strong enough to obtain the necessary market share to make the endeavor viable. Even when Google Fiber entered the Kansas City market in 2011, it found that if it wanted to get people to switch providers, it *had* to offer cable, deviating from its original plan and introducing more cost and complexity than the simple data service it had anticipated. If an OTT cable offering were available when early municipal providers began offering service and when Google entered the Kansas City market, it may have found that offering traditional cable television was unnecessary. More recent municipal FTTP efforts, like Longmont, Colorado, are successfully gaining market share without providing video services. A case study of Longmont is provided in Appendix A.

4.1.4 Cloud Access

"Cloud services" refers to information technology services, such as software, virtualized computing environments, and storage, available "in the cloud" over a user's Internet connection. Enterprise and residential customers alike increasingly use cloud services. With the continually rising popularity of mobile devices like smartphones and tablets, consumers want access to their photos, videos, and music from anywhere. And businesses want employees to have access to important information to keep operations running smoothly, even when they are away from the office.

The business drivers behind cloud computing are ease of use and, in theory, lower operating costs. For example, if you are a business owner, the "cloud" theoretically allows you to use large-scale information services and technologies—without needing to have hardware or staff of your own to support it.

Cloud services eliminate the need to maintain local server infrastructure and software, and instead allow the user to log into a subscription-based cloud service through a Web browser or software client. The cloud is essentially a shift of workload from local computers in the network to servers managed by a provider (and that essentially make up the cloud). This, in turn, decreases the end user's administrative burden for IT services.

Typically, cable modem and DSL services are not symmetrical—thus incumbent network transfer rates to upload to the cloud are significantly slower than download rates. This can cause significant delays uploading to cloud services.

There are also numerous other cloud services that customers frequently use for non-business purposes. These include photo storage services like Flickr and Shutterfly, e-mail services like Gmail and Hotmail, social media sites like Facebook and Twitter, and music storage services like iTunes and Amazon Prime.

By enabling ISPs to reliably serve residents and small businesses with high-speed services, the HBPW's FTTP network will increase their options to use the cloud. Improving on less robust connections (e.g., cellular broadband or cable modem services), the HBPW's network will also enable telecommuters and home-based knowledge workers in Holland to access cloud-based development environments, interact with application developers (both local and remote), and access content distribution network (CDN) development and distribution channels.[50]

4.1.5 Over-the-Top (OTT) Programming

As we noted, OTT programming typically refers to streaming content delivered via a consumer's Internet connection on a compatible device. Consumers' ubiquitous access to broadband networks and their increasing use of multiple Internet-connected devices has led to OTT being considered a disruptive technology for video-based entertainment. The OTT market, which includes providers like Netflix, Hulu, Amazon Instant Video, and iTunes, is expected to grow from about $3 billion in 2011 to $15 billion, by 2016.[51]

In order to provision content, OTT services obtain the rights to distribute TV and movie content, and then transform it into IP data packets that are transmitted over the Internet to a display platform such as a TV, tablet, or smartphone. Consumers view the content through a Web-based portal (i.e., a browser) or an IP streaming device (e.g., Google Chromecast, Roku, Apple TV, Xbox 360, or Internet-enabled TV/Smart TV).

[50] See, for example: "Amazon CloudFront," http://aws.amazon.com/cloudfront/
[51] "Over-the-Top-Video – "First to Scale Wins," Arthur D Little, 2012 http://www.adlittle.com/downloads/tx_adlreports/TIME_2012_OTT_Video_v2.pdf

One potential difference in the delivery of OTT video content to consumers compared to other data traffic is OTT video's high QoS requirement. QoS prioritizes the delivery of video packets over other data where uninterrupted delivery is not as critical, which ultimately translates to a high quality viewing experience for customers. Content buffering and caching for streamed content reduces the need for QoS. Network QoS is designed for and driven by the need to support real-time services such as VoIP and video conferencing.

OTT providers typically have to use the operators' IP bandwidth to reach many of their end users. At the same time, they are a major threat to cable television programming, often provided by the very same cable operators, due to their low-cost video offerings. As a result, many cable operators have introduced their own OTT video services to reach beyond the constraints of their TV-oriented platforms and to facilitate multi-screen delivery.[52]

Even Comcast seemed to embrace OTT by launching its "Streampix" in 2012,[53] though that service was less than successful and was ultimately removed as a standalone offering. In 2015, Comcast announced another attempt at providing OTT content in the form of its "Stream" package,[54] however subscribers must also sign up for Xfinity Internet in order to access "Stream" content.

While the nature of OTT video lends itself nicely to VoD, time-shifted programming, and sleek user interfaces, OTT providers have limited control over the IP transport of content to users, which can cause strains on network bandwidth due to the unpredictable nature of video demand. Cable operators have experimented with rate limiting and bandwidth caps,[55] which would reduce subscribers' ability to access streaming video content. It is also technically possible for cable operators to prioritize their own traffic over OTT video streams, dial down capacity used by OTT on the system, or stop individual OTT streams or downloads.

Some cable operators have attempted to manage OTT on their networks by incorporating the caching of OTT video content from third-party providers (e.g., Netflix) in their data centers in order to improve QoS and reduce congestion on the cable provider's backbone network. This serves as a means for improving the quality of OTT video for video hosted in the data center.

[52] "Cable operators embrace over the top," *FierceCable*, July 2, 2013, http://www.fiercecable.com/special-reports/cable-operators-embrace-over-top-video-studios-thwart-netflix-hulu-options
[53] http://www.geekwire.com/2012/comcast-unveils-499-month-streampix-service-aim-netflix-hulu/.
[54] http://www.forbes.com/fdc/welcome_mjx.shtml.
[55] "Comcast tests new usage based internet tier in Fresno," *Multichannel News*, August 1, 2013 http://www.multichannel.com/distribution/comcast-test-new-usage-based-internet-tier-fresno/144718

4.2 Network Design Considerations

This section provides a high-level overview of certain functional requirements used to prepare the conceptual FTTP design and cost estimate. It also presents the technical details of an FTTP network in terms of performance, reliability, and consumer perceptions based on providers' marketing.

Google changed the industry discussions and customer perceptions of data access when it introduced its plans to deploy an FTTP network and offer a 1 Gbps data connection for $70 per month in Kansas City.[56] Until Google entered the FTTP market, cable operators such as Comcast questioned the need for 1 Gbps speeds and typically indicated that 10 Mbps was sufficient for residential and small business users. (Gigabit speeds were available in a few localities, such as Chattanooga, Tennessee, but Google's brand name meant that Google Fiber had a bigger impact on national awareness around this type of connection.) Since Google's entry, Comcast and other providers have slowly increased their data offering speeds—moving to 25 Mbps, 50 Mbps, and finally gigabit fiber services in selected markets.

Comcast already advertises its 2 Gbps Gigabit Pro service in Holland. However, the service is only available in locations that are less than one-third of a mile from its existing fiber infrastructure and requires users to pay at least $1,000 in activation and installation fees. Comcast has also announced plans to upgrade its existing hybrid fiber-coaxial (HFC) network to DOCSIS 3.1 across its entire service area, including the City of Holland, by 2018. Initially it will offer 1 Gbps service, but DOCSIS 3.1 is capable of offering as much as 10 Gbps service. Comcast has not yet released pricing for DOCSIS 3.1-based services.[57]

It is important to note that Internet access speed represents only one portion of the overall Internet experience, and measuring a network's overall performance on one metric is incomplete. Further, "advertised speed" for residential services is a best-effort commitment, not a guarantee, and does not necessarily reflect actual performance. For example, the advertised speed does not delineate a minimum speed or a guarantee that any given application, such as Netflix, will work all the time.

4.2.1 Why Fiber Optics

For several decades, fiber optic networks have consistently outpaced and outperformed other commercially available physical layer technologies, including countless variants of copper cabling and wireless technologies. The range of current topologies and technologies all have a place and

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[56] https://fiber.google.com/cities/kansascity/plans/.

[57] Mike Dano, "Comcast: We'll cover our entire network with 10 Gbps-capable DOCSIS 3.1 tech as soon as 2018," FierceCable, August 21, 2015, http://www.fiercecable.com/story/comcast-well-cover-our-entire-footprint-10-gpbs-capable-docsis-31-tech-soon/2015-08-21, accessed February 2016.

play important roles in modern internetworking.[58] The evolution of Passive Optical Network (PON) technology has made FTTP architecture extremely cost-effective for dense (and, more recently, even lower and medium-density) population areas.

The specifications and the performance metrics for FTTP networks continue to improve and outperform competing access technologies. In fact, from the access layer up through all segments of the network (the distribution layer and the core, packet-, and circuit-switched transports, and even into the data center), and for almost all wireless "backhaul" communications, optical networking is the standard wireline technology.

Compared to other topologies, fiber-based optical networks will continue to provide the greatest overall capacity, speed, reliability, and resiliency. Fiber optics are not subject to outside signal interference, can carry signals for longer distances, and do not require amplifiers to boost signals in a metropolitan area broadband network.[59]

If an ISP were to build new with no constraints based on existing infrastructure, it would likely begin with an FTTP access model for delivery of all current services; compared to other infrastructure, an FTTP investment provides the highest level of risk protection against unforeseen future capacity demands. In cases where a provider does not deploy fiber for a new route, the decision is often due to the provider's long-term investment in copper OSP infrastructure, which is expensive to replace and may be needed to support legacy technologies.

4.2.2 Fiber Routes and Network Topology

FTTP architecture must be able to support a phased approach to service deployment. Phased deployments can help support strategic or tactical business decisions of where to deploy first, second, or even last. Phasing also allows for well-coordinated marketing campaigns to specific geographic areas or market segments, which is often a significant factor in driving initial acceptance rates and deeper penetration. This is the "fiberhood" approach used by Google and others.

A fiber backbone brings the fiber near each neighborhood, and fiber can be extended as service areas are added in later phases of deployment. This allows for the fiber in individual neighborhoods to be lit incrementally,[60] with each new neighborhood generating incremental revenue.

[58] An internetwork is a network of interconnected networks.
[59] Maximum distances depend on specific electronics—10 to 40 km is typical for fiber optic access networks.
[60] As the name implies, "lit fiber" is no longer dark—it is in use on a network, transmitting data.

The proposed GPON FTTP architecture supports this capability once the core network electronics are deployed and network interconnections are made. The GPON architecture is discussed further in the design report and in Section 4.2.3 below.

In addition to these core considerations, we note that designing the network to support mobile backhaul may allow the HBPW to generate additional revenue from mobile carriers, as well as improve mobile broadband service in the Holland area. Given that this is a longer-term consideration, our financial model does not currently include revenue earned from leasing excess network capacity to cellular providers for mobile backhaul use. We provide more detail on mobile backhaul issues in Appendix B.

4.2.3 Passive Optical Network—Specifications and Technology Roadmap

The first Passive Optical Network (PON) specification to enjoy major commercial success in the U.S. is Gigabit-capable Passive Optical Network (GPON). This is the standard commonly deployed in today's commercial FTTP networks and it is inherently asymmetrical. Providers from Google Fiber to Chattanooga's EPB offer 1 Gbps asymmetrical GPON service with relatively high oversubscription rates (albeit far less than non-FTTP competitors). Our suggested network design allows for provision of symmetrical services ranging from typical levels of oversubscription to dedicated symmetrical capacity per subscriber.

The GPON standard (defined by ITU-T G.984.1) was first established and released in 2004, and while it has since been updated, the functional specification has remained unchanged. There are network speed variants within the specification, but the one embraced by equipment manufacturers and now widely deployed in the U.S. provides asymmetrical network speeds of 1.24 Gbps upstream and 2.49 Gbps downstream.

Since the release of the ITU-T G.984.1 GPON specification, research and testing toward faster PON technologies has continued. The first significant standard after GPON is known by several names: XG-PON, 10GPON, or NG-PON1. The NG-PON1 specification offers a four-fold performance increase over the older GPON standard. Although NG-PON1 has been available since 2009, it was not adopted by equipment manufacturers and has not been deployed in provider networks. We expect the version released in 2015, NG-PON2, to evolve as the de facto next-generation PON standard.

These new standards can be implemented through hardware or software (electronics) upgrades, and are "backward compatible" with the current generation, so all variants can continue to operate on the same network.

The optical layer of the NG-PON2 standard is quite different from GPON. The specification uses a hybrid system of new optical techniques, time division multiplexing (TDM) / wave division multiplexing (WDM) PON (TWDM-PON), that basically multiplexes four 10 Gbps PONs onto one fiber, to provide 40 Gbps downstream. This is a 16-fold performance increase over the current GPON standard.

While efforts continue on an ongoing basis by the standards-development community and hardware manufacturers to deliver a WDM-based solution leveraging wavelength-tunable optics to significantly surpass the 10 Gbps barrier, the more recently announced XGS-PON represents an interim solution to facilitate true symmetrical 10 Gbps services (the "S" in "XGS"). The ITU-T announced simultaneously on March 1, 2016 the approval of an amendment to the NG-PON2 standards with the first-stage approval the "XGS-PON" standard.

The XGS-PON physical layer is based on XG-PON specifications (and likely eliminates any potential demand there might have been for XG-PON), operating within the same windows using fixed wavelength optics. Final approval of the standard is expected later in 2016, and some manufacturers expect widespread commercial deployments to begin in 2017—well before NG-PON2 hardware will be widely available or affordable—enabling providers to deliver symmetrical 10 Gbps services over their PON infrastructure while operating in parallel with existing GPON services.

At minimum, the upgrade pathway for existing GPON deployments will require new enhanced small form-factor pluggable (SFP+) modules on the OLT side within the hub building or equipment cabinet, and a new optical network terminal (ONT) device at the customer premises, with software and firmware upgrades on the FTTP electronics. The migration to WDM-based technologies, like NG-PON2, also require the addition of coexistence elements ("CEx") between the OLT and the PON splitters, which can consist of a range of configurations of passive wavelength filters and couplers. Final details are yet to be announced and will vary by manufacturer, but the NG-PON2 specification requires a migration path and backward compatibility with GPON, facilitated by a coordinated wavelength plan that allows each of these standards to operate over common fiber strands without interfering. FTTP equipment manufacturers are actively testing upgrade steps and strategies for migrating from GPON to NG-PON2.

Table 9: PON Standards

Year	Standard
1994	pi-PON. 50 Mb/s, 1310nm bidirectional, circuit switched
1999	A/B-PON. 622/155 Mb/s, 1550nm down, 1310nm up, ATM-based
2004	G-PON. 2.4/1/2Gb/s, 1490nm down, 1310nm up, packet-based G-PON (2.5)
2009	NG-PON1. 10/2.5Gb/s, 1577nm down, 1270nm up, packet-based XG-PON (10)
2015	NG-PON2. 40G+ capacity XLG-PON (40)
2016	XGS-PON. 10/10 Gb/s, 1577nm down, 1270 up

4.2.4 Managing Network Demand

Perhaps the most fundamental problem solved by IP packet data networking is how to cost-effectively design, build, and operate a network to manage unpredictable demands and bursts of network traffic.

The earliest transport networks (and many of the major Internet backbone segments today) are circuit switched. This means that each network leg is a fixed circuit, running at a fixed speed all the time. Fixed-circuit networks are less flexible and scalable, and utilize capacity far less efficiently than packet-switched networks; they must be precisely designed and planned in advance, because there are fewer mechanisms to deal with unplanned traffic surges or unexpected growth in demand.

"Dial-up" modems provide an example of circuit-switched technology. Copper POTS lines were in huge demand as residential and business customers purchased fax machines and accessed the Internet over modems. Because the POTS technologies could not support all of these uses at the same time, and were limited to slower speeds, phone companies were only able to serve that demand by installing more copper lines.

The packet-switched DSL, cable modem, fiber, and wireless technologies that replaced POTS addressed the limitations of fixed-circuit technologies because the flow of network traffic is determined on a per packet basis, and the network provides robust mechanisms for dealing with unexpected bursts of traffic. The trade-off for flexibility, resiliency, and ease of use is that network speed will vary, depending mainly on the amount of traffic congestion.

4.2.4.1 Oversubscription

An important balancing act in packet networks is between network performance (speed) and network utilization (efficiency). The primary method of achieving this balance is *oversubscription*. Because the vast majority of network users are not actually transmitting data at any given moment, the network can be designed to deliver a certain level of performance based on assumptions around actual use.

Oversubscription is necessary in all packet-switched network environments and is generally beneficial—by enabling the network operator to build only as much capacity as necessary for most scenarios. By way of comparison, the electric industry uses a demand factor to estimate generation requirements. Similarly, a road that has enough capacity to keep most traffic moving at the speed limit most of the time will get congested during peak travel times—but building a road large enough to handle all of the traffic at peak times would be too expensive. Most drivers most of the time have enough room to go the speed limit, but when a lot of users want to be on the road at the same time, everyone has to slow down.

The HBPW will need to evaluate and manage its subscription levels to deliver the optimal balance of performance and efficiency. Although the goal of providing symmetrical *dedicated*[61] 1 Gbps data to all HBPW subscribers is admirable and technically possible, it may not be very practical or affordable. By comparison, Google's 1 Gbps offering is technically neither symmetrical nor dedicated. And while Comcast's 2 Gbps offering might be symmetrical, it is not dedicated.

Services may be burstable, meaning that users may experience the advertised data rates at times, but the average speed will vary greatly based on the traffic being generated over the provider's distribution network. Performance parameters on a burstable service are rarely publicized or realized. Often a network operator cannot change this parameter without changing the network's physical connections.

When looking at FTTP requirements, it is important to understand that the speeds and performance stated in marketing material for consumer services are not the same as a network's actual technical specifications. Actual speeds and performance will depend on the activity of other users on the network. Generally, all residential and small business Internet services are delivered on a best-effort basis and have oversubscription both on the network and in the network's connection to the Internet.

First, let's look at network oversubscription. Today's GPON standard supports FTTP network speeds of up to 2.4 Gbps downstream (to the consumers) and 1.2 Gbps upstream (from the consumers) from a given OLT. Each OLT interface is typically connected to passive optical splitters configured to support up to 32 premises.[62] That is, up to 32 users will share the 2.4 Gbps downstream and 1.2 Gbps upstream.[63] Given that not all users will demand capacity at the same time and that very few applications today actually use 1 Gbps, a provider can reasonably advertise delivery of a symmetrical 1 Gbps service on a best-effort basis and most consumers will have a positive experience. This level of oversubscription at the GPON "access" layer is quite low compared to most modern cable modem networks, which typically share 150 Mbps – 300 Mbps among several hundred users, even while offering service tiers that "burst" to 150 Mbps.

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[61] As its name implies, service is "dedicated" when the link runs directly from the ISP to the user.
[62] Can be deployed in 8 to 1, 16 to 1, and 32 to 1 configurations. Lower ration's reduce the number of subscribers sharing the capacity, but increases the number of FDC's and fiber strands.
[63] In an HFC network as used by Comcast, the network capacity is shared among 250 to 500 users.

NG-PON2 (described above) will likely enable support of 40 Gbps downstream. In four or so years, the NG-PON2 platform should become standard, and although it will initially be somewhat more expensive, pricing will likely quickly match levels similar to today's 2.4 Gbps platform.

Even with today's 2.4 Gbps GPON platform, the network can be designed to support 10 Gbps, 100 Gbps, or other symmetrical speeds. This can be accomplished with a hybrid approach using active Ethernet (AE) and GPON, or by deploying a full AE network, which would require placing active electronics inside Fiber Distribution Cabinets (FDCs) in the field.

The next level of oversubscription is generally in the distribution network between the OLT and the service provider's core network. This portion of the network varies drastically between networks of different size, and is specific to the architecture of a particular network. Most OLT hardware provides 10 Gigabit Ethernet (10 GE) interfaces for uplinks to aggregation switches, frequently with multiple 10 GE interfaces supporting dozens of GPON interfaces (each supporting 16 or 32 customers)—perhaps on the order of 500 or 1,000 customers supported over a pair of redundant 10 GE links. While substantially more oversubscription than at the access layer in a GPON network, most OLT hardware is modularly scalable so that oversubscription can be managed by augmenting uplink capacity as demands grow. Moreover, this layer of the network can generally be upgraded less expensively and, indeed over-engineered in the initial deployment without significantly impacting costs in a relative sense, as the number of network devices and interfaces are far fewer than at the access layer.

The next level of oversubscription is with the network's access to the Internet. Again, since not all users demand capacity at the same time, there is no need to supply dedicated Internet bandwidth to each residential or small business customer. In fact, it would be cost prohibitive to do so: Assuming a DIA cost of $0.50 per Mbps per month, the network operator would pay $500 per month for 1 Gbps of DIA. But an operator with a residential and small business 1 Gbps service could easily use an oversubscription of 500 to 1,000 on DIA today. Then, as users require more bandwidth, the operator simply subscribes to more bandwidth. The preferential approach is to reduce the traffic over the Internet, which is accomplished by peering to other networks, placing servers (such as Netflix) on the HBPW's FTTP network (referred to as on-net), and caching.[64]

All of the applications that the HBPW has identified are possible with 1:32 GPON architecture and reasonable oversubscription. If a bottleneck occurs at the Internet access point, the HBPW can simply increase the amount of commodity bandwidth (DIA) it is purchasing or bring servers such as Netflix on-net. Customers looking for greater than 1 Gbps or who require Committed Interface

[64] Network server or service that saves Web pages or other Internet content locally.

Rates (CIR) can be served via a higher priced Ethernet service rather than the GPON-based 1 Gbps service.

4.2.4.2 Rate Limiting

In some networks, unexpected bursts of network traffic slow things down to unacceptable speeds for everyone using the network. Thus there needs to be a mechanism in place to manage these events for the greater good of everyone sharing the network.

One technique for controlling this is called rate-limiting. It can be implemented in many different ways, but the net result is that it prevents over-congestion on a network during the busiest usage times.

Most consumer Internet services today provide subscribers with a "soft" rate for their data connections. This may allow for some extra speed and capacity during times when the network is uncongested, but it may also mean that the "soft" rate may not be achievable during times when the network is the most congested. Providers need to have this flexibility to cost effectively manage the networks overall performance and efficiency and they do this with subscription levels and rate limiting.

4.2.5 Internet Protocol (IP) Based Applications

The FTTP design will be an all-IP platform that provides a scalable and cost-effective network in the long run. This will allow the HBPW to minimize ongoing costs; increase economies of scale with other network, communications, and media industries; and operate a uniform and scalable network. For example, with an IP-based data network, there would not need to be a separate set of video transport equipment in the headend or hubs, nor a set of dedicated video channels. The transport equipment and the spectrum would become uniform and converge to a single IP platform. Thereafter, network upgrades could be carried out solely based on the evolution of high-speed networking architecture, independent of video processing capabilities often inherent in incumbent provider networks.

4.2.6 Migration from IPv4 to IPv6 Protocol

The Internet is in the process of migrating from the IPv4 to the IPv6 protocol. This upgrade will include several improvements in the operation of the Internet. One of the most notable is the increase in available device addresses, from approximately four billion to 3×10^{38} addresses. IPv6 also incorporates other enhancements to IP networking, such as better support for mobility, multicasting, security, and greater network efficiency; it is being adopted across all elements of the Internet, such as equipment vendors, ISPs, and websites.

Support of IPv6 is not unique to the proposed HBPW FTTP network. Comcast has begun migrating all of its services to IPv6.

Customers with access to IPv6 can connect IPv6-aware devices and applications through their data connection and no longer need to use network address translation (NAT) software and hardware to share the single IP address from the ISP among multiple devices and applications. Each device can have its own address, be fully connected, and (if desired) be visible to outside networks.

One way to think of removing NAT is that it is the IP equivalent of moving from a world of cumbersome telephone systems with a main number and switchboard extension (e.g., 616-555-0000 extension 4422) to one where each individual has a unique direct number (e.g., 616-555-4422). Devices and applications that will particularly benefit from IPv6 include interactive video, gaming, and home automation, because NAT (and other IPv4 workarounds to share limited address space) makes connecting multiple devices and users more complex to configure, and IPv6 will eliminate that complexity and improve performance. With IPv6, each device and user can potentially be easily found, similar to how a phone is reached by dialing its phone number from anywhere in the world.

4.2.7 Multicasting—IP Transport of Video Channels

Traditional Internet video can waste capacity, especially in a “channel” video environment, because it sets up a new stream from the source to each viewer. Even if many people are watching the same program at the same time, a separate copy is streamed all the way from the server (or source) to the user. *Multicasting* is a method of transmitting data to multiple destinations by a single transmission operation in an IP network.

Using multicasting, a cable operator (leveraging the proposed FTTP network) can send a program to multiple viewers in a more efficient way. A multicast-aware network sends only a single copy of any given video stream from its source through the various network routers and switches within the network. When a viewer selects the program, the viewer’s device (set-top converter or computer) requests the multicast stream, a copy of which is then provided to that customer by the underlying network—rather than the originating video server or encoder sending a dedicated unicast stream to that customer, as is the case with OTT video services and other Internet-based video applications. Thus, the stream exists only once over any given segment of the network upstream from the access layer, so even if many neighbors are viewing the same stream, multicast video services can never occupy more capacity than the sum of one copy of each video stream (see Figure 8 and Figure 9).

Figure 8: Unicast IP Network Carries Multiple Copies of Single Video Channel

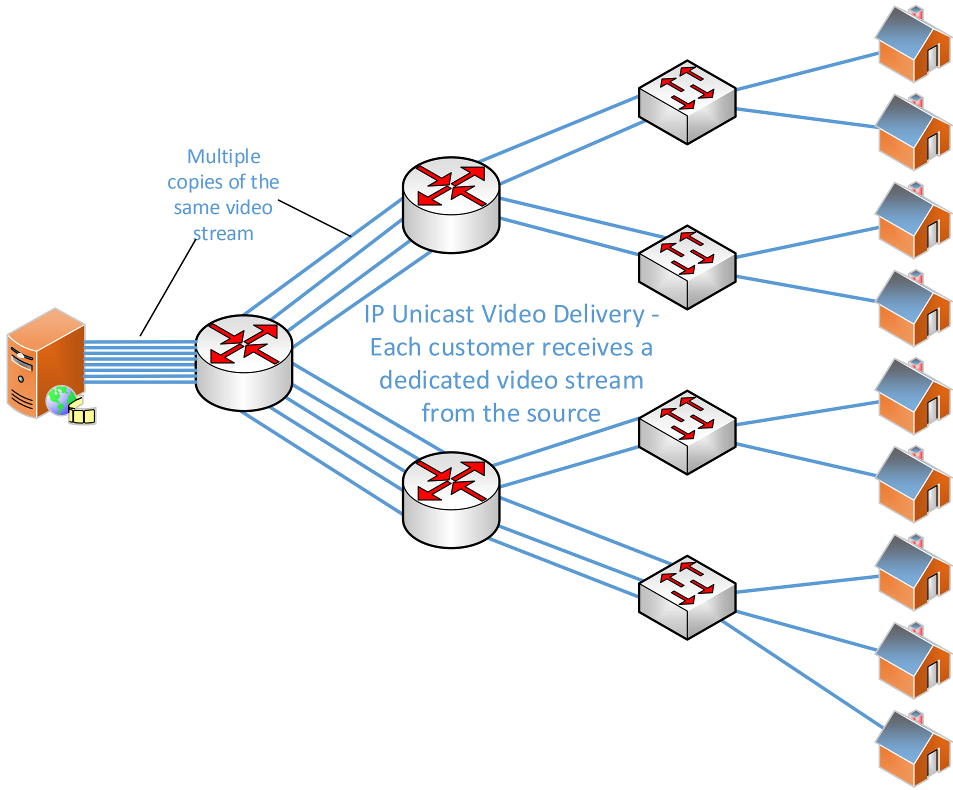
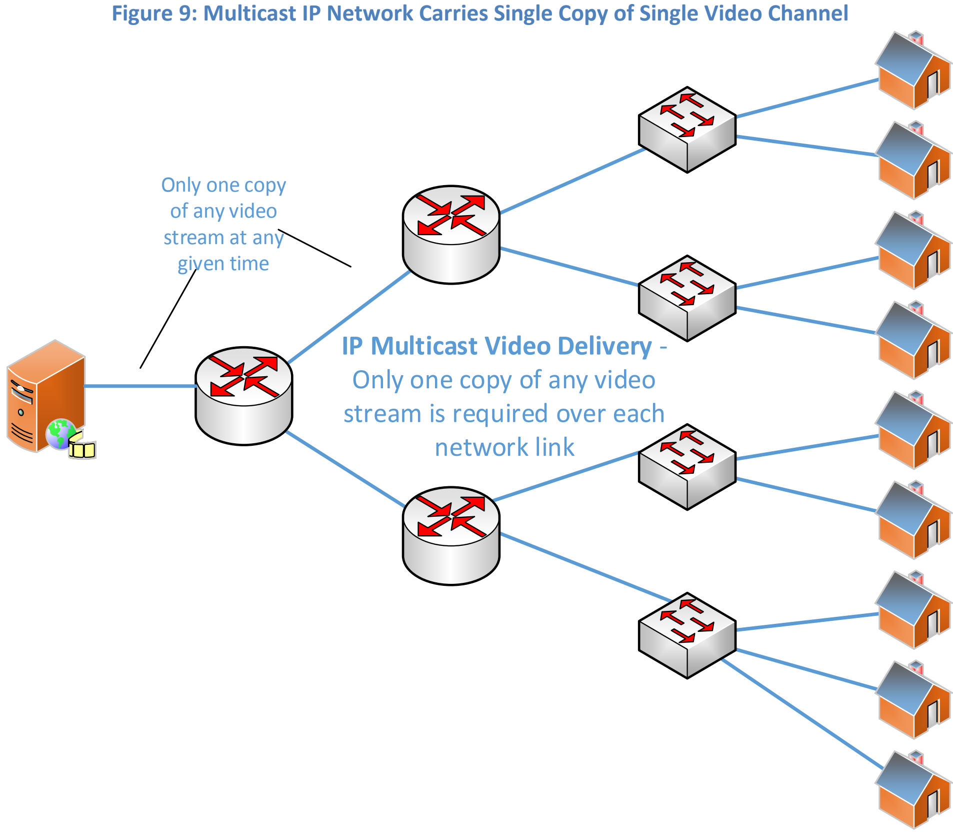


Figure 9: Multicast IP Network Carries Single Copy of Single Video Channel



Multicast is a feature that was optional in IPv4 but standard (and better executed) in IPv6. As multicast-capable and multicast-aware routers and set-top converters become standard, a cable operator and OTT video providers leveraging the HBPW's FTTP network could consider an all-IP video programming offering, and not just video-on-demand (VoD), as multicast provides a means to carry traditional channels over IP without wasting the backbone capacity.

4.3 Target User Groups

Based on our discussions with HBPW staff, we identified two primary categories of potential network users (in addition to the electric utility):

- Residents
- Small businesses and enterprise users

To analyze the user groups, we first estimated the possible number of "passings"—homes and businesses the fiber could potentially pass—for each. Using GIS data, we estimated that there are 28,854 total passings in the HBPW service area. This number is based on the latest electric service drop data provided by the HBPW. Of the 28,854 potential passings, we assume that 24,144 are residential passings while 4,710 are commercial passings.

4.3.1 Residents

The HBPW's primary focus—and the largest potential user group for a HBPW FTTP network—is the residential market. We estimated that there are 23,949 residential passings in HBPW's service area. These do not include households in buildings with 20 or more units.

Residents will require a diverse range of speeds and capabilities—from simple, reliable connectivity at low cost, to extremely high speed, symmetrical services that can support hosting and research and development applications. The fiber network will provide the capability to offer a range of services through the same physical medium, requiring only an upgrade of electronics or software at the user premises, rather than customized physical connections, to deliver higher-capacity services.

4.3.2 Small Businesses and Enterprise Users

We estimate that there are 4,710 commercial passings across the HBPW's service area. In terms of their broadband needs, these small businesses are often more similar to high-capacity residential users than to large enterprise customers. They may need more than just a basic connection, but do not typically require the speeds, capacity, or guaranteed service levels that a large organization or high-end data user needs.

The HBPW's FTTP network must support small businesses and be capable of supporting select institutions and enterprise users. It is important to emphasize that the suggested network design will have enough fiber capacity to provide either Active Ethernet service or Passive Optical Network (PON) service to any business or resident. Our design and cost estimates provide for a conservative business analysis with sufficient fiber strands and network electronics capacity to meet near term demands at nearly any take rate, and includes Active Ethernet (dedicated symmetrical gigabit) hardware support for approximately 10 percent of all business passings. With the recommended network in place, HBPW or another ISP will be able to sell customized service to enterprise customers on a case-by-case basis.

The FTTP network will support basic service levels at virtually any level, complementing the HBPW's dark fiber leasing program by addressing a different market segment. That is, the FTTP offering will serve users whose connectivity needs are not significant enough to warrant executing a dark fiber agreement, but who might require dedicated lit connections of up to 10 Gbps and greater. Similarly, the dark fiber licensing program successfully provides service to users whose connectivity needs would likely not be sufficiently met by an FTTP offering.

5 FTTP Backbone Conceptual Design and Cost Estimates

This section offers a conceptual design model and implementation cost estimates to meet the requirements described in the previous sections, and discusses considerations to help guide implementation phasing and detailed design decisions.

5.1 FTTP Network Design

The physical outside plant (OSP) is both the most expensive part of the network and the longest lasting. The architecture of the physical plant determines the network's scalability for future uses and how the plant will need to be operated and maintained; the architecture is also the main determinant of the total cost of the initiative. Within this category of expenses, we include supporting infrastructure, including physical shelters for electronics, electrical power systems, and environmental control components.

Higher layer components include the OLT hardware (access layer); distribution network switches; and core network routers and switches; and network management systems—and depending on the business model and role of a given network operator, might also include the application-layer systems required for the delivery of video content, voice and video communications, home automation services, and so on. In this case, we include only those systems pertinent to the delivery of high-speed Internet services, but which can also support any range of voice, video, and other interactive services that one or more service providers might want to deliver as OTT Internet-based service or out-of-band using dedicated fiber and/or lit capacity within the active FTTP network.

The particular technical approach and network electronics architecture drive certain baseline requirements for the underlying fiber optic infrastructure, such as fiber strand capacity requirements in certain segments of the network, type and quantity of outdoor equipment and fiber distribution cabinets, and requirements for physical path diversity of backbone connections. In consideration of the relatively long lifespan of the fiber infrastructure compared to particular network electronics options, service offerings, or even business models, the system-level design developed for purposes of our cost estimates assumes a best-in-class approach that is flexible enough to accommodate a wide range of short-term and long-term technical approaches.

The recommended design is a hierarchical data network with different attributes at each layer, targeting a balance of critical scalability and flexibility, both in terms of the initial network deployment and capability to accommodate the increased demands of future applications and technologies.

The functional objectives driving this hierarchical FTTP data network are:

- ***Capacity –*** ability to provide efficient transport for subscriber data, even at peak levels, supporting any passive splitting ratio and/or dedicated fiber connections to each customer, with little or no oversubscription except at the core layer where peering occurs with upstream ISPs so that capacity can be increased readily as demands dictate;

- ***Availability and physical path diversity –*** provide high levels of redundancy, reliability, and resiliency to quickly detect faults and re-route traffic around diverse fiber paths in the event of a fiber break or equipment failure, with the option to place active backbone nodes located within close proximity to every potential customer and interconnected over diversely routed backbone rings;

- ***Scalability –*** ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies, with sufficient fiber capacity to support ongoing reduction of PON split ratios and/or increase in dedicated Active Ethernet connections.

- ***Flexibility –*** ability to provide different levels and classes of service into different customer environments, as well as the ability to support an open access network or a single-provider network. Separation between service providers can be provided on the physical (separate fibers) or logical (separate VLAN or VPN) layers.

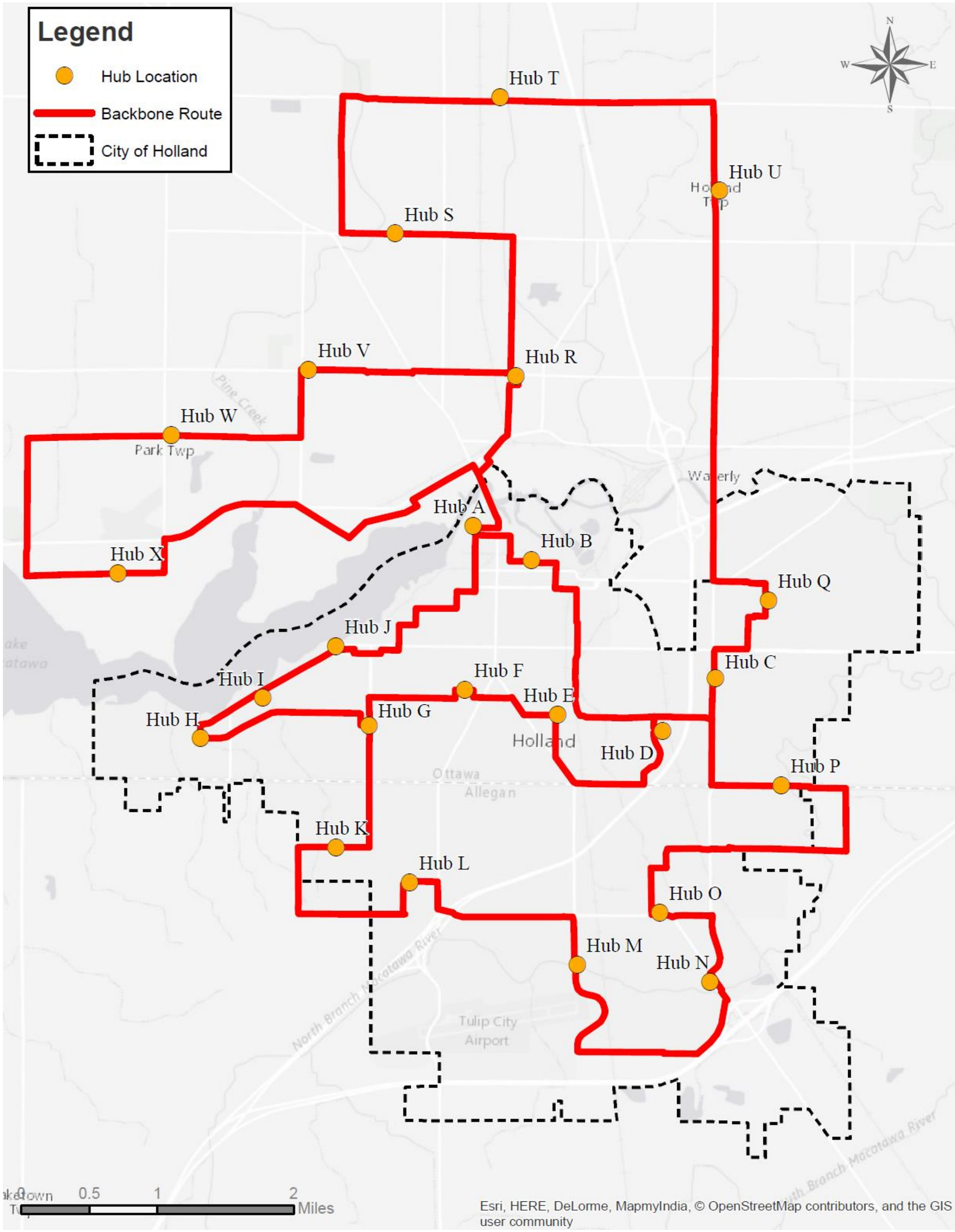
- ***Security –*** controlled physical access to all equipment and facilities, plus network access control to devices.

5.1.1 Design Overview and Key Metrics

The network design model includes a backbone network layer providing connectivity between hub facilities and fiber distribution cabinets (FDC) located throughout the HBPW electric service area. Hub and FDC locations were chosen primarily to coincide with HBPW properties, and in certain cases, placed within the public right-of-way or on City or County properties. To the extent possible, the backbone design aligns with existing HBPW fiber resources, maximizing the potential cost savings associated with the use of this fiber and/or the existing fiber pathways, particularly for crossings of railroad tracks, bodies of water, and highways—all of which are considerations in this case.

Furthermore, we sought to identify candidate hub locations such that the service areas for each could be defined to encompass roughly the same number of serviceable passings. Specifically, the backbone design targets a density of approximately 1,000 passings per hub / FDC, creating service areas for each that can be accommodated through a consistent configuration of network electronics and physical cabinet layout—an important consideration for maintenance and support efficiencies. Figure 10 illustrates this backbone design, including candidate hub locations.

Figure 10: FTTP Network Backbone



The backbone network, consisting of approximately 45 miles of fiber routes, almost all of which are aligned with existing HBPW fiber routes, provides fully diverse connectivity between four primary hub locations and 20 FDCs. Coupled with an appropriate network electronics configuration, this design serves to greatly increase the reliability of fiber services provided to the customers compared to that of more traditional cable and telephone networks. The backbone design minimizes the average length of non-diverse distribution plant between the provider's electronics and each customer (much less than a mile, in most cases), thereby reducing the probability of service outages caused by a fiber break.

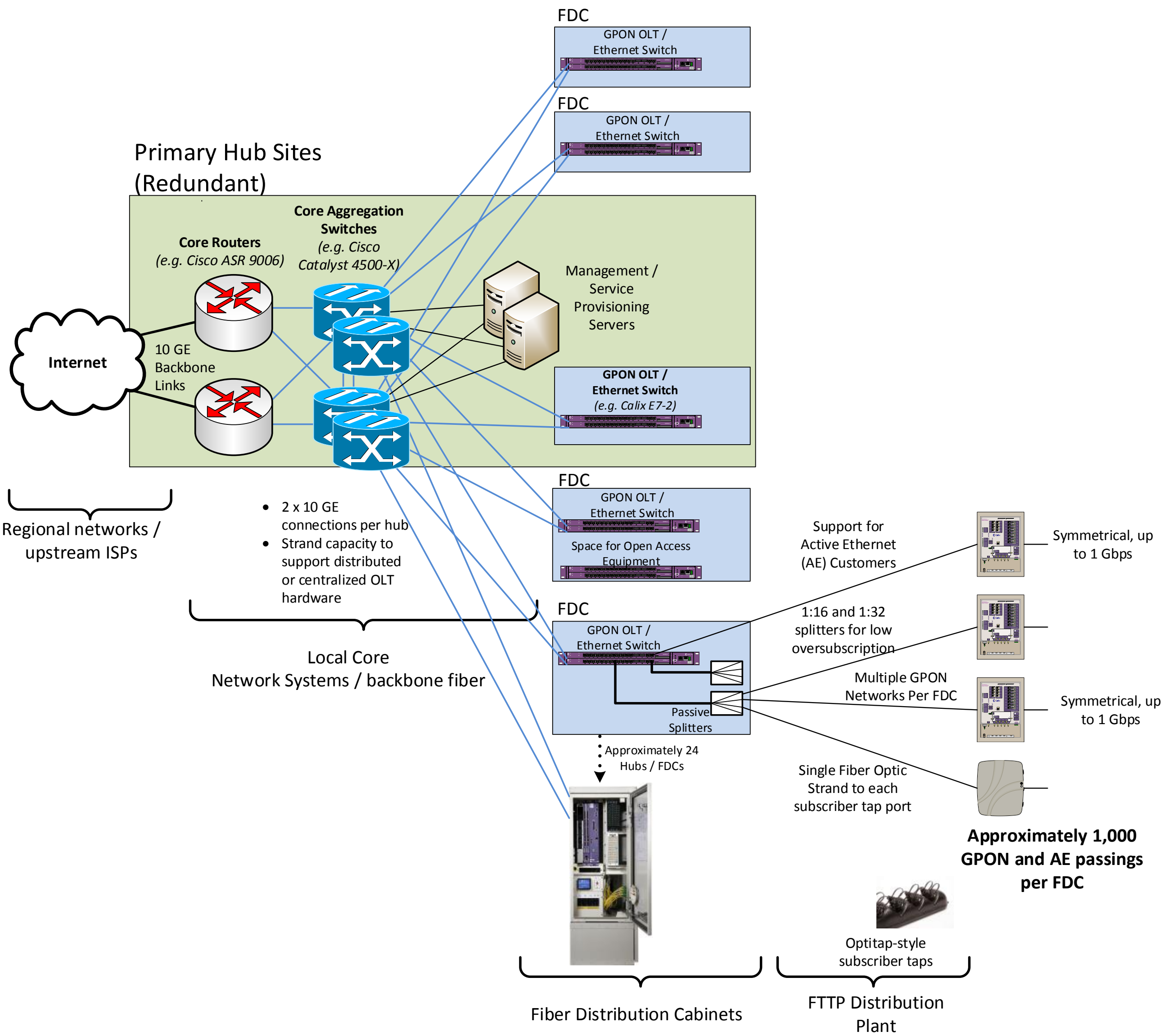
For the sake of cost estimation, we assume the backbone network will include:

- Equipment shelters located at four primary hub sites, functioning as core and distribution-layer hubs to support redundant core network electronics. The hub structure will likely consist of a pre-fabricated concrete shelter (approximately 10-foot by 12-foot), equipped with redundant air conditioners, backup generator and uninterruptible power supplies, and inert gas fire suppression system;
- FDCs placed at approximately 20 additional locations along the backbone fiber routes, functioning as active distribution hubs suitable to support hardened network electronics with backup power and an active heat exchanger; and

A dedicated fiber cable of at least 288-strand count.

Figure 11 illustrates the recommended reference design model for the FTTP network. The drawing illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexible nature of the architecture to support multiple subscriber models and classes of service.

Figure 11: High-Level FTTP Architecture



The distribution fiber plant, encompassing the physical fiber cable from the hubs to the customers, is based on a "home-run" fiber architecture—meaning a dedicated fiber strand is available from a given hub to each passing. Compared to more traditional FTTP designs that generally employ optical splitters in the field (between the hubs and the premises in the figure above), thereby reducing the size of "feeder" cables, this design requires larger strand-counts and hub facilities capable of terminating a greater quantity of fiber strands.

This home-run architecture offers greater scalability to meet long-term needs, and is consistent with best practices for an open access network model that might potentially be required to support multiple network operators, or at least multiple retail service providers requiring dedicated physical connections to some or all customers. Whether centralizing network electronics in the primary hub locations and including only passive splitters in each FDC, deploying a combination of active and passive components, or implementing a fully active Ethernet network with dedicated connections to each customer, this design model fully supports any of these technical approaches.

The design model assumes placement of manufacturer-terminated fiber "taps" within the right-of-way or HBPW easements, providing environmentally hardened fiber connectors for customer service drop cables. This is an industry-standard approach to minimize customer activation times and reduces the potential for damage to distribution cables and splices by eliminating the need for service installers to perform splices in the field. The design model and assumptions employed for cost estimation yield the following totals:

Table 10: Summary of Design Model Metrics

Physical Plant	
Total passings	28,854
Average Passing density	61 passings per route mile
Total hubs	4
Total FDCs	20
Total backbone routes (new and existing)	45.5 miles
Total new backbone routes	2.2
Total distribution plant path	472
Total distribution cable placement	1,091 miles
Estimated aerial / underground plant	55% aerial / 45% underground
Total new pole attachments	10,604 poles
Network Electronics	
Total GPON interfaces	928 (14,848 customers at 1:16 split or 29,696 customers at 1:32 split)
Total Active Ethernet (1 GE) interfaces	464
Aggregate Access Capacity	2,773 Gbps downstream 1,618 Gbps upstream
Aggregate Distribution Network capacity (OLT to Distribution Layer)	480 Gbps
Aggregate core capacity (Distribution Layer to Core)	80 Gbps
Maximum oversubscription	1:361

5.1.2 Backbone and Primary Hub Sites

The primary hub sites in an FTTP network generally contain core network electronics that aggregate physical connectivity from the access and distribution layers of the networks, and may also contain servers and other systems related to the provision of particular services and applications. The proposed network design includes four primary hub sites comprised of equipment shelters providing secure datacenter-like environments for sensitive network electronics—one each located at the following sites:

- Hub A – James DeYoung Power Plant, 64 Pine Ave.
- Hub D – Service Center, 625 Hastings Ave.
- Hub G – Ottawa Ave. Substation
- Hub R-–James St. Substation

Each of the primary hub shelters will be capable of hosting Operational Support Systems (OSS) for one or more providers, such as provisioning servers, fault and performance management systems, and remote access systems. Each provides a point-of-presence for any business partner, content provider, or service provider for collocation purposes, and to gain access to the subscriber network to deliver services via the FTTP network. Furthermore, providers and businesses can gain access to these core resources at any location along the diversely routed backbone ring in the event space requirements or physical access needs demand separate facilities for a given provider or customer.

For cost estimation purposes, we assume that primary hubs will involve the placement of a precast concrete shelter providing an operating environment similar to that of a data center. This includes clean power sources, UPS batteries, and diesel power generation for survival through sustained commercial outages. The facility must provide strong physical security, limited/controlled access, environmental controls for humidity and temperature, and an inert gas fire suppression system.

Although these will be located at existing HBPW facilities, constructing these as dedicated shelters allows access to be controlled for outside contractors and staff responsible for FTTP operations—and conversely, to limit the need to provide access for these individuals to electric substations and other HBPW utility infrastructure outside of their purview.

Figure 12: Sample Hub Facility

In the proposed design, Hubs A and D will house core, distribution, and access-layer network components. Hubs G and R will house distribution and access layer network components, and will serve as launching points for expansion of the network beyond the currently anticipated service area.

The distribution network is the layer between the network core and the access electronics that facilitates the final connections to the customers, and can comprise multiple physical and electronic aggregation points that vary in function and scale depending on the specific design. In this model, each of the four primary hubs functions as distribution node, and also contains access network electronics and passive splitter components.

All four primary hubs will be interconnected over diversely routed backbone rings forming high availability core and distribution layers, including aggregation of redundant and diversely routed uplinks from access OLT hardware. Each primary hub site will be equipped with distribution layer switches capable of high-density aggregation of 10 GE connections from the access-layer OLT hardware.

The primary hubs will serve as peering points for outside connections; house core systems for third-party service providers leveraging the HBPW network as a last mile open access provider; and facilitate dedicated connections to high-end business customers requiring connections at speeds of 10 Gbps, or greater.

Attachment 1 illustrates the physical fiber topology of the backbone network; Attachment 2 provides a logical depiction of the network electronics layers and their connectivity; Attachment 3 illustrates the physical backbone fiber routes; and Attachment 5 provides a detailed bill of materials (BOM) for candidate network electronics, including core and distribution network electronics. We note that our pricing is based on Cisco hardware at anticipated discount levels to offer a conservative estimate for a scalable architecture, though a wide range of manufacturers, including Juniper, Ciena, Alcatel-Lucent, Avaya, Brocade, and others have competitive offerings in some or all of the required categories.

5.1.3 Access Network Hubs and Electronics

Access network electronics will be housed primarily in Fiber Distribution Cabinets (FDCs) located throughout the service footprint. FDCs can be placed in the right-of-way, either on a concrete pad or mounted on a pole, or can reside in a building. Our model recommends installing sufficient FDCs to support higher-than-anticipated levels of subscriber penetration and future growth potential. This approach will accommodate future subscriber growth with minimal re-engineering. Passive optical splitters are modular and can be added to an existing FDC as required to support subscriber growth, or to accommodate unanticipated changes to the fiber distribution network with potential future technologies.

Specifically, the proposed design model includes 20 secondary hubs consisting of environmentally-hardened equipment cabinets to house access-layer electronics, optical splitters, and related passive fiber optic termination materials. The proposed fiber backbone will provide diverse physical paths between all hub locations so that the only single points of failure in the network exist in the "last mile" physical plant between the subscribers and the nearest hub enclosure or shelter.

The distribution fiber cable plant downstream from each hub/FDC consists of feeder and access fiber. The feeder fiber generally provides connectivity between each FDC and multiple network access points (NAPs) located throughout the distribution plant, consisting of fiber splice enclosures and/or optical splitters. The access fiber generally consists of cable plant connecting individual customer fiber connections to these aggregation NAPs, and may include outdoor taps providing environmentally hardened connectors for customer drop cables.

The distribution and access network design proposed in this report is flexible and scalable enough to support two different electronics architectures:

1. Housing the core, distribution, and access network electronics centrally within the primary hubs, using only passive devices (optical splitters and patches) within each of the FDCs; or

2. Pushing the distribution and access network electronics further into the network by housing them at the FDCs.

By housing all access network electronics only in primary hubs, the network would not require power at the individual FDCs. Choosing a network design that only supports this architecture may reduce certain implementation costs by allowing for smaller, passive FDCs in the field. However, this architecture will limit the redundancy capability from the FDCs to the hubs. By pushing the network electronics further into the field, the network gains added resiliency by allowing the access electronics to be fed from the redundant backbone network with automatic path protection switching to protect in the event of a fiber break. If backbone fiber is cut, the subscribers connected to a given FDC would still have network access.

Selecting a design that supports both of these models, as proposed, would allow HBPW to accommodate many years of shifting technology trends. In this case, the FDCs would be slightly larger, require electrical power connections, and contain active heat exchangers and backup battery systems (Figure 13), but would mitigate physical limitations to technology choices.

Figure 13: Active FDC Example (Calix OD-2000)

This design also increases the attractiveness of the FTTP infrastructure as a utility to facilitate access for competitive providers seeking to target specific market niches not served by HBPW, and requiring a limited initial investment in hardware of their own. The fiber rich design allows these providers to enter the market with a small deployment of network electronics (i.e., placing electronics only at the primary hub sites for a small number of customers), while allowing them to grow their network in response to demand by pushing electronics closer to their subscribers as capacity or particular service level requirements dictate.

In this model, we assume the use of Gigabit Passive Optical Network (GPON) electronics for the vast majority of HBPW subscribers, and Active Ethernet for a small percentage of subscribers (typically business customers) that request a premium service or require greater bandwidth. GPON is the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga EPB. Furthermore, we believe that this hybrid GPON-Active Ethernet architecture, particularly when coupled with the recommended physical architecture, will fully meet demand for the entire lifecycle of the initial hardware platform deployment of at least five to seven years.

Even with NG-PON2 hardware on the horizon and the recently announced XGS-PON standards promising to deliver 10 Gbps services over PON networks as early as 2017, we recommend GPON as the appropriate platform for its first generation of FTTP offerings—at least for the vast majority of its customers. XGS-PON is expected by some manufacturers to be introduced at price points approximately 30 percent to 40 percent higher than that of GPON for OLT, and potentially higher for the ONT hardware. The availability of XGS-PON is likely to push GPON hardware costs downward even further, thereby increasing its value position to serve the vast majority of HBPW customers when coupled with a flexible physical architecture supporting lower split ratios.

XGS-PON may offer a mechanism to introduce 10 Gbps services more widely, if demand warrants, as hardware becomes available. Manufacturers are already retooling existing product lines to support XGS-PON, and a single XGS-PON interface can be used to "feed" two or more "PONs"—meaning XGS-PON can be deployed on a 1:64 split basis overlaid on a network with GPON operating at a 1:32 or 1:16 split ratio, serving a limited number of 10 Gbps customers with reduced hardware costs.

NG-PON2 hardware will be significantly more expensive when it is available, and manufacturers have not begun to offer hard timelines for when it will be available for widespread consumption beyond limited trials. Eventually, even NG-PON2 hardware is likely to reach price points similar to today's GPON hardware; while not recommended for HBPW in the near term, NG-PON2 demonstrates that the physical fiber infrastructure built now will support future generations of electronics providing capacity increases of many orders of magnitude.

Providers of gigabit services today typically provide these services on GPON platforms. Even though the GPON platform is limited to 1.24 Gbps upstream and 2.49 Gbps downstream for the subscribers connected to a single PON splitter, operators have found that the statistical variations in actual subscriber usage generally means that all subscribers can obtain 1 Gbps on a peak basis (without provisioned rate-limiting), even if the capacity is shared by multiple users in a PON.

Although peak demand by a given customer may spike to several hundred megabits per second, or even close to 1 Gbps (likely only when performing a speed test), providers have found recent per customer average demand is closer to 1 Mbps even when the service is not rate limited. Even if we remove video services from the equation and assume upwards of 1 Gbps per PON is used continuously for on-demand and IP multicast video (more than three simultaneous 4K resolution video streams per customer in a 1:16 split), Neilson's Law,[65] which states that a high-end user's connection speed grows by 50 percent per year, suggests the demand presented by other applications and OTT services would not exceed GPON capacity until about 2025.

By casual observation of broadband speeds available over the past decade or two, Neilson's Law seems to have proven fairly accurate—at least as far as can be expected of a prognostication tool based mostly on observation of market trends and technology development—and is still probably as good as any forecasting tool to conservatively assess capacity demand.

Even in networks providing "dedicated" connections, oversubscription occurs further upstream in the network—no Internet connection is truly "dedicated." As discussed earlier, GPON manufacturers have a development roadmap to 10 Gbps and faster speeds as user demand increases beyond what GPON can support in the access layer, but these technologies will not be needed to support 1 Gbps service offerings until they are far more affordable many years from now.

GPON supports high-speed broadband data, and is easily leveraged by triple-play carriers for voice, video, and data services. The GPON OLT uses single-fiber (bi-directional) SFP modules to support multiple (most commonly 32) subscribers per PON. GPON uses passive optical splitting, which is performed inside fiber distribution cabinets (FDC), within the access network, or both, connecting fiber interfaces on the OLTs to the customer premises. In the proposed "home-run" access network architecture, all splitters are housed in the FDCs, each of which is equipped to support roughly 1,000 customers.

Active Ethernet (AE) provides a symmetrical (up/down) service that is commonly referred to as Symmetrical Gigabit Ethernet. AE can be provisioned to run at sub-gigabit speeds, and easily supports legacy voice (GR-303 and TR-008) and next-generation voice-over-IP (SIP and MGCP) services. For subscribers receiving Active Ethernet service, a single dedicated fiber connects between the subscriber premises and an access network Ethernet switch with no optical splitting. Because AE requires dedicated fiber (home-run) from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is a significant equipment cost differential at the access layer to provision an AE subscriber versus a GPON subscriber. The recommended fiber plant design will provide Active Ethernet service or GPON service to all passings, enabling HBPW to select electronics based on the mix of services it plans to offer—and can modify or upgrade electronics to change the mix of services as demands grow. Furthermore, the recommended

[65] https://www.nngroup.com/articles/law-of-bandwidth/

design entails the placement of equipment capable of providing a mix of both GPON and AE connections—managed and provisioned on a common platform, either from the same OLT line cards or by mixing different line cards in the same hardware chassis.

Attachment 5 provides a detailed bill of materials (BOM) for candidate network electronics, including OLT hardware and related components. We note that although our pricing is based on Calix hardware, several manufacturers, including Adtran and Alcatel-Lucent, can deliver competitive products meeting the recommended configurations.

5.1.4 Customer Premises Equipment (CPE) and Service Drops

In the final segment of the recommended FTTP distribution plant, fiber runs from the FDC to subscriber taps located in the right-of-way near the customers' homes and office buildings. The taps consist of factory assembled connector housings in which the fiber strands terminate. The service installer uses a pre-connectorized drop cable to connect the tap to the subscriber premises without the need for fiber optic splicing. The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects to customer premises equipment (CPE).

We have specified two CPE kits (residential and business) to offer various features and capabilities and to meet subscriber requirements, either of which can be provided in an indoor or outdoor configuration. Both consist primarily of an Optical Network Terminal (ONT) capable of either GPON or Ethernet media conversion (or both), providing copper-based (RJ-45) Gigabit Ethernet interfaces at the customer demarcation. The recommended design includes installation of an uninterruptible power supply (UPS) for each, and installation of at least one network cable drop within the home or business to connect to customer equipment.

Either CPE configuration can support symmetrical gigabit per second service rates, and include an integrated VoIP gateway to provide telephone services. The residential CPE configuration includes an Internet gateway with WiFi capabilities. The business CPE assumes the customer provides their own firewall or router at the service demarcation, but includes additional costs for more extensive indoor cabling and service provisioning support.

Attachment 5 provides a detailed bill of materials (BOM) for candidate network electronics, including the two CPE kits.

5.2 FTTP Network Cost Estimates and Phasing

FTTP construction will entail costs in three basic categories:

- OSP labor and materials
- Network electronics
- Subscriber activation costs (service drop cables and CPE)

Our model assumes a mix of aerial and underground fiber construction, based on the prevailing mix of utilities in the City, and a 39.6 percent take rate. [66] Please note this take rate is only used as a placeholder for discussion in this section; as seen in the full financial analysis in Section 5, which shows the impact of take rate on construction cost, cash flow, and net income.

The estimated cost to construct the proposed FTTP OSP throughout the existing HBPW electric service footprint is approximately $44.4 million—which corresponds to a cost of approximately $1,540 per passing,[67] not including drop cable installation, CPE, or network electronics. With an estimated $3.1 million in network electronics required, the total per passing cost increases to approximately $1,650.

With average per customer activation costs of just under $1,400, including CPE and drop cable installation, the total network implementation cost is estimated to be $63.2 million at a take rate of 39.6 percent. Table 11 summarizes the cost estimates.

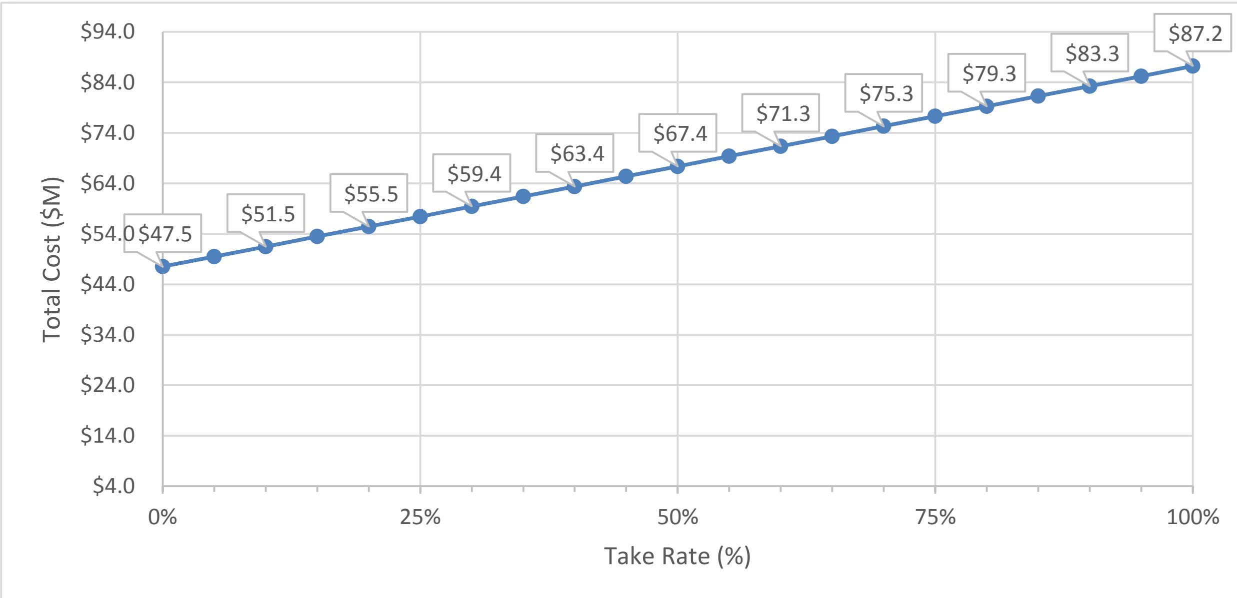
[66] Take rate is the percentage of subscribers who purchase services from an enterprise, and is a crucial driver in the success of an FTTP retail model. If the take rate is not met, the enterprise will not be able to sustain itself and its operational costs will have to be offset through some funding source to avoid allowing the enterprise to fail.
[67] The model counts each potential residential or business customer as a passing, so single-unit buildings count as one passing, while each unit in a multi-dwelling or multi-business building is treated as a single passing.

Table 11: Estimated FTTP Deployment Costs (Assuming a 39.6 Percent Take Rate)

Cost Component	Total Estimated Cost
Backbone OSP Construction Costs	
OSP Engineering	$ 6,180,000
Quality Control/Quality Assurance	3,285,000
General OSP Construction Cost	29,858,000
Special Crossings	-
Backbone and Distribution Plant Splicing	2,005,000
Backbone Hub, Termination, and Testing	3,111,000
Subtotal	**$ 44,439,000**
Backbone Network Electronics Costs	
Core and Distribution Network Equipment	$ 738,000
Access Equipment (GPON and Active Ethernet OLT)	2,336,000
Subtotal:	**$ 3,074,000**
Subscriber Activation Costs	
FTTP Service Drop and Lateral Installations	$ 9,340,000
Customer Premises Equipment and Installation	6,386,000
Subtotal:	**$ 15,726,000**
Total Estimated Cost:	**$ 63,239,000**

Figure 14 illustrates the total FTTP implementation costs as a function of the total initial take rate.

Figure 14: Estimated FTTP Costs Are Take Rate-Dependent



In the sections following, we describe our cost estimation methodology, and provide more detail on the estimated costs. We also discuss assumptions related to operating costs, and discuss implementation phasing considerations.

5.2.1 OSP Cost Estimation Methodology and Assumptions

Reaching every residence and business within the HBPW electric service footprint will require building FTTP infrastructure along the vast majority of the nearly 450 miles of street miles. 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 are further varied by 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. Our estimation methodology involves the extrapolation of estimated costs on the basis of street mileage for strategically selected sample designs, as well as field surveys to ascertain unique attributes of particular service areas.

We first developed the system-level backbone network design, as described in the previous sections, to serve as the basis for subdividing the City into these smaller service areas. We then surveyed a broad sampling of the HBPW electric service area to estimate averages for key metrics impacting construction methodology and cost, such as requirements for special crossings (bridges, railways, etc.), the number of utility poles per mile, and the estimated level of utility pole make-ready construction required to facilitate aerial construction of fiber. This preliminary survey was performed via Google Earth Street View and supplied GIS data, allowing a large area to be surveyed cost effectively.

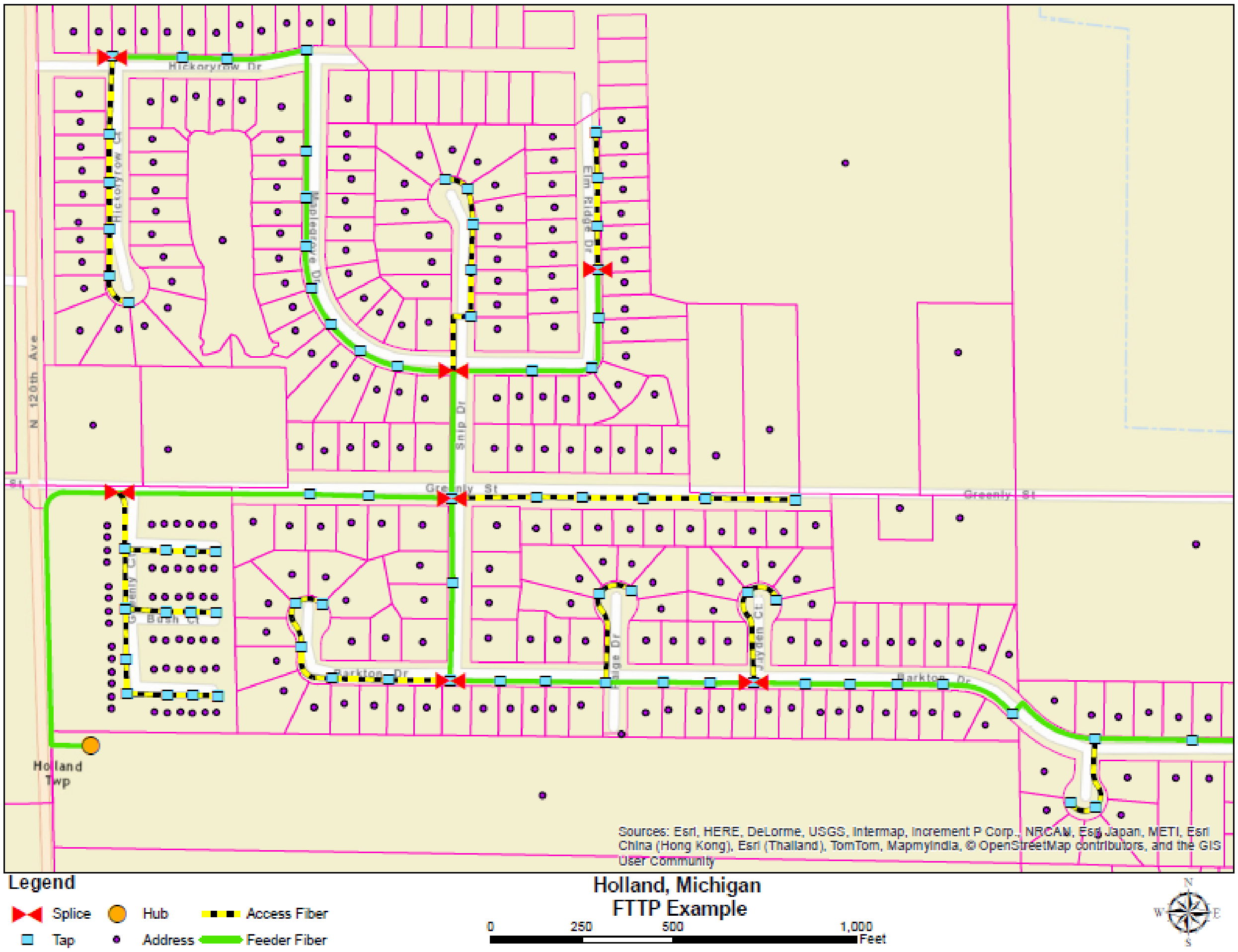
Our observations determined that there tend to be relatively large, contiguous subsections of the overall service area in which the electric utility infrastructure (as well as cable television in most cases) is almost entirely underground or aerial, and for which each can further be subdivided into areas having relatively consistent passing density (passings per street mile). As such, we delineated the entire service area on the basis of density and existing utility infrastructure type (aerial versus underground) according to the following seven categories:

- High density (>75 passings per street mile)
    a. Aerial – 110 passings/mile on average
    b. Underground – 146 passings/mile on average
    c. Urban (downtown) Underground – 83 passings/mile on average
- Medium density (25 to 75 passings per street mile)
    a. Aerial – 69 passings/mile on average
    b. Underground - 75 passings/mile on average
- Low density (<25 passings per street mile)
    a. Aerial – 16 passings/mile on average
    b. Underground – 12 passings/mile on average

Attachment 6 provides a map that illustrates the delineations of the electric service area based on these categories.

We developed sample designs within each of the representative areas, selected to approximate the average density of passings per street mile for the entire category. These sample designs, coupled with key metrics derived through GIS analysis and surveys, were used to extrapolate quantities for corresponding labor and material units. Figure 15 below is a sample design illustrating each of the components of the distribution plant.

Figure 15: Sample FTTP Distribution Layer Design



The survey of existing OSP revealed certain key metrics related to aerial infrastructure that informed the cost estimate. In general, we believe aerial construction is viable as a cost savings alternative to underground construction along approximately 55 percent of the total network routes—those areas identified as aerial in Attachment 6. Within these areas, we expect no more than 20 percent of the poles will require significant make-ready work, consisting of 1.5 attachment relocations per pole on average, at an average cost of $150 each. Furthermore, we expect less than 5 percent of the poles in aerial areas will require replacement—note that we assume poles that have been "topped" represent ongoing pole renewal efforts not included in these estimates.

We also note that a significant number of residential areas are fed from pole lines located in rear easements, often made directly inaccessible by homeowners' fences. We assume that HBPW has appropriate polices and equipment in place to gain access and effect necessary make-ready work without significantly impacting costs.

Additional assumptions used to formulate our cost estimates based on input from HBPW staff include:

- Little or no hard rock will encountered during underground construction requiring special cutting or drilling equipment;
- Available space exists within existing conduit under special crossings (railroads, bridges, bodies of water, and highways) for new backbone cable to avoid new permitting and encroachment/licensing fees;
- Overhead crossings of private property requiring encroachment/licensing fees (i.e. railroad) can be overlashed without incurring new licensing fees; and
- Utility pole replacement, when required, will average approximately $1,000 per pole based on recent records.

5.2.2 Fiber Construction Cost Estimates

The fiber construction cost estimates detailed below entail a turnkey implementation executed using contractor resources from design to acceptance testing. Backbone and distribution fiber plant implementation costs are estimated to be $44.4 million, not including service drops. At a take rate of 39.6 percent, we estimate fiber service drop connections costing an additional $9.3 million (just under $820 per drop on average), yielding a total OSP cost of approximately $53.8 million.

Our estimates assume the 45 mile backbone can be constructed primarily along existing fiber routes, or routes required for distribution plant to serve new customers, consisting of a new 288-strand cable. Only 2.2 miles of the backbone are anticipated to occur over standalone paths. Additional cost savings may be possible if sufficient spare strand capacity is available along existing fiber routes; certainly timeframes can be reduced for activating particular service areas where backbone need not be constructed. However, to maximize flexibility of the backbone, we include this dedicated capacity even along existing fiber routes.

Cost estimates assume the installation of 2-inch flexible HDPE conduit using horizontal directional drilling along all underground routes (two 2-inch conduits along underground backbone routes). Cost estimates are inclusive of all project management, quality assurance, engineering, permitting, materials, and labor anticipated, including permanent hard surface restoration, traffic control, and work area protection. Table 12 provides details OSP construction costs, broken down by key line items and passing density.

Table 12: FTTP OSP Construction Cost Estimates

Cost Component	Phase 1 Backbone	Phase 2 High Density (> 75 passings/mi)	Phase 3 Medium Density (25-75 passings/mi)	Phase 4 Low Density (< 25 passings/mi)	Total Estimated Cost
Backbone OSP Construction Costs					
OSP Engineering	$29,000	$741,000	$4,449,000	$961,000	$6,180,000
Quality Control/Quality Assurance	$15,000	$394,000	$2,365,000	$511,000	$3,285,000
General OSP Construction Cost	$1,138,000	$3,210,000	$21,229,000	$4,281,000	$29,858,000
Special Crossings	$ –	$ –	$ –	$ –	$ –
Backbone and Distribution Plant Splicing	$4,000	$251,000	$1,575,000	$175,000	$2,005,000
Backbone Hub, Termination, and Testing	$1,498,000	$277,000	$1,150,000	$186,000	$3,111,000
				Subtotal	**$ 44,390,000**
Subscriber Activation Costs					
FTTP Service Drop and Lateral Installations	$ –	$1,257,000	$7,151,000	$932,000	$9,340,000
				Subtotal:	**$9,340,000**
Total Estimated Cost:	$2,684,000	$6,130,000	$37,919,000	$7,046,000	$53,779,000
Total Estimated Passings:	**N/A**	**5,678**	**21,977**	**1,199**	**28,854**

A more detailed breakdown of the OSP costs is included in Attachment 4. The cost components itemized in the table above include the following scope of tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.

- ***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.
- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.
- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.
- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.
- ***FTTP Service Drop and Lateral Installations*** **–** consists of all costs related to fiber service drop installation, including OSP construction on private property, building penetration, and inside plant construction to a typical backbone network service "demarcation" point; also includes all materials and labor related to the termination of fiber cables at the demarcation point. A take rate of 35 percent was assumed for standard fiber service drops.

The following table provides estimated OSP construction costs broken down based on areas of defined passing density with and without service drop costs, illustrating the range of relative costs per passing for different types of service areas.

Phase	Distribution Plant Mileage	Total Cost (with drops)	Total Cost (without drops)	Passings	Cost per Passing (Distribution Only)	Cost Per Plant Mile (Distribution Only)
Total:	475	53,779,704	$44,439,766	28,854	$1,540	$90,000
Backbone	2.2	$2,685,137	$2,685,137	–	N/A	$1,208,037
High Density	56.9	$6,130,228	$4,873,389	5,678	$858	$85,604
Med. Density	341.7	$37,917,982	$30,767,229	21,977	$1,400	$90,042
Low Density	73.8	$7,046,356	$6,114,012	1,199	$5,099	$82,836

Where applicable, cost estimates are based on contract labor and material rates we have seen in other competitively bid fiber projects, as well as supplied HBPW contractor rates.

5.2.3 Network Electronics Cost Estimates

Core, distribution, and access layer network electronics are estimated at a total cost of approximately $3.1 million, not including CPE. An additional cost for CPE of $6.4 million at a take rate of 39.6 percent yields a total network electronics cost of $9.5 million. All cost estimates include estimated installation and integration costs. Table 13 provides estimated network electronics costs, broken down by project "phases" corresponding to areas of defined passing density.

Table 13: FTTP Network Electronics Cost Estimate

Cost Component	Phase 1	Phase 2	Phase 3	Phase 4	Total Estimated Cost
	Backbone	High Density (> 75 passings/mi)	Medium Density (25-75 passings/mi)	Low Density (< 25 passings/mi)	
Backbone Network Electronics Costs					
Core and Distribution Network Equipment	$ 738,000	$ –	$ –	$ –	$ 738,000
Access Equipment (GPON and Active Ethernet OLT)	$ –	$483,000	$1,732,000	$121,000	$2,336,000
				Subtotal:	**$3,074,000**
Subscriber Activation Costs					
Customer Premises Equipment and Installation	$ –	$1,257,000	$4,864,000	$265,000	$6,386,000
				Subtotal:	**$ 6,386,000**
Total Estimated Cost:	$738,000	$1,740,000	$6,596,000	$386,000	**$9,460,000**

CPE equipment and installation costs are estimated at approximately $530 for a standard residential subscriber and $700 for a business subscriber, both inclusive of onsite configuration of the CPE, installation of an uninterruptible power supply (UPS), and installation of at least one network cable drop within the home or business to connect to customer equipment.

We note that the HBPW operates an existing Ethernet backbone comprised of Alcatel-Lucent 7210 Service Access Switches (SAS), interconnected in a topology of multiple rings operating at 10 Gbps speeds. While it may be possible to leverage this backbone for the near term in place of certain core and distribution network electronics included in our cost estimates, we expect that the useful lifespan of this hardware and capacity demands will require upgrades to hardware supporting dense aggregation of 10 GE connections within the timeframe of the initial FTTP network buildout.

Attachment 5 provides a detailed bill of materials (BOM) for a candidate network electronics supporting an FTTP deployment throughout the HBPW electric service area.

5.2.4 Network Maintenance Costs

Fiber optic cable is resilient compared to copper telephone lines and cable TV coaxial cable. The fiber itself does not corrode, and fiber cable installed over 30 years ago is still in good condition. However, fiber can be vulnerable to accidental cuts by unrelated construction, traffic accidents, and severe weather. One of the larger costs associated with OSP maintenance are associated with performing locates for underground plant in response to locate requests initiated through the state-mandated one-call “811” damage prevention system (i.e. the MISS DIG System).

Costs associated with maintenance and repair can be highly variable on a year-to-year basis, particularly for required undergrounding, relocations due to new construction conflicts, and fiber breaks - but over time these costs trend towards averages we have seen in networks of varying size. In particular, we recommend planning for expenses associated with OSP maintenance of approximately 1 percent of the total construction cost, or approximately $540,000 for the full network. Included within this figure is an estimated fiber break per year for every 10 miles of plant, with repair costs ranging from $5,000 to $10,000 per incident.

An estimated $380,000 annually is required for network electronics maintenance. This covers a range of strategies entailing a mix of manufacturer maintenance contracts and warehousing spare components. In general, the level of equipment redundancy provided by the recommended architecture eliminates the need for maintenance contracts that provide rapid, advanced replacement of failed hardware. Instead, our estimates include costs for maintenance contracts providing next business day replacement of failed components for the core and distribution layers of the network, as well as an annual budgetary estimate equivalent to 15 percent of the total cost of access layer equipment to cover spares, replacements, and/or equivalent maintenance contracts.

5.2.5 Implementation Phasing Considerations

The cost estimates generated for this analysis reveal potentially significant details to guide a cost-effective FTTP deployment that maximizes return on investment, and perhaps more importantly, offers insights into how to phase construction to capture new revenues with the least amount of new investment. Market demand and other factors impacting take rate notwithstanding, per passing OSP construction costs will play a significant role in the business case for an FTTP deployment.

An initial focus on FTTP deployment within the boundaries of the City of Holland, for example, provides a substantial reduction in per passing cost without necessitating any deviation in the recommended architecture. Serving an estimated 15,654 passings (based on electric service drop GIS data), the total estimated FTTP implementation cost is $29.8 million with a take rate of 39.6 percent. This encompasses per passing costs of approximately $1,420, including electronics (but not including subscriber activation costs), compared to $1,650 per passing for the full deployment throughout the entire electric service area.

For sake of comparison, Table 14 details the full FTTP implementation costs for a deployment limited to City of Holland boundaries, including subscriber activation costs at a take rate of 39.6 percent.

Table 14: Estimated FTTP Deployment Costs Within City of Holland Boundaries (Assuming a 39.6 Percent Take Rate)

Cost Component	Phase 1 Backbone	Phase 2 High Density (> 75 passings/mi)	Phase 3 Medium Density (25-75 passings/mi)	Phase 4 Low Density (< 25 passings/mi)	Total Estimated Cost
Backbone OSP Construction Costs					
OSP Engineering	$29,000	$689,000	$1,801,000	$362,000	$2,881,000
Quality Control/Quality Assurance	$15,000	$366,000	$957,000	$193,000	$1,531,000
General OSP Construction Cost	$684,000	$2,776,000	$7,714,000	$1,976,000	$13,152,000
Special Crossings	$ –	$ –	$ –	$ –	$ –
Backbone and Distribution Plant Splicing	$2,000	$219,000	$639,000	$67,000	$927,000
Backbone Hub, Termination, and Testing	$1,030,000	$207,000	$440,000	$71,000	$1,748,000
				Subtotal:	**$20,239,000**
Backbone Network Electronics Costs					
Core Network Equipment	$667,000	$ –	$ –	$ –	$667,000
Distribution and Access Equipment (GPON OLT)	$ –	$483,000	$846,000	$40,000	$1,369,000
				Subtotal:	**$2,036,000**
Subscriber Activation Costs					
FTTP Service Drop and Lateral Installations	$ –	$942,000	$2,844,000	$230,000	$4,016,000
Customer Premises Equipment and Installation	$ –	$1,085,000	$2,299,000	$81,000	$3,465,000
				Subtotal:	**$7,481,000**
Total Estimated Cost:	$2,427,000	$6,767,000	$17,540,000	$3,020,000	**$29,756,000**
Total Estimated Passings:	**N/A**	**4,901**	**10,387**	**366**	**15,654**

Without limiting the deployment to a particular political boundary, consideration should be given to density and construction type delineations when determining project phasing. HBPW can minimize risk and maximize the potential to reach its entire service area with FTTP through a strategic approach to project phasing. Indeed, high-density and medium-density aerial construction areas will tend to provide the best mix of cost per passing and reduced time to market of FTTP services given the particular construction environment throughout the HBPW electric service footprint. Not including the backbone, these areas represent less than 44 percent of the estimated total distribution plant costs (not including drops), but reach almost 57 percent of the total potential passings.

Outside of particular economic development benefits, or potentially the ability to reach customers with particularly high capacity demands, the low-density areas should constitute longer-term targets, in general. Throughout the electric service area, the low-density areas represent nearly 15 percent of the total distribution plant costs (not including service drops), but only 4 percent of the total passings. Investments in these areas may need to be examined on a case-by-case basis with respect to serving particular customers.

6 Financial Projections

The financial analysis in this section assumes the HBPW owns and operates the FTTH infrastructure; provides open access to competitive providers; and provides retail services itself to residents and businesses in the community. This financial analysis is based on a number of assumptions, outlined below.

In the analysis we assume the HBPW offers three retail services, at prices that compare favorably to similar services in other cities:[68]

- A 1 Gbps residential service at $80 per month,
- A 1 Gbps small commercial service at $85 per month, and
- A 1 Gbps medium commercial service at $220 per month (including service-level agreement)

We also assume that the HBPW will offer two wholesale transport services:

- A 1 Gbps residential service at $62 per month, and
- A 1 Gbps small commercial service at $66 per month

We assume a 39.6 percent take rate for both residential and business customers—and that for each sector, 90 percent will choose 1 Gbps retail service and 10 percent will choose 1 Gbps wholesale transport. (For the business sector, we further assume that 5 percent of businesses will obtain the higher-level retail service, 85 percent will opt for the lower-level retail service, and 10 percent will go with wholesale transport service.)

The financial analysis for this base case scenario is as follows:

[68] A 1 Gbps high-speed retail data offering for $80 per month for residential customers and $85 per month for small business users is a good benchmark for the HBPW to pursue. This is close to Google's price point, and is lower than some other providers. For example, Ting Internet announced that it will be serving Charlottesville, Virginia and Westminster, Maryland with a 1 Gbps offering for $89 per month. *See:* https://ting.com/internet

Table 15: Base Case Financial Analysis with 39.6 Percent Take Rate

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,996,344	$ 10,996,344	$ 10,996,344	$ 10,996,344
Total Cash Expenses	(2,251,000)	(3,790,970)	(3,790,970)	(3,790,970)	(3,790,970)
Depreciation	(1,893,940)	(5,864,230)	(3,777,560)	(3,716,080)	(3,678,700)
Interest Expense	(1,800,000)	(2,427,220)	(1,563,910)	(766,120)	(129,110)
Taxes	-	-	-	-	-
Net Income	$ (3,047,858)	$ (1,086,076)	$ 1,863,904	$ 2,723,174	$ 3,397,564
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,708,492	$ 529,080	$ (232,240)	$ 5,951,130	$ 16,035,400
Depreciation Reserve	-	2,024,620	2,506,540	1,545,840	3,012,200
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,758,492	$ 4,803,700	$ 4,524,300	$ 9,746,970	$ 21,297,600

This analysis does not indicate or review whether obtaining this required take rate is realistic; rather, it reflects the take rate necessary to maintain a positive cash flow, considering all other assumptions in the model. The complete model is provided in Appendix C.

Please note that we used a “flat-model” in the analysis. With a “flat-model,” inflation and salary cost increases are not used in the analysis because it is assumed that 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 can greatly overstate net revenues in the out-years since net revenues would then also increase by the same inflation factor.

6.1 Financing Costs and Operating Expenses

This financial analysis assumes a combination of bonds and loans will be necessary. We expect that the HBPW will seek a 20-year bond and two 10-year loans—one in year two, one in year three. Principal repayment on the 20-year bond will start in year four; principal repayment on both 10-year loans will start in year three.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, a debt service reserve account is maintained at 5.0 percent of the total issuance amount. An interest reserve account equal to years one and two interest expense is maintained for the first two years.

Our analysis estimates total financing requirements to be $45 million in bonds and $17.2 million in loans.[69]

- We assume a 20-year bond in a total amount of $45 million to be issued in full in year one.

[69] The scope of work for this report does not include a review of the HBPW’s bonding capability or review of local or state bonding restrictions. A more detailed review and opinion from the HBPW’s accountants of bonding capability and restrictions is recommended, if bonding is pursued.

- This bond is issued a 4.0 percent finance rate and principal payments start in year four.
- A loan totaling $5.2 million is issued in year two, with principal payments starting in year three.
- A loan totaling $12 million is issued in year three, with principal payments starting in year three.
- Loans are issued at 5.0 percent.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network equipment will need to be replaced after 10 years. Last mile and CPEs as well as other miscellaneous implementation costs will need to be accounted for after five years. Network equipment will be replaced or upgraded at 80 percent of its original cost, miscellaneous implementation costs will be at 75 percent, and last mile and CPEs will be at 75 percent.[70] The model plans for a depreciation reserve account starting in year four—this funds future electronics replacements and upgrades.

Table 16 shows operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network matures and the customer base increases.

[70] In addition, starting in year four, we assume an annual cost of 1 percent of the total accrued CPE value for miscellaneous replacements and upgrades.

Table 16: Operating Expenses in Years 1, 5, 10, 15, and 20

	Year 1	Year 5	Year 10	Year 15	Year 20
Operating Expenses					
Support Services	$ 96,890	$ 205,700	$ 205,700	$ 205,700	$ 205,700
Insurance	50,000	100,000	100,000	100,000	100,000
Utilities	15,000	30,000	30,000	30,000	30,000
Office Expenses	36,000	50,000	50,000	50,000	50,000
Locates & Ticket Processing	10,000	38,000	38,000	38,000	38,000
Contingency	25,000	50,000	50,000	50,000	50,000
Billing Maintenance Contract	15,000	25,000	25,000	25,000	25,000
Fiber Maintenance	177,760	444,390	444,390	444,390	444,390
Vendor Maintenance Contracts	-	380,000	380,000	380,000	380,000
Legal and Lobby Fees	150,000	50,000	50,000	50,000	50,000
Consulting	100,000	25,000	25,000	25,000	25,000
Marketing	500,000	250,000	250,000	250,000	250,000
Education and Training	8,100	15,050	15,050	15,050	15,050
Customer Handholding	-	-	-	-	-
Customer Billing (Unit)	3,130	13,710	13,710	13,710	13,710
Allowance for Bad Debts	28,970	109,960	109,960	109,960	109,960
Churn (acquisition costs)	7,820	34,280	34,280	34,280	34,280
Pole Attachment Expense	126,700	126,700	126,700	126,700	126,700
Internet	65,630	287,930	287,930	287,930	287,930
Sub-Total	$ 1,441,000	$ 2,285,720	$ 2,285,720	$ 2,285,720	$ 2,285,720
Labor Expenses	$ 810,000	$ 1,505,250	$ 1,505,250	$ 1,505,250	$ 1,505,250
Sub-Total	$ 810,000	$ 1,505,250	$ 1,505,250	$ 1,505,250	$ 1,505,250
Total Expenses	$ 2,251,000	$ 3,790,970	$ 3,790,970	$ 3,790,970	$ 3,790,970
Principal and Interest	$ 1,800,000	$ 5,984,570	$ 5,984,570	$ 3,698,930	$ 3,698,930
Facility Taxes	-	-	-	-	-
Sub-Total	$ 1,800,000	$ 5,984,570	$ 5,984,570	$ 3,698,930	$ 3,698,930
Total Expenses, P&I, and Taxes	$ 4,051,000	$ 9,775,540	$ 9,775,540	$ 7,489,900	$ 7,489,900

Table 17 shows the income statement for years one, five, 10, 15, and 20.

Table 17: Income Statement

		Year 1		Year 5		Year 10		Year 15		Year 20
a. Revenues										
Internet - Residential	$	2,028,864	$	8,901,576	$	8,901,576	$	8,901,576	$	8,901,576
Internet - Business		477,468		2,094,768		2,094,768		2,094,768		2,094,768
Enterprise		-		-		-		-		-
Connection Fee (net)		390,750		-		-		-		-
Provider Fee		-		-		-		-		-
Assessments		-		-		-		-		-
Ancillary Revenues		-		-		-		-		-
Total	$	2,897,082	$	10,996,344	$	10,996,344	$	10,996,344	$	10,996,344
b. Content Fees										
Internet	$	65,630	$	287,930	$	287,930	$	287,930	$	287,930
Total	$	65,630	$	287,930	$	287,930	$	287,930	$	287,930
c. Operating Costs										
Operation Costs	$	1,375,370	$	1,997,790	$	1,997,790	$	1,997,790	$	1,997,790
Labor Costs		810,000		1,505,250		1,505,250		1,505,250		1,505,250
Total	$	2,185,370	$	3,503,040	$	3,503,040	$	3,503,040	$	3,503,040
d. EBITDA	$	646,082	$	7,205,374	$	7,205,374	$	7,205,374	$	7,205,374
e. Depreciation		1,893,940		5,864,230		3,777,560		3,716,080		3,678,700
f. Operating Income (EBITDA less Depreciation)	$	(1,247,858)	$	1,341,144	$	3,427,814	$	3,489,294	$	3,526,674
g. Non-Operating Income										
Interest Income	$	-	$	11,890	$	11,890	$	9,490	$	13,160
Interest Expense (10 Year Bond)		-		-		-		-		-
Interest Expense (20 Year Bond)		(1,800,000)		(1,296,180)		(1,296,180)		(775,610)		(142,270)
Interest Expense (Loan)		-		(279,620)		(279,620)		-		-
Total	$	(1,800,000)	$	(1,563,910)	$	(1,563,910)	$	(766,120)	$	(129,110)
h. Net Income (before taxes)	$	(3,047,858)	$	(1,086,076)	$	1,863,904	$	2,723,174	$	3,397,564
i. Facility Taxes	$	-	$	-	$	-	$	-	$	-
j. Net Income	$	(3,047,858)	$	(1,086,076)	$	1,863,904	$	2,723,174	$	3,397,564

Table 18 shows the cash flow statement for years one, five, 10, 15, and 20. The unrestricted cash balance is approximately $44,000 in year one and $459,000 in year 10. By year 15, the unrestricted cash balance is approximately $3.3 million and it is $6.2 million by year 20.

Table 18: Cash Flow Statement

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (3,047,858)	$ (1,086,076)	$ 1,863,904	$ 2,723,174	$ 3,397,564
Cash Flow	$ 15,708,492	$ 58,644	$ (391,656)	$ 1,918,024	$ 1,937,764

	Year 1	Year 5	Year 10	Year 15	Year 20
Principal Payments	$ -	$ 3,546,660	$ 4,408,770	$ 2,923,320	$ 3,556,660
Interest Payments	1,800,000	2,437,910	1,575,800	775,610	142,270
Total Debt Service	$ 1,800,000	$ 5,984,570	$ 5,984,570	$ 3,698,930	$ 3,698,930

	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$ 15,708,492	$ 529,080	$ (232,240)	$ 5,951,130	$ 16,035,400
Funded Depreciation	-	2,024,620	2,506,540	1,545,840	3,012,200
Restricted Cash Balance (Interest Reserve)	1,800,000	-	-	-	-
Restricted Cash Balance (Debt Service Reserve)	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,758,492	$ 4,803,700	$ 4,524,300	9,746,970	$ 21,297,600

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, implementing, and lighting a fiber network. Table 19 shows the capital additions costs in years one, two, and three, and the total for years one through three.

This analysis projects that capital additions in year one will total approximately $23.6 million. These costs will total approximately $24.8 million in year two, and $15.4 million in year three. This totals just under $64 million for total capital additions costs for years one through three.

Table 19: Capital Additions

	Year 1	Year 2	Year 3	Total Years 1 to 3
Network Equipment				
Core Network Equipment	$ 738,000	$ -	$ -	$ 738,000
Distribution and Access Equipment (GPON OLT)	934,400	934,400	467,200	2,336,000
Additional Annual Capital	-	-	-	-
Total	$ 1,672,400	$ 934,400	$ 467,200	$ 3,074,000
Outside Plant and Facilities				
Total Backbone and FTTP	$ 17,775,600	$ 17,775,600	$ 8,887,800	$ 44,439,000
Additional Annual Capital	-	-	-	-
Total	$ 17,775,600	$ 17,775,600	$ 8,887,800	$ 44,439,000
Last Mile and Customer Premises Equipment				
CPE Gbps (medium commercial)	$ 15,400	$ 26,600	$ 25,900	
CPE Residential & Small Commercial	$ 1,443,900	$ 2,442,830	$ 2,447,300	$ 6,334,030
Enterprise CPE and Drop	-	-	-	-
Average Drop Cost	2,128,290	3,601,340	3,607,060	9,336,690
Total	$ 3,587,590	$ 6,070,770	$ 6,080,260	$ 15,738,620
Miscellaneous Implementation Costs				
Splicing	$ -	$ -	$ -	
Vehicles	150,000	-	-	
Emergency Restoration Kit	50,000	-	-	
Work Station, Computers, and Software	$ 17,000	$ 11,000	$ 8,000	$ 36,000
Fiber OTDR and Other Tools	85,000	-	-	85,000
Generators & UPS	-	-	-	-
OSS	300,000	-	-	300,000
Additional Annual Capital	-	-	-	-
Total	$ 602,000	$ 11,000	$ 8,000	$ 621,000
Total Capital Additions	$ 23,637,590	$ 24,791,770	$ 15,443,260	$ 63,872,620

6.2 Operating and Maintenance Expenses

The cost to deploy an FTTP network goes far beyond fiber implementation. Network deployment requires additional staffing for sales and marketing, network operations, and other functions. The addition of new staff and inventory requirements will require office and warehousing space:

- Expand office facilities for management, technical and clerical staff
- Expand retail "storefront" to facilitate customer contact and enhance their experience doing business with the FTTP enterprise
- Provide warehousing for receipt and storage of cable and hardware for the installation and on-going maintenance of the broadband infrastructure
- Establish location to house servers, switches, routers, and other core-network equipment

Training new and existing staff is important to fully realize the economies of starting the FTTP network. The training will be particularly important in the short-term as the new enterprise establishes itself as a unique entity providing services distinct from the dark fiber services provided by the HBPW today.

The HBPW already has billing software and capabilities, and the enterprise might save money by using these, if possible. The estimated incremental cost of billing for the new FTTP enterprise is 10 cents per bill. In addition, we have included a $50,000 set-up fee.

The expanded business and increased responsibilities will require the addition of new staff. Marketing and sales are critical. It is important to be proactive in setting customer expectations, addressing security concerns, and educating the customers on how to initiate services.

The initial additional positions, staffing levels, and base salaries are shown in Table 20. These numbers assume that two shifts of customer service representative support is provided and one and one-half shifts of customer technicians are available. Changing to full 24x7 will increase staffing costs. Changing the support to 7am to 8pm (or other reduced hours) will decrease the required number of staff.

Note that Table 20 lists only new employees—the model assumes no existing staff will be allocated to the enterprise.

Table 20: Labor Expenses

Service Position Total	Year 1	Year 2	Year 3	Year 4	Year 5+
Business Manager	0.50	1.00	1.00	1.00	1.00
Market & Sales Manager	1.00	1.00	1.00	1.00	1.00
Broadband Service Engineer	1.00	1.00	1.00	1.00	1.00
Customer Service Representative	2.00	5.00	7.00	7.00	7.00
Service Technicians/Installers & IT Support	2.00	3.00	5.00	5.00	5.00
Sales and Marketing Representative	1.00	2.00	2.00	2.00	2.00
Fiber Plant O&M Technicians	1.00	1.00	1.00	1.00	1.00
Total	8.50	14.00	18.00	18.00	18.00
Total Customers	2,605	7,013	11,428	11,428	11,428
Customers per Employee	306.47	500.93	634.89	634.89	634.89
Total Salaries	$ 600,000	$ 905,000	$ 1,115,000		

6.3 Summary of Operating and Maintenance Assumptions

Additional key operating and maintenance assumptions include:

- Salaries and benefits are based on estimated market wages. See Table 20 for a list of staffing requirements. Benefits are estimated at 35 percent of base salary.
- Insurance is estimated to be $50,000 in year one and $100,000 from year two on.
- Utilities are estimated to be $15,000 in year one and $30,000 from year two on.
- Office expenses are estimated to be $36,000 in year one and $50,000 from year two on.
- Locates and ticket processing are estimated to start in year one at $10,000, increase to $19,000 in year two, and increase to $38,000 from year three on.
- Contingency is estimated to be $25,000 in year one and $50,000 from year two on.
- Billing and maintenance contract fees are estimated at $15,000 in year one, and $25,000 from year two on.

- Legal fees are estimated to be $150,000 in year one, $75,000 in year two, and $50,000 from year three on.
- Consulting fees are estimated at $100,000 in year one, $50,000 in year and two, and $25,000 from year three on.
- Marketing and promotional expenses are estimated to be $500,000 in year one, and $250,000 from year two on.

Vendor maintenance contract fees are expected to start at $380,000 in year two and remain steady from year two on. Annual variable and operating expenses not including direct Internet access include:

- Education and training are calculated as 1 percent of direct payroll expense.
- Customer billing (incremental) is estimated to be $0.10 per bill per month.
- Allowance for bad debts is computed as 1 percent of revenues.
- Churn is anticipated to be 1.5 percent annually.

Fiber network maintenance costs are calculated at 1 percent of the total construction cost, per year. This is estimated based on a typical rate of occurrence in an urban environment, and the cost of individual repairs. This is in addition to staffing costs to maintain fiber.

6.4 Sensitivity Scenarios

This section shows the large impact that small fluctuations in take rate, subscriber fees, and other key assumptions can have on financial modeling. Note that many of these scenarios may not be realistically attainable. They are meant to demonstrate the sensitivity of these assumptions to the financial projections.

We specifically examine the impact of the three largest operating expense items (staffing, vendor maintenance contracts, and Internet access).

6.4.1 Adding Upfront or Annual Fees Would Reduce the Required Take Rate

In this section, we demonstrate how a relatively small annual utility fee or a special assessment per passing would offset costs and reduce the required take rate.

By adding a $125,000 annual utility fee, the required take rate drops to 38.9 percent—and leads to a virtually identical total cash balance in year 20 as in the base case.

Table 21: Adding $125,000 Annual Utility Fee Reduces Required Take Rate to 38.9 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 3,022,082	$ 10,934,960	$ 10,934,960	$ 10,934,960	$ 10,934,960
Total Cash Expenses	(2,252,250)	(3,781,120)	(3,781,120)	(3,781,120)	(3,781,120)
Depreciation	(1,893,940)	(5,809,460)	(3,758,500)	(3,697,020)	(3,659,640)
Interest Expense	(1,800,000)	(2,427,260)	(1,563,830)	(765,880)	(128,720)
Taxes	-	-	-	-	-
Net Income	$ (2,924,108)	$ (1,082,880)	$ 1,831,510	$ 2,690,940	$ 3,365,480
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,832,242	$ 795,974	$ (177,136)	$ 5,783,274	$ 15,645,124
Depreciation Reserve	-	2,008,190	2,539,780	1,640,450	3,168,180
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,882,242	$ 5,054,164	$ 4,612,644	$ 9,673,724	$ 21,063,304

If the HBPW were instead to charge a special assessment of $1,000 per passing and $500 per connection, while eliminating the customer connection charge from the base case scenario, and decreasing the bonds (to $16 million) and loans (to $8.2 million), the required take rate would drop to 27 percent.

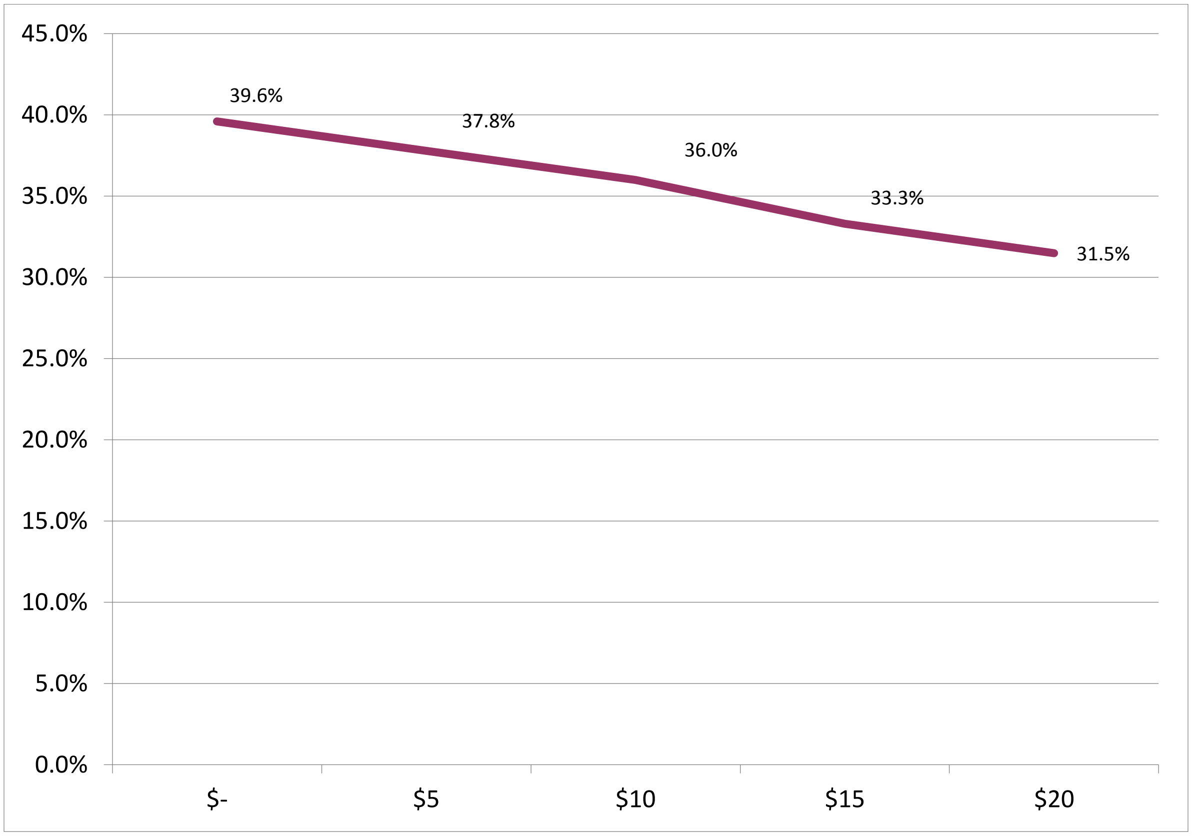
Table 22: Adding Special Assessments Reduces Required Take Rate to 27 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 15,350,832	$ 7,496,664	$ 7,496,664	$ 7,496,664	$ 7,496,664
Total Cash Expenses	(2,375,540)	(3,385,950)	(3,385,950)	(3,385,950)	(3,385,950)
Depreciation	(1,893,940)	(4,841,490)	(3,421,040)	(3,359,560)	(3,322,190)
Interest Expense	(640,000)	(943,910)	(571,960)	(265,480)	(33,750)
Taxes	-	-	-	-	-
Net Income	$ 10,441,352	$ (1,674,686)	$ 117,714	$ 485,674	$ 754,774
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 3,097,702	$ 1,267,794	$ 3,618,464	$ 9,209,614	$ 16,380,784
Depreciation Reserve	-	1,717,690	3,129,700	3,316,830	5,931,020
Interest Reserve	640,000	-	-	-	-
Debt Service Reserve	800,000	800,000	800,000	800,000	800,000
Total Cash Balance	$ 4,537,702	$ 3,785,484	$ 7,548,164	$ 13,326,444	$ 23,111,804

6.4.2 Adding Funding to Decrease Borrowing Would Lower Required Take Rate

Using funds that do not need to be paid back to help cover implementation costs can reduce the required take rate. In Figure 16 we show the impact of increasing funding amounts from $5 million to $20 million, in $5 million increments.

Figure 16: Impact of Initial Funding on Required Take Rate



Decreasing borrowing by adding $5 million in funding would lower the required take rate to 37.8 percent—and would lead to a total cash balance in year 20 that is similar to the base case scenario.

Table 23: Adding $5 Million in Funding and Decreasing Borrowing Reduces Required Take Rate to 37.8 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,497,732	$ 10,497,732	$ 10,497,732	$ 10,497,732
Total Cash Expenses	(2,251,000)	(3,761,400)	(3,761,400)	(3,761,400)	(3,761,400)
Depreciation	(1,893,940)	(5,718,430)	(3,726,800)	(3,665,320)	(3,627,950)
Interest Expense	(1,600,000)	(2,236,400)	(1,420,290)	(679,940)	(112,890)
Taxes	-	-	-	-	-
Net Income	$ (2,847,858)	$ (1,218,498)	$ 1,589,242	$ 2,391,072	$ 2,995,492
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 16,408,492	$ 1,301,002	$ 368,352	$ 6,350,782	$ 16,235,552
Depreciation Reserve	-	1,980,890	2,595,160	1,797,860	3,427,620
Interest Reserve	1,600,000	-	-	-	-
Debt Service Reserve	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Total Cash Balance	$ 20,008,492	$ 5,281,892	$ 4,963,512	$ 10,148,642	$ 21,663,172

Similar to the scenario above, doubling the additional funding to $10 million would further reduce the required take rate, to 36 percent, while tripling the funding, to $15 million, would reduce the necessary take rate to 33.3 percent. Adding $20 million in funding lowers the required take rate to 31.5 percent.

Table 24: Adding $10 Million in Funding and Decreasing Borrowing Reduces Required Take Rate to 36 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 9,994,452	$ 9,994,452	$ 9,994,452	$ 9,994,452
Total Cash Expenses	(2,251,000)	(3,731,660)	(3,731,660)	(3,731,660)	(3,731,660)
Depreciation	(1,893,940)	(5,572,040)	(3,675,830)	(3,614,350)	(3,576,980)
Interest Expense	(1,400,000)	(2,045,570)	(1,276,670)	(593,750)	(96,660)
Taxes	-	-	-	-	-
Net Income	$ (2,647,858)	$ (1,354,818)	$ 1,310,292	$ 2,054,692	$ 2,589,152
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 17,108,492	$ 2,116,024	$ 990,084	$ 6,749,494	$ 16,412,714
Depreciation Reserve	-	1,936,980	2,684,160	2,050,950	3,844,800
Interest Reserve	1,400,000	-	-	-	-
Debt Service Reserve	1,750,000	1,750,000	1,750,000	1,750,000	1,750,000
Total Cash Balance	$ 20,258,492	$ 5,803,004	$ 5,424,244	$ 10,550,444	$ 22,007,514

Table 25: Adding $15 Million in Funding and Decreasing Borrowing Reduces Required Take Rate to 33.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 9,246,948	$ 9,246,948	$ 9,246,948	$ 9,246,948
Total Cash Expenses	(2,251,000)	(3,544,140)	(3,544,140)	(3,544,140)	(3,544,140)
Depreciation	(1,893,940)	(5,352,670)	(3,599,160)	(3,537,680)	(3,500,300)
Interest Expense	(1,200,000)	(1,854,800)	(1,132,940)	(507,250)	(79,910)
Taxes	-	-	-	-	-
Net Income	$ (2,447,858)	$ (1,504,662)	$ 970,708	$ 1,657,878	$ 2,122,598
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 17,808,492	$ 2,851,712	$ 1,161,812	$ 6,312,762	$ 15,369,692
Depreciation Reserve	-	1,871,070	2,818,450	2,432,120	4,472,850
Interest Reserve	1,200,000	-	-	-	-
Debt Service Reserve	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 20,508,492	$ 6,222,782	$ 5,480,262	$ 10,244,882	$ 21,342,542

Table 26: Adding $20 Million in Funding and Decreasing Borrowing Reduces Required Take Rate to 31.5 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 8,747,400	$ 8,747,400	$ 8,747,400	$ 8,747,400
Total Cash Expenses	(2,251,000)	(3,514,570)	(3,514,570)	(3,514,570)	(3,514,570)
Depreciation	(1,893,940)	(5,206,850)	(3,548,390)	(3,486,910)	(3,449,530)
Interest Expense	(1,000,000)	(1,663,980)	(989,330)	(421,060)	(63,690)
Taxes	-	-	-	-	-
Net Income	$ (2,247,858)	$ (1,638,000)	$ 695,110	$ 1,324,860	$ 1,719,610
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 18,508,492	$ 3,622,150	$ 1,756,330	$ 6,701,760	$ 15,554,620
Depreciation Reserve	-	1,827,330	2,907,130	2,684,270	4,888,470
Interest Reserve	1,000,000	-	-	-	-
Debt Service Reserve	1,250,000	1,250,000	1,250,000	1,250,000	1,250,000
Total Cash Balance	$ 20,758,492	$ 6,699,480	$ 5,913,460	$ 10,636,030	$ 21,693,090

6.4.3 Reducing or Increasing Staffing Levels and Costs Changes Required Take Rates

To demonstrate the impact of staffing costs on the financial projections, the scenario below shows that reducing staffing costs (all other things remaining equal) will reduce the required take rate.

Table 27: Reducing Staffing Costs by 20 Percent Reduces Required Take Rate to 38.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,329,110	$ 11,541,420	$ 11,541,420	$ 11,541,420	$ 11,541,420
Total Cash Expenses	(2,222,350)	(4,430,400)	(4,430,400)	(4,430,400)	(4,430,400)
Depreciation	(2,751,220)	(6,263,130)	(4,143,520)	(3,998,960)	(3,998,960)
Interest Expense	(1,762,500)	(2,440,830)	(1,857,260)	(1,154,900)	(268,010)
Taxes	-	-	-	-	-
Net Income	$ (4,406,960)	$ (1,592,940)	$ 1,110,240	$ 1,957,160	$ 2,844,050
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 488,640	$ 2,081,490	$ 2,289,420	$ 4,013,570	$ 5,771,760
Depreciation Reserve	-	4,005,080	6,069,490	795,340	1,295,980
Interest Reserve	1,600,000	-	-	-	-
Debt Service Reserve	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Total Cash Balance	$ 4,088,640	$ 8,086,570	$ 10,358,910	$ 6,808,910	$ 9,067,740

Alternatively, increasing labor costs by 20 percent would require an increased take rate of 41.4 percent.

Table 28: Increasing Staffing Costs by 20 Percent Increases Required Take Rate to 41.4 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 11,495,664	$ 11,495,664	$ 11,495,664	$ 11,495,664
Total Cash Expenses	(2,413,000)	(4,186,950)	(4,186,950)	(4,186,950)	(4,186,950)
Depreciation	(1,893,940)	(6,010,460)	(3,828,620)	(3,767,140)	(3,729,770)
Interest Expense	(1,800,000)	(2,427,110)	(1,564,130)	(766,750)	(130,160)
Taxes	-	-	-	-	-
Net Income	$ (3,209,858)	$ (1,128,856)	$ 1,915,964	$ 2,774,824	$ 3,448,784
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,546,492	$ (30,272)	$ (397,542)	$ 6,209,528	$ 16,716,018
Depreciation Reserve	-	2,068,540	2,417,140	1,292,020	2,593,960
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,596,492	$ 4,288,268	$ 4,269,598	$ 9,751,548	$ 21,559,978

The same impacts can be seen if the HBPW were to increase or reduce its staffing levels, as illustrated by the following scenarios.

Table 29: Increasing Customer Service Representative Shifts (from 1.5 to 3), Eliminating Contracted After-Hours Support

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,996,344	$ 10,996,344	$ 10,996,344	$ 10,996,344
Total Cash Expenses	(2,313,190)	(3,967,050)	(3,967,050)	(3,967,050)	(3,967,050)
Depreciation	(1,894,740)	(5,867,030)	(3,779,660)	(3,718,180)	(3,680,800)
Interest Expense	(1,800,000)	(2,427,220)	(1,563,920)	(766,150)	(129,160)
Taxes	-	-	-	-	-
Net Income	$ (3,110,848)	$ (1,264,956)	$ 1,685,714	$ 2,544,964	$ 3,219,334
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,642,302	$ (168,400)	$ (1,813,920)	$ 3,485,280	$ 12,685,350
Depreciation Reserve	-	2,025,740	2,500,900	1,533,330	2,992,800
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,692,302	$ 4,107,340	$ 2,936,980	$ 7,268,610	$ 17,928,150

Table 30: Reducing Customer Service Representative and Technician Shifts by Two Staff Each

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,996,344	$ 10,996,344	$ 10,996,344	$ 10,996,344
Total Cash Expenses	(1,964,670)	(3,504,640)	(3,504,640)	(3,504,640)	(3,504,640)
Depreciation	(1,892,340)	(5,862,630)	(3,776,360)	(3,714,880)	(3,677,500)
Interest Expense	(1,800,000)	(2,427,230)	(1,563,900)	(766,100)	(129,090)
Taxes	-	-	-	-	-
Net Income	$ (2,759,928)	$ (798,156)	$ 2,151,444	$ 3,010,724	$ 3,685,114
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 16,002,822	$ 1,969,370	$ 2,641,770	$ 10,258,930	$ 21,777,020
Depreciation Reserve	-	2,023,980	2,509,880	1,553,130	3,023,440
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 20,052,822	$ 6,243,350	$ 7,401,650	$ 14,062,060	$ 27,050,460

Table 31: Reducing Customer Service Representative and Technician Shifts by Two Staff Each and Reducing Take Rate to 38.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,620,660	$ 10,620,660	$ 10,620,660	$ 10,620,660
Total Cash Expenses	(1,964,670)	(3,482,400)	(3,482,400)	(3,482,400)	(3,482,400)
Depreciation	(1,892,340)	(5,753,070)	(3,738,220)	(3,676,740)	(3,639,370)
Interest Expense	(1,800,000)	(2,427,310)	(1,563,730)	(765,630)	(128,310)
Taxes	-	-	-	-	-
Net Income	$ (2,759,928)	$ (1,042,120)	$ 1,836,310	$ 2,695,890	$ 3,370,580
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 16,002,822	$ 1,254,498	$ 251,398	$ 6,170,788	$ 15,992,208
Depreciation Reserve	-	1,991,100	2,576,420	1,742,430	3,335,490
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 20,052,822	$ 5,495,598	$ 5,077,818	$ 10,163,218	$ 21,577,698

6.4.4 Decreasing Pricing Affects the Required Take Rate or the Total Cash Balance

In the following scenarios, we show that decreasing the pricing would have an impact on either the total cash balance (substantially decreasing it by year 20) or the required take rate (substantially increasing it).

Table 32: Decreasing Pricing by 10 Percent Increases Required Take Rate to 45.9 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 12,745,656	$ 12,745,656	$ 12,745,656	$ 12,745,656
Total Cash Expenses	(2,457,160)	(5,086,246)	(5,086,246)	(5,086,246)	(5,086,246)
Depreciation	(1,893,940)	(6,375,810)	(3,955,960)	(3,894,480)	(3,857,110)
Interest Expense	(1,800,000)	(2,426,840)	(1,564,690)	(768,340)	(132,770)
Taxes	-	-	-	-	-
Net Income	$ (3,254,018)	$ (1,143,240)	$ 2,138,760	$ 2,996,590	$ 3,669,530
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,502,332	$ (649,342)	$ 430,730	$ 8,579,474	$ 20,603,856
Depreciation Reserve	-	2,178,180	2,194,610	659,500	1,551,440
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,552,332	$ 3,778,838	$ 4,875,340	$ 11,488,974	$ 24,405,296

Alternatively, if pricing were decreased but the required take rate were to remain the same as in the base case, the total cash balance at year 20 would be significantly reduced.

Table 33: Decreasing Pricing by 10 Percent with Same Take Rate Lowers Total Cash Balance

Income Statement	1	5	10	15	20
Total Revenues	$ 2,897,082	$ 10,996,344	$ 10,996,344	$ 10,996,344	$ 10,996,344
Total Cash Expenses	(2,457,160)	(4,695,561)	(4,695,561)	(4,695,561)	(4,695,561)
Depreciation	(1,893,940)	(5,864,230)	(3,777,560)	(3,716,080)	(3,678,700)
Interest Expense	(1,800,000)	(2,427,220)	(1,563,910)	(766,120)	(129,110)
Taxes	-	-	-	-	-
Net Income	$ (3,254,018)	$ (1,990,667)	$ 959,313	$ 1,818,583	$ 2,492,973
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,502,332	$ (2,945,856)	$ (8,230,132)	$ (6,552,978)	$ (991,664)
Depreciation Reserve	-	2,024,620	2,506,540	1,545,840	3,012,200
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,552,332	$ 1,328,764	$ (3,473,592)	$ (2,757,138)	$ 4,270,536

6.4.5 Impact of Wholesale Service Levels

In the scenario below, we have reduced the technician and customer service representative staffing by 50 percent, and have assumed that wholesale ISPs will serve 50 percent of subscribers.

Table 34: Wholesale ISPs Serve 50 Percent of Subscribers, HBPW Reduces Staffing

Income Statement	1	5	10	15	20
Total Revenues	$ 2,669,658	$ 9,999,456	$ 9,999,456	$ 9,999,456	$ 9,999,456
Total Cash Expenses	(2,084,930)	(3,320,480)	(3,320,480)	(3,320,480)	(3,320,480)
Depreciation	(1,893,140)	(5,862,230)	(3,776,060)	(3,714,580)	(3,677,200)
Interest Expense	(1,800,000)	(2,427,230)	(1,563,900)	(766,100)	(129,080)
Taxes	-	-	-	-	-
Net Income	$ (3,108,412)	$ (1,610,484)	$ 1,339,016	$ 2,198,296	$ 2,872,696
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,651,138	$ (1,434,250)	$ (4,824,870)	$ (1,270,840)	$ 6,184,130
Depreciation Reserve	-	2,023,820	2,510,600	1,554,830	3,026,120
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,701,138	$ 2,839,570	$ (64,270)	$ 2,533,990	$ 11,460,250

If, instead, the wholesale ISPs were to continue to serve 10 percent of subscribers (as in the base case), and wholesale pricing were to be lowered (to $47 residential, $51 commercial), the financial forecast would be as follows:

Table 35: Wholesale ISPs Serve 10 Percent of Subscribers at Reduced Wholesale Rates

Income Statement	1	5	10	15	20
Total Revenues	$ 2,850,282	$ 10,790,604	$ 10,790,604	$ 10,790,604	$ 10,790,604
Total Cash Expenses	(2,250,530)	(3,788,920)	(3,788,920)	(3,788,920)	(3,788,920)
Depreciation	(1,893,940)	(5,864,230)	(3,777,560)	(3,716,080)	(3,678,700)
Interest Expense	(1,800,000)	(2,427,220)	(1,563,910)	(766,120)	(129,110)
Taxes	-	-	-	-	-
Net Income	$ (3,094,188)	$ (1,289,766)	$ 1,660,214	$ 2,519,484	$ 3,193,874
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 15,662,162	$ (253,220)	$ (2,032,990)	$ 3,131,930	$ 12,197,750
Depreciation Reserve	-	2,024,620	2,506,540	1,545,840	3,012,200
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 19,712,162	$ 4,021,400	$ 2,723,550	$ 6,927,770	$ 17,459,950

6.4.6 Funding Capital Additions with a Special Assessment

In the scenario below, we have assumed a special assessment is created and applied to recover the amount of the first three years of capital additions ($63.9 million). Assuming the take rate remains unchanged (39.6 percent) the retail pricing can be reduced by 40 percent (for example the residential 1 Gbps service drops to $48 per month). This scenario requires an initial loan of $1 million to assist in O&M expenses as subscribers are added.

Table 36: Use of Special Assessment Reduces Retail Pricing by 40 Percent

Income Statement	1	5	10	15	20
Total Revenues	$ 1,452,622	$ 6,372,814	$ 6,372,814	$ 6,372,814	$ 6,372,814
Total Cash Expenses	(2,236,560)	(3,744,740)	(3,744,740)	(3,744,740)	(3,744,740)
Depreciation	(1,893,940)	(5,864,230)	(3,777,560)	(3,716,080)	(3,678,700)
Interest Expense	(50,000)	(34,210)	(1,100)	3,860	7,530
Taxes	-	-	-	-	-
Net Income	$ (2,727,878)	$ (3,270,366)	$ (1,150,586)	$ (1,084,146)	$ (1,043,096)
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 166,062	$ 5,948,694	$ 11,422,002	$ 17,025,070	$ 22,689,348
Depreciation Reserve	-	2,024,620	2,506,540	1,545,840	3,012,200
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$ 166,062	$ 7,973,314	$ 13,928,542	$ 18,570,910	$ 25,701,548

6.4.7 Public-Private Partnership – Shared Risk and Investment

In Appendix A we discuss several evolving public-partnership model. A model that appears to have early interest is a public–private partnership model based upon shared investment and risk plays to the strengths of both the public and private sector partners. Any locality thinking about an FTTP deployment is not doing so because it is a moneymaker or a good strategy for bringing in new revenues. Rather, it is a powerful strategy for education, healthcare, and economic development. Thus in a shared investment model, from the standpoint of a locality, the risk is shared but the community still receives 100 percent of indirect benefits, even if they all do not all appear on the project's financial statements. For the private partner, it means less upfront investment and capital (risk), with an opportunity for future revenues.

Two examples of this model are Ting's deployment in Westminster Maryland and, more recently, Google Fiber's plan in Huntsville Alabama. In these models the municipality builds and maintains the fiber infrastructure and then leases dark fiber to the retail provider. The provider then is responsible for the electronics and operating the retail business.

The dark fiber lease price in both these cases is unique to the cities; there does not exist a standard template for determination of a lease price (which might, for example, be on a per passing or a per strand mile basis). As a placeholder we created an initial financial model for a dark fiber lease. In the model we have removed all capital costs for electronics, electronics O&M, network replenishments, staffing for network operations, and staffing and expenses for retail services. We have provided this model in a separate spreadsheet to HBPW staff.

Given the reduction of capital expenses, the required borrowing is reduced to $55 million (assuming that the HBPW will own the drops to the premises[71]) and operating expenses are

[71] In Huntsville it appears that Google owns the drop while in Westminster, the City owns the drop.

reduced to $1.3 million per year (not including debt service). In order to maintain a positive cash flow, the required dark fiber lease payment starts at $1 million in year 1, increasing to $6.8 million in year 3 and beyond. The resulting financial forecast is shown below. Please note the replenishments in this forecast are for vehicles and equipment used in maintaining dark fiber only.

Table 37: Dark Fiber Lease Example – Public–Private Partnership

Income Statement	1	5	10	15	20
Total Revenues	$ 1,000,000	$ 6,800,000	$ 6,800,000	$ 6,800,000	$ 6,800,000
Total Cash Expenses	(944,980)	(1,306,410)	(1,306,410)	(1,306,410)	(1,306,410)
Depreciation	(1,432,440)	(4,207,890)	(2,310,900)	(2,310,900)	(2,310,900)
Interest Expense	(1,800,000)	(2,136,080)	(1,465,790)	(768,850)	(135,470)
Taxes	-	-	-	-	-
Net Income	$ (3,177,420)	$ (850,380)	$ 1,716,900	$ 2,413,840	$ 3,047,220
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 18,261,130	$ (188,670)	$ 1,791,950	$ 7,749,140	$ 16,297,720
Depreciation Reserve	-	336,640	440,620	454,500	468,380
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	$ 22,311,130	$ 2,397,970	$ 4,482,570	$ 10,453,640	$ 19,016,100

Appendix A: Review of Potential Alternative FTTP Business Models

The HBPW desires to operate its expanded FTTP network on a hybrid open access basis (i.e., the HBPW will continue to offer wholesale access to the network to qualified ISPs, while also selling retail data services to customers itself). In this section, we consider a range of alternative FTTP business models as a way to outline a range of operational considerations.

In light of the high programming costs and declining demand associated with providing traditional cable service, the HBPW will likely benefit most from focusing on a data-only offering as it expands its retail service. If a data-only offering does not prove to be viable, the HBPW can then readjust its approach and potentially partner with a private provider that can offer IP-based video line-up. One important goal is for the HBPW to drive the market by showing consumers that a high-capacity data product is sufficient to meet all their content needs, and can lead to overall telecommunications savings.

Retail Data-Only

In this model, the HBPW would build, own, and operate an FTTP network, and offer data services to residential and small business customers. This is often referred to as an "over-build" model because the new provider builds new communications infrastructure "over" the wires and cables of existing broadband providers. This is the model used most frequently by municipal utilities in the U.S.

This model requires the HBPW to finance network build-out, and potentially to finance operations in the event that network revenues do not cover expenses. It also requires the HBPW to define and update services on an ongoing basis, establish consumer-level sales and marketing efforts, and establish consumer-level help desk and other support mechanisms. The retail model requires the broadest range of staff additions, training, marketing, and other activities to operate and maintain the business venture.

There are a number of different services HBPW could offer over its networks. Historically, most municipalities that have built FTTP networks provided voice, video and data services, mimicking the triple-play bundles offered by traditional cable and telecom providers. However, increasing competition from over-the-top (OTT) service providers has led some recent municipal FTTP providers to focus exclusively on data services.[72]

[72] Jason Meyers, "Colorado Gigabit Network Shuns Video, Embraces OTT," Light Reading, June 27, 2014, http://www.lightreading.com/video/video-services/colorado-gigabit-network-shuns-video-embraces-ott/d/d-id/709648, accessed February 8, 2016.

Retail Data and Voice Example

To date, data-only models have not proved successful in the U.S. However, given the decline in cable television subscribers and the evolution of OTT, some municipals are looking at dropping the cable line-up from their offerings. Indeed, the most recent municipal entrant in the FTTP market—Longmont, Colorado—decided only to provide retail data services and a private-label VoIP telephone service.

In Longmont, a city of 80,000 located 30 miles north of Denver, city officials felt improving broadband access was critical in order to support the City's economic development goals. During the late 1990s, the municipal electric utility, Longmont Power and Communications (LPC), built a 17-mile fiber ring around the City to modernize its electric grid. They took advantage of the low incremental cost of adding additional fiber strands and built a network with enough capacity to serve as a citywide backbone loop.[73]

After a challenging political struggle against incumbent carriers, the City passed a ballot referendum in 2011 to reinstate the City's authority to use the network to offer data services (a referendum is necessary in Colorado thanks to a 2005 state law blocking municipalities from using publicly owned infrastructure to offer communication services). In 2013, Longmont voters authorized a $45 million revenue bond to fund buildout of the last-mile portion of the network.

LPC is completing construction in phases, allowing the utility to begin generating revenue while the buildout continues over four years.[74] Customers in some areas began receiving service at the end of 2014, right when a number of other cities in Colorado also voted to authorize similar municipal FTTP efforts. Soon after, Comcast announced it would double its speed at no additional costs in many locations in Colorado, including Longmont.[75]

Intense competition has forced LPC to aggressively market its service, and take steps to reduce churn. LPC branded the service NextLight, and have created a variety of marketing materials aimed at associating NextLight with speed, reliability and local control.[76]

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[73] Christopher Mitchell, "Comcast vs. Community: The Future of Broadband Competition," *The Huffington Post*, October 25, 2011, http://www.huffingtonpost.com/christopher-mitchell/comcast-internet-laws_b_1022016.html accessed February 10, 2016.

[74] Tony Kindelspire, "Longmont fiber: While Construction's still months away, things are busy behind the scenes," Times-Call Business, March 1, 2014, http://www.timescall.com/business/ci_25256839/longmont-fiber-while-constructions-still-months-away-things, accessed February 10, 2016.

[75] Ryan Tronier, "Comcast doubles Internet speeds in the wake of local communities deregulating ISP rules," The Denver Channel, November 10, 2014, http://www.thedenverchannel.com/thenow/comcast-doubles-internet-speeds-in-the-wake-of-local-communities-deregulating-isp-rules, accessed February 10, 2016.

[76] Karen Antonacci, "Longmont City Council Gets Look at NextLight Fiber Optic Internet Service," Times Call, October 21, 2014, http://www.timescall.com/longmont-local-news/ci_26773926/longmont-city-council-gets-look-at-nextlight-fiber, accessed February 10, 2016.

LPC needed to reach a 38 percent take rate within five years in order to pay off the bond in 11 years. They anticipated that customer churn would be a potential hurdle to achieving cash flow, especially if incumbent carriers began offering special deals to customers within LPC's service area. In order to encourage customers to sign up early, and avoid switching back and forth between carriers based on temporary discounts, LPC offers a charter-membership rate for customers that sign up within the first three months that the service is available in their area. Charter members receive 1 Gbps service for $50 per month, half the price of the non-discounted rate. If customers miss the three-month window of eligibility for charter-membership, they can still become eligible for a discounted rate of $60 per month after they pay the full price of $100 per month for one full year.

In order to encourage customer loyalty, customers can keep their initial discounted rate for as long as they continue to purchase the service. The rate stays with both the premises and the customer, so if a customer moves, the new tenant can take over the discounted rate. If charter members move to a new location within the service area, they can also bring the discounted rate with them. However, if customers switch to a different service provider, they forfeit their discount and must pay the full rate of $100 per month for 1 Gbps service.[77]

NextLight offers data and digital voice service, but does not offer any kind of video service. Providing a video service would have added an additional $7-10 million in capital costs,[78] and increasing competition from OTT providers has eroded the profitability of video services in recent years. Instead of fighting against the cord-cutting trend and struggling to sign up enough video providers to pay off the necessary capital investment, LPC links to "A Guide to Cable TV Cord-Cutting" on its website.[79] While some industry experts believe that customers prefer to purchase voice, video and data in a single bundle, and expect a lack of video to negatively impact take rates, LPC's experience seems to challenge these assumption. NextLight has already achieved an adoption rate beyond 40 percent in the first areas served, well in excess of expected demand.

NextLight offers a 1 Gbps service for $100 per month ($50 per month for charter members), a 25 Mbps service for $40 per month, and a digital voice service for $25 per month to residential customers, as well as additional data and voice options for small business and enterprise

[77] Karen Antonacci, "Longmont City Council Gets Look at NextLight Fiber Optic Internet Service," Times Call, October 21, 2014, http://www.timescall.com/longmont-local-news/ci_26773926/longmont-city-council-gets-look-at-nextlight-fiber, accessed February 10, 2016.
[78] Tony Kindelspire, "Longmont fiber: While Construction's still months away, things are busy behind the scenes," Times-Call Business, March 1, 2014, http://www.timescall.com/business/ci_25256839/longmont-fiber-while-constructions-still-months-away-things, accessed February 10, 2016.
[79] "Learn about Broadband," City of Longmont, http://www.longmontcolorado.gov/departments/departments-e-m/longmont-power-communications/broadband-service/learn-about-broadband, accessed February 10, 2016.

customers. While stronger-than-expected demand has created some challenges for staff, it has made the project more profitable than expected, allowing the build-out to be completed ahead of schedule.[80]

Open Access Models

The HBPW, like other localities that have developed open access networks, has enabled retail providers to deliver service over its network—giving consumers greater choice and flexibility in picking a provider, and ultimately broadening availability.

Opening the network to providers of complementary services ensures the maximum use of network assets. Currently, the HBPW partners with six ISPs to use the existing HBPW fiber network to provide data transport services to enterprise customers. Once the FTTP network construction is complete, HBPW could establish similar arrangements with voice and video service providers, enhancing consumer choice in the Holland area.

Open Access, Data-Only

In this model, the HBPW builds FTTP and wholly controls the fiber asset, while private sector service provider(s) are selected to offer retail data services over the FTTP network. In this model, the HBPW's role is limited to building and maintaining the FTTP network. The open access model (also referred to as the "wholesale" or "passive layer" model) separates the infrastructure from the retail service.

In this model, the HBPW is in the business of infrastructure, not communications service provision. HBPW's customer is *not* the retail consumer; rather, it is the service provider. By building an open infrastructure on which capacity is leased to private sector providers, the HBPW would address the key barrier to market entry for potential retail providers: the cost of FTTP infrastructure. The result is the potential for new competition-delivering, enhanced services.

The HBPW operates its existing fiber network using an open-access model, partnering with six ISPs to provide data services to enterprise customers. As the HBPW expands its fiber assets to reach customer premises, it plans to continue to lease its FTTP network to ISPs to provide data services to residential and small business customers.

Open Access to Support Data, Voice, and Video

In this model, the HBPW builds FTTP and wholly controls the asset, while private sector service provider(s) are selected to offer data, voice, and video services over it. Similar to the open access

[80] "NextLight Frequently Asked Questions," City of Longmont, http://www.longmontcolorado.gov/departments/departments-e-m/longmont-power-communications/broadband-service/learn-about-broadband/broadband-frequently-asked-questions accessed February 10, 2016.

FTTP, data-only model, the HBPW's role is limited to building and maintaining the FTTP network. This model differs from the previously outlined open access data-only FTTP model only in that additional retail services (voice and video) are enabled by the infrastructure.

Public-Private Partnership Models

Similar to the open access model, a public–private partnership model engages private sector provider(s) to offer services. The difference between this model and the open access model is that the HBPW may choose varying levels of control and involvement in a partnership to build the FTTP, which will affect potential risk.

In the open access model, the HBPW retains control of the fiber infrastructure, including network maintenance and expansion. A public–private partnership may follow that model, or a chosen partner may propose to operate and maintain the fiber network on behalf of the HBPW. These partnerships are often tailored to the communities that develop them and entail specific parameters that directly benefit both the community and the chosen private partner.

For example, public entities may encourage new investment through economic development incentives and other measures to reduce costs for infrastructure deployment. Or a public entity and a private entity might share the capital costs, operations, and maintenance of a broadband network. We outline here three different partnership arrangement that municipalities have entered into with private companies to improve broadband services in their area.

Model 1: Public Investment with Private Partners

One public–private partnership model involves substantial public investment. It is a variation on the traditional municipal ownership model for broadband infrastructure, in which a public entity takes on all the risk, but also has full control of the project.

The emerging innovation makes use of the traditional public–private partnership structure used in Europe and increasingly in the U.S. for infrastructure projects such as highways, toll roads, and bridges, where a private partner takes responsibility for design, construction, financing, operations, and maintenance.[81] The model seeks to leverage the strengths of the private sector to deliver turnkey services and solutions over an extended time of 20 to 40 years.

For example, the state of Maryland is pursuing private companies to design, build, operate, and help pay for a light-rail project to serve the Washington metro area suburbs.[82] Under the

[81] "Financial Structuring of Public–Private Partnerships (P3s)," U.S. Department of Transportation, 2013, http://www.fhwa.dot.gov/ipd/pdfs/p3/factsheet_04_financialstructuring.pdf.

[82] Katherine Shave, "Maryland gets approval to seek public–private partnership to build, operate Purple Line," *Washington Post,* Nov. 6, 2013, http://www.washingtonpost.com/local/trafficandcommuting/maryland-transportation-officials-get-approval-to-pursue-private-partners-for-purple-line-deal/2013/11/06/93c1546a-470b-11e3-bf0c-cebf37c6f484_story.html.

proposed public–private partnership, Maryland and private partners would split the construction costs for the project and the state would later reimburse the private construction costs over five years. The private sector would assume the financial risks of any construction delays or cost overruns. The state would then pay the private partners a concessionaire to operate and maintain the line for 30 to 35 years.

We are now seeing the public–private partnership model applied to broadband in the U.S. market. Though, we have seen it in other construction projects, broadband is new because unlike transportation infrastructure, broadband is to a certain extent a competitive marketplace. Thus, applying it to broadband is new and innovative, but also creates a political and financial risk for the public sector, given that public–private partnerships often provide a guaranteed revenue stream to a private partner.

If the broadband network is unsuccessful at generating revenues the public sector remains on the hook for those payments. Despite these risks, the model offers considerable benefits to the public sector by removing significant financial and logistical barriers to large-scale public broadband projects.

Macquarie Capital and partner companies have pioneered the model in the U.S. Macquarie is an Australian investment firm that provides advisory and capital raising services to corporate and government clients in areas such as infrastructure, utilities, telecommunications, media, entertainment and technology.[83] They are currently in the midst of a complex process with localities that are members of the UTOPIA Network, an FTTP network in Utah that is owned by 15 member communities.[84] Following a 6–5 split among the 11 member cities, the UTOPIA board voted in 2014 to turn over operation and management of the network to Macquarie.[85] The private company will finish construction of the network and provide Internet service to all residents for 30 years in exchange for a monthly utility fee paid by the residents of the member communities.

The proposal is attractive given the turnkey private financing, deployment, operations, and revenue-sharing solutions that Macquarie can deliver. However, the requirement of guaranteed public funding in the form of a utility fee to all residents is not politically viable for some

[83] http://www.macquarie.com/us/about/company/macquarie-capital#.
[84] http://www.utopianet.org/about-utopia/.
[85] Benjamin Wood, "UTOPIA board votes to move forward with Macquarie deal," *Desert News,* June 30, 2014, http://www.deseretnews.com/article/865606086/UTOPIA-board-votes-to-move-forward-with-Macquarie-deal.html?pg=all.

communities. As a result, a small handful of UTOPIA member communities have dropped out of the proposal.

Macquarie is also working with the Commonwealth of Kentucky on a private–public partnership to build an open-access, middle-mile broadband network across the state.[86] Under the partnership, the Commonwealth will own the network and contribute some funding for construction. Macquarie will finance the bulk of construction and have a 30-year contract to operate and maintain the network. Revenues generated by leasing the network to Internet providers will be split between the Commonwealth and Macquarie.

The public sector is not dependent solely on private parties like Macquarie to develop similar projects. There are likely other entities that would engage in this type of arrangement that leverages private sectors strengths while recognizing that some public funding is necessary to enable next generation connectivity. Public investment and public–private partnership models that leverage private partners with turnkey solutions are attractive because they remove significant challenges from public sector, but also require a community to take on some risk. As a result, the model will appeal to some communities, but not to others.

Model 2: Public Sector Incenting Private Investment

In another model of public–private partnership, the cost to the public sector is significantly reduced. The model focuses on more modest measures by the public sector to enable or encourage greater private sector investment. The most prominent example of the model is Google Fiber, including its deployments in Kansas City and Austin.

The model is seen as the ideal for many communities given that public cost is minimized and Google's requirements have largely focused on engagement with the company and making local government processes more efficient. In return, communities fortunate enough to attract Google's investment not only benefit from the company's own deployment of FTTP infrastructure, but also upgrades from the incumbent cable and telephone companies. The model relies on the private companies to make the investment, while partner communities take certain steps to enable them come into the market to build in an expeditious, efficient, low-cost manner. Though Google Fiber is the most prominent example, there is significant interest by smaller companies as well who may not be able to deploy FTTP but deliver next-generation broadband to businesses and intuitions on a more targeted basis.

Even as the cost/risk for public sector is largely reduced compared to other models, there is a potential public relations risk. Public expectations can get very high with the announcement of

[86] Rachel Aretakis, "Partnership to build high-speed broadband network in Kentucky," *Louisville Business First,* Dec. 23, 2014, http://www.bizjournals.com/louisville/news/2014/12/23/artnership-to-build-high-speed-broadband-network.html?page=all.

new fiber deployment. If the community is strongly identified as a partner, when something goes wrong with private sector business plan or deployment, the public sector may held accountable for the private sector failure.

There are a number of strategies localities can take to encourage new private investment and reduce some of the costs and time for private sector entities to deploy advanced broadband services. They can take the form of specific economic development incentives such as tax benefits to encourage providers to build new infrastructure. For example, MetroNet, a small Midwest Internet provider, developed a partnership with the City of Crawfordsville, Indiana to purchase the municipal utility's fiber network. The city is assisting MetroNet with financing the purchase and expanding the footprint of the fiber network.[87]

MetroNet has entered other communities where they did not purchase existing infrastructure, but where the municipality has provided other tax benefits, and modified permitting process to allow for ease of access. Again, a major consideration for a partner like this is the high likelihood that the private entity will *not* build to all areas of the community. If a private company is not beholden to the City via a clearly articulate partner relationship, it is unlikely that the private company will build to areas of the community where it does not anticipate easily recovering its costs.

Another key strategy is to develop and strengthen the local infrastructure assets that enable the deployment of broadband.[88] These include public assets such as fiber, conduit, and real estate. For example, new network deployments can benefit enormously from access to existing government fiber strands, underground communications conduit in which fiber is placed, or real estate where equipment or exterior huts can be located. The City's existing fiber network and infrastructure may be usable to some degree to incent private investment—for example, a private entity may need access to only a small amount of dark fiber to serve certain areas.[89]

Communities can further facilitate the underground construction of conduit and fiber by implementing a "dig-once" policy for all road and related transportation projects, and facilitating in-building access for new providers through construction specifications for new buildings. These

[87] "MetroNet plans to expand current fiber optic system," "The Paper of Montgomery County Online, Mar. 18, 2014, http://thepaper24-7.com/Content/News/Local-News/Article/MetroNet-plans-to-expand-current-fiber-optic-system/23/22/44447.

[88] "Gigabit Communities: Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community," CTC Technology & Energy, Inc., Jan. 2014, p. 6 – 12, http://www.ctcnet.us/wp-content/uploads/2014/01/GigabitCommunities.pdf.

[89] As we previously noted, the City's existing dark fiber infrastructure must be fully evaluated to determine what, if any, portion of it is usable for the FTTP network.

policies are generally implemented through revisions to existing municipal codes or by developing new ordinances.

Building and expanding your broadband assets over time is a low-cost, low-risk strategy that will have real impact and expand options down the road. For example, Mesa, Arizona began a dig-once initiative in the early 2000s to install its own rings of conduit during private sector construction projects, and then to sell access back to the private sector. Anytime the city was required to open up a street, such as to install water or sewer utilities, it also put in conduit.[90] In some instances, the City also added fiber to empty conduit for city purposes or to potentially lease out to private providers. In total, the city installed 150 to 200 miles of conduit. The City in particular targeted four economic development areas, including developing redundant conduit, fiber, and electric infrastructure. Among those areas was land around the Phoenix-Mesa Gateway Airport, where Apple recently announced that it would invest $2 billion to build a data center for the company's global networks investment.[91]

A second important strategy is to improve access to information—an asset that communities might not have considered. Sharing information demonstrates a willingness to engage with the private sector to spur investment. Communities should seek to make data available wherever possible both for public and private uses.

GIS or similar databases that hold such information as street centerlines, home, and business locations, demographics, existing utilities, locality infrastructure, rights-of-way, and available easements can be extremely helpful for a locality's own broadband planning, potential public–private partnerships, or a network service provider that is evaluating the deployment of new infrastructure into a community.

Access to this information may attract and speed new construction by private partners, while enabling the community to meet its goals for new, better broadband networks—and potentially to realize revenues for use of the assets.

Finally, localities can take steps to make government processes around permitting, rights-of-way access, and inspections more efficient and smooth to help with broadband construction. These actions can signal to private partners that there is an investment opportunity in the jurisdiction and that the locality will not be a bottleneck or create additional costs. These steps should take into consideration the needs of the community, balance public interest and public safety, and account for local resources and capacity. For example, localities should be fully transparent about

[90] "Transcript: Community Broadband Bits Episode 139," Institute for Local Self-Reliance, Feb. 26. 2015, http://muninetworks.org/content/transcript-community-broadband-bits-episode-139.
[91] http://azgovernor.gov/governor/news/governor-doug-ducey-announces-major-apple-expansion-arizona.

the range of permitting and rights-of-way processes, including timelines, to enable the communication industry to expeditiously plan and deploy networks.

The above strategies (including assets, data and efficient processes) can make a difference in the economics of build out for a private partner. However, they will not dramatically change the underlying economics of broadband networks construction and service. In a best-case scenario, the public sector can potentially reduce the construction of a broadband network in a way that can be substantial but not transformative for developing next-generation broadband infrastructure.

Indeed, many incumbent providers overstate the extent to which communities and regulation are the problem. If a community is offering the equivalent of economic development or other benefits to a company to entice them to invest in next generation infrastructure that is different than the business relationship a community already has with existing providers and incumbents. Communities can and should offer those benefits to incumbents if they will also invest in the same kind of next-generation infrastructure. Communities should be wary of private sector entities seeking benefits without offering concrete investment proposals. From a business standpoint, incumbents do not need additional benefits to keep maintaining their existing broadband networks and services.

Model 3: Shared Investment and Risk

A public–private partnership model based upon shared investment and risk plays to the strengths of both the public and private sector partners. Any locality thinking about an FTTP deployment is not doing so because it is a moneymaker or a good strategy for bringing in new revenues. Rather, it is a powerful strategy for education, healthcare, and economic development. Thus in a shared investment model, from the standpoint of a locality, the risk is shared but the community still receives 100 percent of indirect benefits, even if they all do not all appear on the project's financial statements. For the private partner, it means less upfront investment and capital (risk), with an opportunity for future revenues.

This model offers an extraordinary opportunity for innovation. However, we are in the early stages of what it looks like—and the model is in no way a sure thing for communities. In 10 years, we may be able to look back and have the data points to develop the best practices necessary for success. At the moment though, early actors are developing new and exciting partnerships to bring next-generation broadband to their communities. In the following case studies, we briefly describe some of those projects.

Case Study: Champaign–Urbana, Illinois

The University of Illinois and the two cities of Champaign and Urbana, Illinois have worked together over the past number of years to expand broadband infrastructure and connectivity across the area. Those efforts included the development of the Urbana-Champaign Big Broadband (UC2B) network, which is now owned and operated by a not-for-profit (NFP) corporation.[92] Through a range of different strategies and by leveraging local private capital, state funds, and federal funds, UC2B built fiber rings specifically engineered to enable FTTP deployment in the most cost-effective manner. It also built FTTP in select parts of the community with lowest adoption rates on theory that those parts of the community would be the last place private sector would deploy; so the public sector went there first.

U2CB leveraged its existing investment to attract a private partner, iTV-3, an Illinois company with FTTP experience. The two partners, entered into an agreement that gives iTV-3 access to U2CB fiber through an indefeasible right of use (IRU) at no cost in return for meeting community's goals of deploying additional FTTP with the following requirements:[93]

1. Gigabit service speeds
2. Wholesale access on the network to competing companies
3. No cherry picking—all neighborhoods have equal opportunity to get services if presales reach 50 percent of residents

Under this model, Champaign–Urbana receives 100 percent of economic development and other benefits in return for taking on approximately 30 percent of the (cost) risk. It also means the community can now focus on driving demand and adoption, while relying on an experienced private partner to handle customer service, marketing, and operations.

Case Study: Garret County, Maryland

Garret County, in far western Maryland, is a relatively remote community in Appalachia surrounded on two sides by West Virginia, on one side by Pennsylvania. The County has struggled to get broadband in a number of remote parts of the community. Where broadband is available, it is inadequate DSL service that does not meet the FCC's minimum definition for broadband, let alone the requirements for home-based businesses. The incumbent provider has not made any plans to expand or upgrade service offerings.

Though mobile broadband is available, bandwidth caps mean that it is not viable for economic or educational activities. For example, parents who home-school their children can run through their bandwidth cap in one day of downloading educational videos. Beyond these challenges for residents, the county has struggled to attract and retain businesses.

In response, the County has gradually and incrementally built out fiber in some areas, with a focus on connecting specific institutions. It is now in negotiations with a viable private partner to

[92] http://uc2b.net/about/.
[93] http://uc2b.net/wordpress/wp-content/uploads/2014/05/UC2B-iTV3-Press-Packet.pdf.

leverage some of that fiber and additional public funding to support the deployment a fixed wireless broadband network that will serve up to 3,000 homes in the most remote parts of the county. The private partner will also put its own capital toward the construction of the network, along with its technical and operational capabilities to manage the network. The partnership may involve significant cost to the County, but also massive benefit for residents and business in the newly served areas.

Case Study: Westminster, Maryland

Westminster is a bedroom community of both Baltimore and Washington, D.C., where currently 60 percent of the working population leaves in the morning to commute to work elsewhere. The area has no major highways and thus, from an economic development perspective, has limited options for creating new jobs. Incumbents have also traditionally underserved the area with broadband.

The City began an initiative 12 years ago to bring better fiber connectivity to community anchor institutions through a middle-mile fiber network. In 2010, the State of Maryland received a large award from the federal government to deploy a regional fiber network called the Inter-County Broadband Network (ICBN) that included infrastructure in Westminster.

Westminster saw an opportunity to finish the goal of the network by expanding the last-mile of the network.

At the time, though, it did not have any clear paths to accomplish the goal. City leaders looked around at other communities and realized quickly that they would have to do something unique. Unlike FTTP success stories such as Chattanooga, Tennessee they did not have a municipal electric utility to tackle the challenge. They also did not have the resources, expertise, or political will to develop from scratch, a municipal fiber service provider to compete with the incumbents. As a result, they needed to find a hybrid model.

As the community evaluated its options, it became clear that the fiber infrastructure itself was the City's most durable asset. All local governments spend money on durable assets with long lifespans, such as roads, water, and sewer lines, and other infrastructure that is used for the public good. The leaders asked, why not think of fiber in the same way? The challenge then was to determine the breakdown of the network: What part would the private sector partner handle and what part could the City take responsibility for?

The hybrid model that made the most sense required the city to build, own, and maintain the dark fiber,[94] and to look to partners who would light the fiber and handle the customer service relationship with residents and businesses.

The model would keep the city out of operational aspects where a considerable amount of the risk lies in terms of managing the technological and customer service aspects of a network. The City solicited responses from potential private partners through a request for proposal (RFP). Its goal was to determine who was interested in the project, and who shared the City's vision.

It was challenging to find partners who were willing to share infrastructure and operations. Eventually the City selected an upstart ISP called Ting, with a strong track record of customer service as a mobile operator. Ting shared Westminster's vision of a true public–private partnership and of maintaining an open access network.

Under the terms of the partnership, the City is building and financing all of the fiber (including drops to customer premises) through a bond offering and tax dollars from the property tax base. Ting is leasing fiber with a two-tiered lease payment. One fee is based upon the number of premises the fiber passes (as the network grows both in size and customers there is an upside for the community) and the second fee is based on number of subscribers they enroll.

As the network grows, Ting will help fund the network capital expenditures, which will lessen the financial burden on Westminster. In the future, additional operators may become partners on the network as well, opening the door to additional services for the community and revenues for the city.

[94] Fiber configured to support a GPON architecture.

Appendix B: Over-the-Top Providers and Next-Generation Applications

Getting to traditional open access where multiple ISPs offer service has been slow and problematic in the United States. Focusing on other forms of open access provides a viable and attractive substitute, and may ultimately eliminate the need for traditional open access. One of the most important elements to successfully redefine open access is the emergence and evolution of over-the-top (OTT) providers and next-generation applications to support consumers' needs.

OTT or "value added" services have evolved more quickly in the voice market than with video, though it is not a new concept in either. Recent announcements of expanded OTT video offerings suggest that consumers are seeking alternatives to traditional video services, and the market is responding.

Consider important changes in the landline telephone market over the past decade to illustrate what is likely to happen with video content. Ten years ago, home telephones were still nearly ubiquitous, even in households where all members subscribed to wireless phone service. Yet data from a December, 2013 National Institutes of Health (NIH) report showed that more than a quarter of households in Santa Clara County were wireless only, with no landline telephone.[95]

National usage has continued to decline—January through June 2014 was the first six-month period during which a majority of U.S. children lived in households with wireless-only telephone service.[96] This decline was possible due to increasingly accessible and affordable cellular and wireless service along with other alternatives to landline—programs like Skype and Google Voice, services like Vonage and Lingo, and technology like magicJack and Ooma.

The cable industry may be poised to see a similar shift toward nontraditional technologies, applications, and services that allow consumers greater flexibility and choice. An increased desire for OTT offerings could have a significant industry impact,[97] though this will likely be more gradual than changes to the voice industry because of cable content owners' great degree of control. Major industry shifts have been predicted,[98] but major industry changes have been slower to materialize than in the voice industry.

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[95] National Institutes of Health. (2014). Wireless Substitution: State-level Estimates from the National Health Interview Survey, 2012 (Report No. 1250). Retrieved from http://www.cdc.gov/nchs/data/nhsr/nhsr070.pdf.
[96] National Institutes of Health. (2014). Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January-June 2014. Retrieved from http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201412.pdf.
[97] This change is not without other risks to the HBPW. Unless legislation changes in accordance with the industry, this market transition to OTT services could have serious adverse consequences to City cable franchise fee and utility tax revenue.
[98] http://www.businessinsider.com/cord-cutters-and-the-death-of-tv-2013-11.

To understand why the shift may be gradual, consider Google Fiber's entry into the Kansas City market just a few years ago as an example of the firmly rooted power of cable. Google Fiber found that a data product alone was not strong enough to obtain the necessary market share to make its endeavor viable. If it wanted to get people to switch providers, Google Fiber *had* to offer cable, deviating from its original plan and introducing more cost and complexity than the simple data service it intended to offer. Google Fiber may have found that offering traditional cable television was unnecessary if OTT cable options with a broad range of content were widely available when it entered the Kansas City market.

In 2011, Google Fiber was forced to set a precedent offering traditional cable services when entering the Kansas City market, and has necessarily continued these offerings in subsequent markets. It will likely eventually phase out its traditional cable offering as more OTT content becomes available and consumers seek other, less costly alternatives to traditional cable.

Smart mobile devices, where content can come from cellular networks or WiFi networks, add network choice to the consumer list. As more non-traditional content providers emerge, greater programming variety becomes available via OTT, network choice grows, and network operators offer a wider variety of pricing plans, the demand for alternative access to content may increase.

Consumer demand and expectation is another potentially key driving factor that may facilitate change in the industry. Due to the always-on and at-your-fingertips nature of applications and services that are supported by access to the Internet, consumers have come to expect "on-demand" services and control over their choices in ways that have not previously existed.[99] Consumers who are used to having Internet access—especially digital natives[100]—are accustomed to quickly and easily receiving the goods and services they desire. There is an increasing expectation among consumers in the U.S. that services will be readily available on-demand with minimal effort. By simply engaging an App on a smartphone or clicking a mouse on a laptop, consumers expect instant access to goods, services, and content.

Further, in part because of the growth of cloud services, there is an increased consumer desire for simplicity and integration among services and content. And because of technological advancements and "cheap computing power,"[101] the costs associated with what would have been luxuries for the rich only a few years ago are now attainable for the average household.

[99] http://www.businessinsider.com/the-on-demand-economy-2014-7.
[100] http://www.cnn.com/2012/12/04/business/digital-native-prensky/.
[101] http://www.economist.com/news/leaders/21637393-rise-demand-economy-poses-difficult-questions-workers-companies-and.

The market has begun to shift more dramatically with the emergence of additional OTT content. Dish Network launched an OTT service in early 2015 that offers sports programming on channels such as ESPN as well as other programming and popular TV channels without a cable subscription. The service, called Sling TV, is streamed over the Internet.[102] It does not require any additional hardware and is enabled by installing an application on a device such as a smartphone, tablet, laptop, or Internet-connected television. Sling TV currently is priced at $20 per month with no time commitments, but it is complex and fraught with limitations and restrictions.[103] Traditional cable content providers' attempts at OTT have seen varying degrees of success, but it is significant in the industry for these providers to even acknowledge the need for these services.[104]

In addition to recent entrants to the OTT market, there are numerous established services and applications that will likely continue to promote change in the cable industry and drive an increase in consumers' desire for greater choice and control over how they access content. Standalone media-streaming boxes like Apple TV and Roku have enabled consumers to stream content with applications such as YouTube, Netflix, and Hulu without a cable subscription since 2008. These "cord-cutters" cancel their cable subscriptions in favor of accessing their favorite content via applications and services streamed over the Internet. An ever-increasing percentage of consumers are getting these services using mobile devices.

Since the debut of Apple TV and Roku, similar devices like the Chromecast, Google Nexus, and Amazon Fire TV have entered the market, allowing consumers greater choice. Further, consumers can now purchase smart TVs, which come with preinstalled platforms that support streaming applications. These devices require no additional hardware—with only an Internet connection, consumers can stream music, TV shows, movies, and even play games.

While Comcast's own attempt at OTT content through its "Streampix" offering was not a huge success,[105] that pursuit illustrates the cable giant's understanding of streaming as the future of content delivery. The fact that its broadband subscriptions surpassed its cable subscribers this year further puts to rest the notion that the video industry can move forward without embracing new and innovative content delivery mechanisms. Further, Comcast has announced that it will begin offering a new streaming service,[106] and it is reportedly in talks with "nontraditional" content and media providers.[107]

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[102] https://www.sling.com/.
[103] http://www.pcworld.com/article/2909572/sling-tv-channel-guide-all-the-programming-and-all-the-restrictions-all-in-one-chart.html.
[104] As we noted in Section 4.1.5, Comcast is poised this year to make its second attempt at an OTT offering.
[105] http://www.lightreading.com/video/ott/comcast-turns-off-streampix/d/d-id/711098.
[106] http://corporate.comcast.com/comcast-voices/a-new-streaming-tv-service-from-comcast, accessed July 2015.
[107] http://blogs.wsj.com/cmo/2015/07/24/this-chart-shows-why-comcast-would-be-interested-in-vice-media-and-buzzfeed/.

Although the video industry has been slow to change, traditional content providers have begun efforts in recent years to provide OTT content to keep up with consumer demand for greater flexibility, and to compete with companies like Netflix and Hulu. Comcast's own recent developments show that this understanding is beginning to resonate with even the largest providers.

Verizon FiOS announced earlier this year its own "a la carte" offering called Custom TV, which allows consumers to choose from bundled packages that more appropriately reflect their programming desires and include less unwanted channels.[108] While this is not a true OTT application, it demonstrates the recognition within the incumbent market that consumers are dissatisfied with traditional content delivery and are seeking alternate choices.

Further, HBO announced plans last year to offer its own OTT service;[109] it began offering HBO NOW on a variety of platforms and devices in mid-2015.[110] Access to premium programming like sports and HBO has been a stubborn barrier to customers who want to eliminate their cable subscriptions (and to competitors that want to disrupt the market). Often, consumers would happily give up enormous cable bills in favor of more streamlined, inexpensive services—but they do not take the leap because they want specific programming that is only available over cable. It is significant when a content powerhouse like HBO acknowledges the importance of change in the industry.

Companies that hope to compete in the video market will likely find that they must adjust their business models, marketing strategies, and understanding of consumer demands and desires. Perhaps one of the most significant illustrations of this is that, for the first time ever, Comcast's broadband subscribers outnumbered its cable subscribers—an unprecedented and major shift in the industry.[111]

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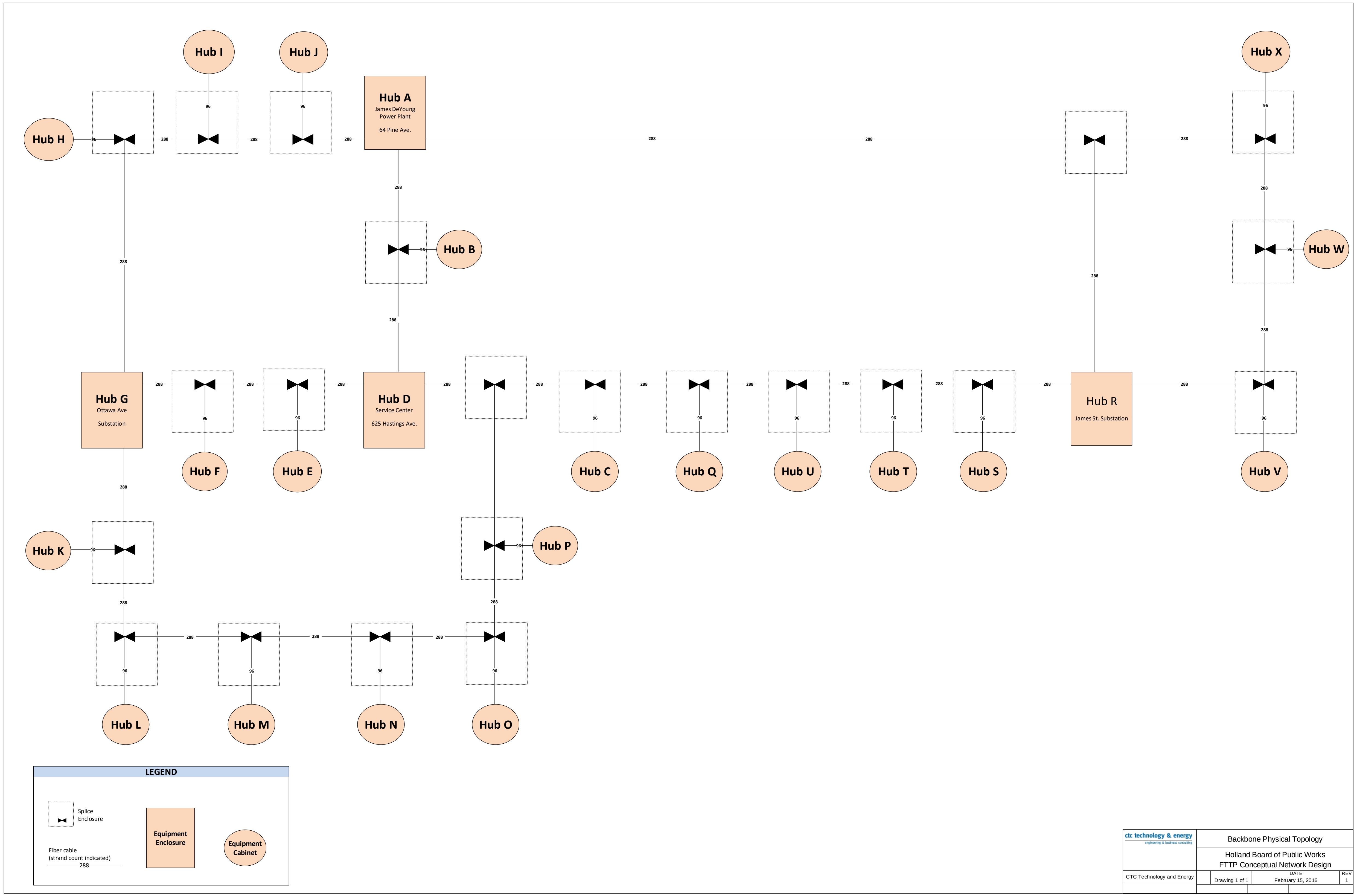
[108] http://arstechnica.com/business/2015/04/verizons-new-custom-tv-is-small-step-toward-a-la-carte-pricing/.
[109] HBO to Launch Standalone Over-the-Top Service in U.S. Next Year. 2014 October 15. http://variety.com/2014/tv/news/hbo-to-launch-over-the-top-service-in-u-s-next-year-1201330592/.
[110] https://order.hbonow.com/.
[111] http://www.nytimes.com/2015/05/05/business/media/comcasts-earnings-rise-10-driven-by-high-speed-internet.html?_r=0.

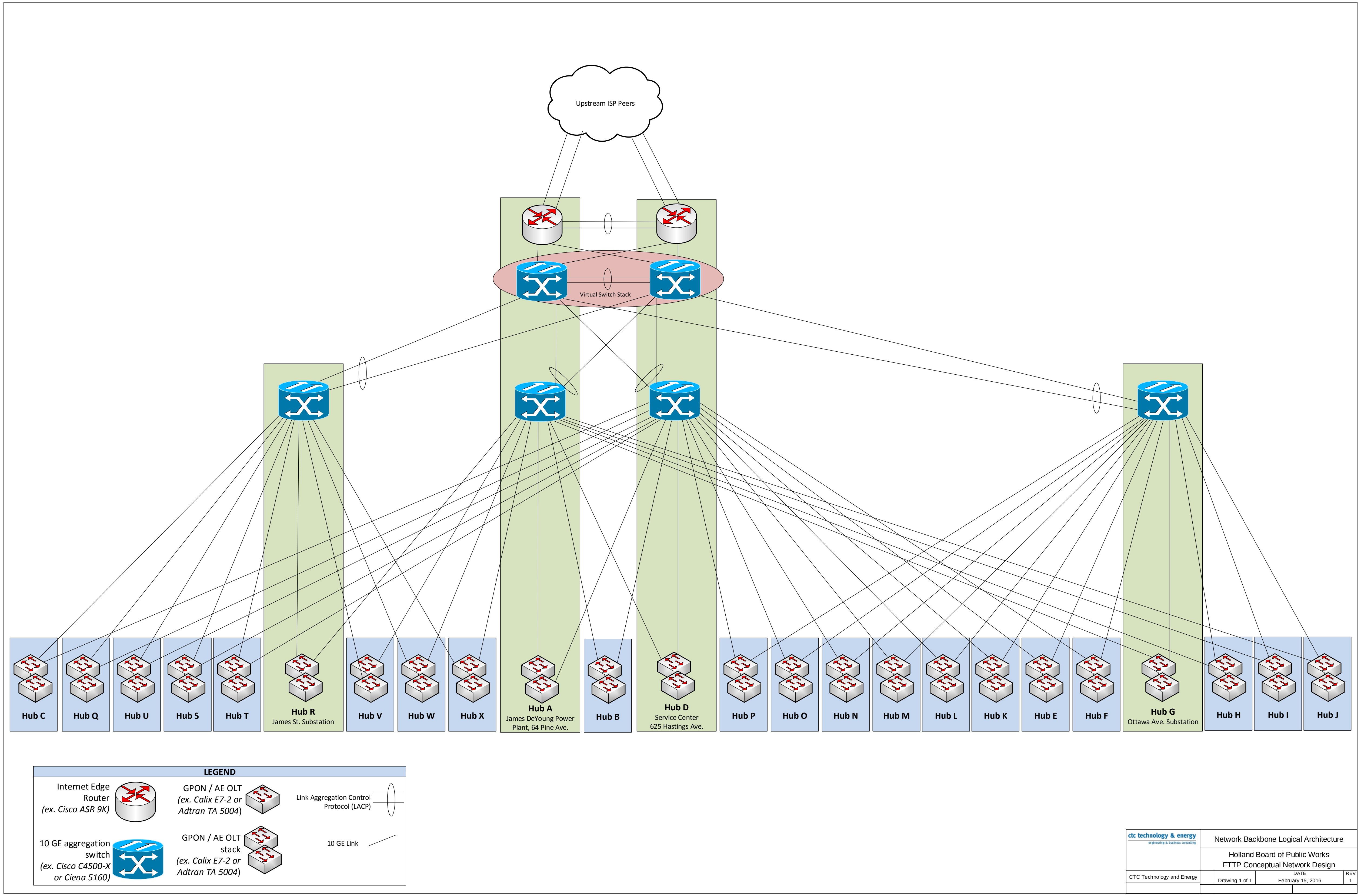
Appendix C: Financial Model

The financial model was provided to the HBPW in Excel format.

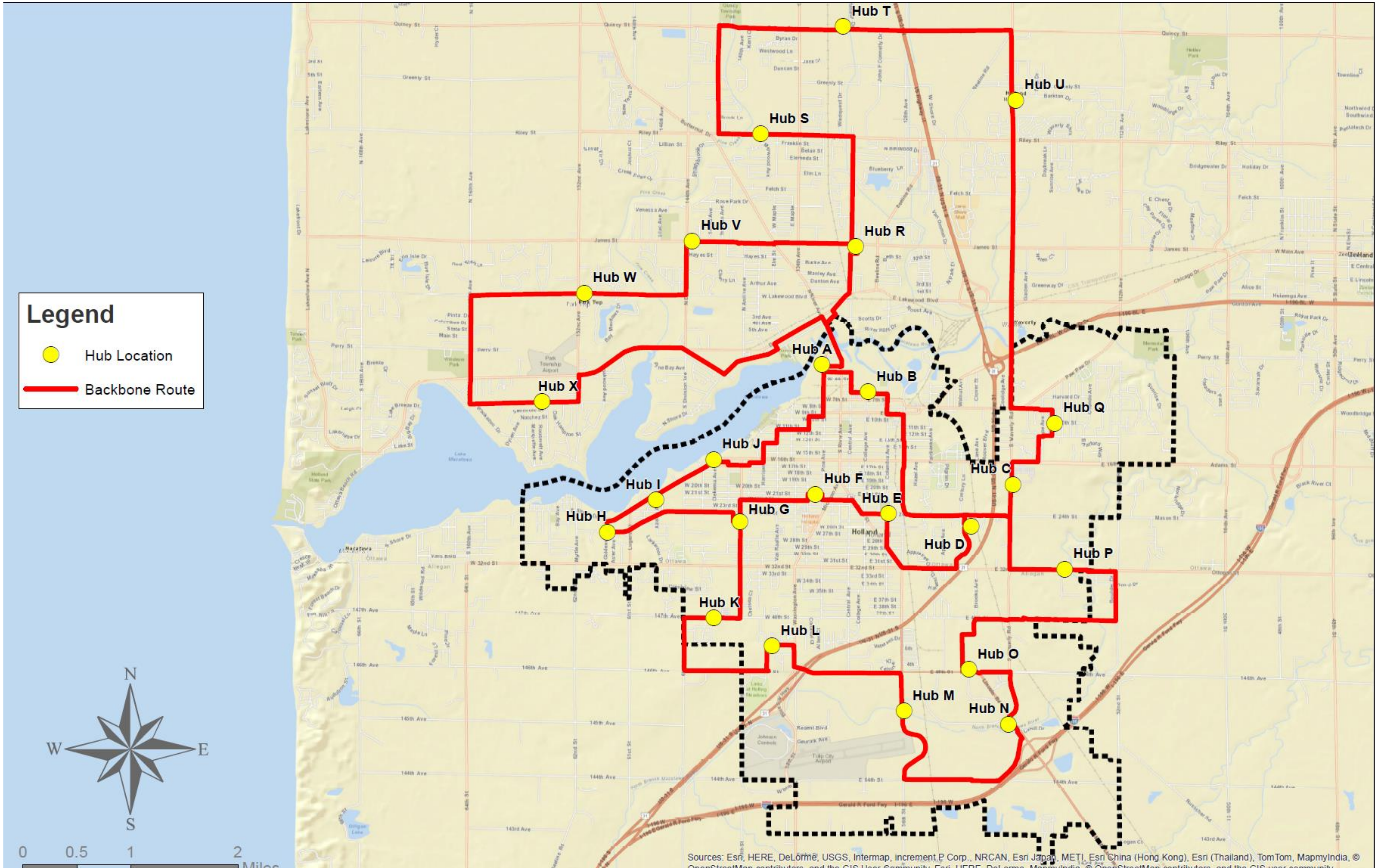
Attachment 1: Physical Fiber Topology



Attachment 2: Logical FTTP Network Architecture



Attachment 3: FTTP Backbone Proposed Fiber Routes



Attachment 4: OSP Cost Estimate Breakdowns (39.6 Percent Take Rate)

Segment / Area Name	Passings	Standalone Underground Segment Footage	Standalone Aerial Segment Footage	Shared Underground Segment Footage	Shared Aerial Segment Footage	Total Segment Footage	Total Segment Mileage (Total)	OSP Engineering	Quality Control/Quality Assurance	Standalone General OSP Construction	Shared Route / Incremental OSP Construction	Special Crossings	Backbone and Distribution Plant Splicing	FTTP Distribution Termination Costs	Backbone Hub, Termination, and Testing	FTTP Service Drop and Lateral Installations	Total Cost
A-B	N/A	-	-	3,652	-	3,652	0.69	$ -	$ -	$ -	$ 15,155.80	$ -	$ -	N/A	$ 196,611.84	N/A	$ 211,767.64
B-D	N/A	-	-	10,635	-	10,635	2.01	$ -	$ -	$ -	$ 44,135.25	$ -	$ -	N/A	$ 33,884.32	N/A	$ 78,019.57
C-D	N/A	-	-	4,854	-	4,854	0.92	$ -	$ -	$ -	$ 20,144.10	$ -	$ 2,247.43	N/A	$ 33,884.32	N/A	$ 56,275.85
D-E	N/A	-	-	8,313	-	8,313	1.57	$ -	$ -	$ -	$ 34,498.95	$ -	$ -	N/A	$ 196,611.84	N/A	$ 231,110.79
E-F	N/A	-	-	4,289	-	4,289	0.81	$ -	$ -	$ -	$ 17,799.35	$ -	$ -	N/A	$ 33,884.32	N/A	$ 51,683.67
F-G	N/A	-	-	5,131	-	5,131	0.97	$ -	$ -	$ -	$ 21,293.65	$ -	$ -	N/A	$ 33,884.32	N/A	$ 55,177.97
G-H	N/A	1,030	-	6,169	-	7,199	1.36	$ 2,539.89	$ 1,349.92	$ 16,617.53	$ 25,601.35	$ -	$ -	N/A	$ 196,611.84	N/A	$ 242,720.53
H-I	N/A	-	-	3,389	-	3,389	0.64	$ -	$ -	$ -	$ 14,064.35	$ -	$ -	N/A	$ 33,884.32	N/A	$ 47,948.67
I-J	N/A	-	-	3,896	-	3,896	0.74	$ -	$ -	$ -	$ 16,168.40	$ -	$ -	N/A	$ 33,884.32	N/A	$ 50,052.72
J-A	N/A	-	-	10,606	-	10,606	2.01	$ -	$ -	$ -	$ 44,014.90	$ -	$ -	N/A	$ 33,884.32	N/A	$ 77,899.22
G-K	N/A	1,305	-	4,755	-	6,060	1.15	$ 3,218.01	$ 1,710.34	$ 21,054.25	$ 19,733.25	$ -	$ -	N/A	$ -	N/A	$ 45,715.85
K-L	N/A	250	-	9,419	-	9,669	1.83	$ 616.48	$ 327.65	$ 4,033.38	$ 39,088.85	$ -	$ -	N/A	$ 33,884.32	N/A	$ 77,950.68
L-M	N/A	-	-	9,413	-	9,413	1.78	$ -	$ -	$ -	$ 39,063.95	$ -	$ -	N/A	$ 33,884.32	N/A	$ 72,948.27
M-N	N/A	3,377	-	9,746	-	13,123	2.49	$ 8,327.38	$ 4,425.92	$ 54,482.91	$ 40,445.90	$ -	$ -	N/A	$ 33,884.32	N/A	$ 141,566.42
N-O	N/A	2,224	-	2,692	-	4,916	0.93	$ 5,484.18	$ 2,914.79	$ 35,880.95	$ 11,171.80	$ -	$ -	N/A	$ 33,884.32	N/A	$ 89,336.04
O-P	N/A	3,550	-	12,001	-	15,551	2.95	$ 8,753.98	$ 4,652.65	$ 57,274.01	$ 49,804.15	$ -	$ -	N/A	$ 33,884.32	N/A	$ 154,369.10
P-D	N/A	-	-	5,252	-	5,252	0.99	$ -	$ -	$ -	$ 21,795.80	$ -	$ -	N/A	$ 33,884.32	N/A	$ 55,680.12
C-Q	N/A	-	-	5,082	-	5,082	0.96	$ -	$ -	$ -	$ 21,090.30	$ -	$ -	N/A	$ -	N/A	$ 21,090.30
Q-U	N/A	-	-	18,091	-	18,091	3.43	$ -	$ -	$ -	$ 75,077.65	$ -	$ -	N/A	$ 33,884.32	N/A	$ 108,961.97
U-T	N/A	-	-	11,975	-	11,975	2.27	$ -	$ -	$ -	$ 49,696.25	$ -	$ -	N/A	$ 33,884.32	N/A	$ 83,580.57
T-S	N/A	-	-	13,649	-	13,649	2.59	$ -	$ -	$ -	$ 56,643.35	$ -	$ -	N/A	$ 33,884.32	N/A	$ 90,527.67
R-A	N/A	-	-	7,876	-	7,876	1.49	$ -	$ -	$ -	$ 32,685.40	$ -	$ -	N/A	$ 196,611.84	N/A	$ 229,297.24
R-V	N/A	-	-	8,168	-	8,168	1.55	$ -	$ -	$ -	$ 33,897.20	$ -	$ -	N/A	$ 33,884.32	N/A	$ 67,781.52
V-W	N/A	-	-	7,937	-	7,937	1.50	$ -	$ -	$ -	$ 32,938.55	$ -	$ -	N/A	$ 33,884.32	N/A	$ 66,822.87
W-X	N/A	-	-	14,442	-	14,442	2.74	$ -	$ -	$ -	$ 59,934.30	$ -	$ -	N/A	$ 33,884.32	N/A	$ 93,818.62
X-A	N/A	-	-	17,369	-	17,369	3.29	$ -	$ -	$ -	$ 72,081.35	$ -	$ 2,247.43	N/A	$ 33,884.32	N/A	$ 108,213.10
S-R	N/A	-	-	9,864	-	9,864	1.87	$ -	$ -	$ -	$ 40,935.60	$ -	$ -	N/A	$ 33,884.32	N/A	$ 74,819.92
	N/A	-	-	-	-		0.00	$ -	$ -	$ -	$ -	$ -	$ -	N/A	$ -	N/A	$ -
												$ -	$ -		$ -		
Area A - High Density (Urban) Underground	551	35,225	-	-	-	35,225	6.67	$ 86,862.37	$ 46,166.48	$ 628,023.36	$ -	$ -	$ 33,822.73	$ 49,861.67	$ 49,861.67	$ 278,866.09	$ 1,123,602.70
Area B - High Density Aerial	4350	-	245,075	-	-	245,075	46.42	$ 604,331.91	$ 321,196.38	$ 2,159,918.04	$ -	$ -	$ 186,367.00	$ 157,446.89	$ 157,446.89	$ 663,337.77	$ 4,092,597.99
Area C -High Density (Residential) Undergrou	777	20,286	-	-	-	20,286	3.84	$ 50,023.22	$ 26,586.84	$ 422,145.60	$ -	$ -	$ 30,979.25	$ 69,656.97	$ 69,656.97	$ 314,635.90	$ 914,027.78
Area D - Medium Density Aerial	11988	-	1,051,867	-	-	1,051,867	199.22	$ 2,593,808.35	$ 1,378,583.24	$ 9,302,976.13	$ -	$ -	$ 920,199.62	$ 593,998.01	$ 593,998.01	$ 1,827,932.52	$ 16,617,497.86
Area E - Medium Density Underground	9989	752,305	-	-	-	752,305	142.48	$ 1,855,116.92	$ 985,976.12	$ 11,925,961.12	$ -	$ -	$ 654,302.71	$ 556,306.70	$ 556,306.70	$ 5,322,820.60	$ 21,300,484.17
Area F - Low Density Aerial	534	-	81,466	-	-	81,466	15.43	$ 200,886.84	$ 106,769.35	$ 479,378.54	$ -	$ -	$ 45,760.92	$ 70,125.69	$ 70,125.69	$ -	$ 902,921.34
Area G - Low Density Underground	665	308,246	-	-	-	308,246	58.38	$ 760,107.18	$ 403,989.37	$ 3,801,909.82	$ -	$ -	$ 129,545.53	$ 115,538.57	$ 115,538.57	$ 932,344.63	$ 6,143,435.11
Totals:	28854	**1,127,799**	**1,378,407**	**228,665**	**-**	**2,734,871**	**517.97**	**$ 6,180,077**	**$ 3,284,649**	**$ 28,909,656**	**$ 948,960**	**$ -**	**$ 2,005,473**	**$ 1,612,935**	**$ 3,110,953**	**$ 9,339,938**	**$ 53,779,704**

Attachment 5: Candidate Network Equipment BOM

Core and Distribution Network Electronics

Core Routers					
Make	***Model***	***Description***	***Qty.***	***Unit List Price***	***Extended Discount Price***
Cisco	ASR-9006-AC-V2	ASR 9006 AC Chassis with PEM Version 2e	2	$ 9,000.00	$ 10,800.00
Cisco	ASR-9006-FAN-V2	ASR-9006 Fan Tray Version 2	4	$ 3,800.00	$ 9,120.00
Cisco	PWR-3KW-AC-V2	3KW AC Power Module Version 2	4	$ 2,800.00	$ 6,720.00
Cisco	PWR-CAB-AC-USA	Power Cord for AC V2 Power Module (USA)	4	$ -	$ -
Cisco	A9K-RSP440-LT	ASR9K RSP 180G/slot upgradeable to 440G/slot 8GB RAM	4	$ 32,000.00	$ 76,800.00
Cisco	A9K-LI-LIC	A9K Lawful Intercept License	2	$ 20,000.00	$ 24,000.00
Cisco	XR-A9K-PXK9-05.03	Cisco IOS XR IP/MPLS Core Software 3DES	2	$ 15,000.00	$ 18,000.00
Cisco	A9K-4T16GE-TR	4X10GE / 16X1G Combo Linecard, Service Edge Optimized	4	$ 45,000.00	$ 108,000.00
Cisco	SFP-10G-SR	10GBASE-SR SFP Module	12	$ 995.00	$ 7,164.00
				Equipment Subtotal:	***$ 260,604.00***
Core Aggregation Switches					
Make	***Model***	***Description***	***Qty.***	***Unit List Price***	***Extended Discount Price***
Cisco	**WS-C4500X-F-32SFP+**	Catalyst 4500-X 32 Port 10G IP Base, Back-to-Front, No P/S	6	$ 28,000.00	$ 100,800.00
Cisco	C4KX-PWR-750AC-F/2	Catalyst 4500X 750W AC back to front cooling 2nd PWR supply	6	$ 2,000.00	$ 7,200.00
Cisco	C4KX-PWR-750AC-F	Catalyst 4500X 750W AC back to front cooling power supply	6	$ 2,000.00	$ 7,200.00
Cisco	C4KX-NM-BLANK	Catalyst 4500X Network Module Blank	6	$ -	$ -
Cisco	C4500X-IPB	IP Base license for Catalyst 4500-X	6	$ -	$ -
Cisco	CAB-US515-C15-US	NEMA 5-15 to IEC-C15 8ft US	12	$ -	$ -
Cisco	S45XUK9-38E	CAT4500-X Universal Crypto Image	6	$ -	$ -
Cisco	SFP-10G-LRM	10GBASE-LRM SFP Module	0	$ 995.00	$ -
Cisco	SFP-10G-SR	10GBASE-SR SFP Module	24	$ 995.00	$ 14,328.00
Cisco	SD-X45-2GB-E	Catalyst 4500 2GB SD Memory Card	6	$ 500.00	$ 1,800.00
Cisco	GLC-LH-SMD	1000BASE-LX/LH SFP transceiver module, MMF/SMF, 1310nm, DOM	0	$ 995.00	$ -
Cisco	SFP-10G-LR	10GBASE-LR SFP Module	60	$ 3,995.00	$ 143,820.00
Cisco	GLC-SX-MMD	1000BASE-SX SFP transceiver module, MMF, 850nm, DOM	0	$ 500.00	$ -
				Equipment Subtotal:	$ 275,148.00
Management and Network Services					
		NMS server hardware	1	$ 15,000.00	$ 15,000.00
		NMS server licensing	1	$ 15,000.00	$ 15,000.00
		DNS, DHCP, NTP server cluster	1	$ 25,000.00	$ 25,000.00
				Equipment/licensing subtotal:	$ 55,000.00

Annual Maintenance Contracts					
Make	***Model***	***Description***	***Qty.***	***Unit List Price***	***Extended Discount Price***
Cisco	CON-SNT-ASR90061	SNTC-8X5XNBD ASR 9006 AC Chassis with PEM Version 2	2	$ 459.00	$ 826.20
Cisco	CON-SNT-A9KR44LT	SNTC-8X5XNBD ASR9K RSP 180G/slot	2	$ 1,700.00	$ 3,400.00
Cisco	CON-SNT-A9KLILIC	SNTC-8X5XNBD A9K Lawful Intercept License	2	$ 1,060.00	$ 2,120.00
Cisco	CON-SNT-XRA9KPX5	SNTC-8X5XNBD Cisco IOS XR IPMPLS Core Software 3DES	2	$ 765.00	$ 1,530.00
Cisco	CON-SNT-A9K16FSE	SNTC-8X5XNBD 4X10GE / 16X1G Combo	0	$ 3,825.00	$ -
Cisco	CON-SNT-A9K16FSE	SNTC-8X5XNBD 4X10GE / 16X1G Combo	0	$ 3,825.00	$ -
Cisco	CON-SNT-C45XF32S	SMARTNET 8X5XNBD Catalyst 4500-X 32 Port 10G IP Base, Bac	6	$ 1,800.00	$ 10,800.00
					$ -
		NMS server licensing	1	$ 10,000.00	$ 10,000.00
				Annual Maintenance Total:	**$ 28,676.20**

Access Network Electronics

Combined GPON OLT / Active Ethernet Distribution Equipment (High Density)					
Make	**Model**	**Description**	**Qty.**	**Unit List Price**	**Extended Discount Price**
Calix	E7-2	E7-2 chassis, 1 RU with redundant power supplies	12	$ 800.00	$ 5,760.00
Calix	GPON-8	OLT Line card with 8 GPON and 4 GE interfaces	24	$ 9,796.00	$ 141,062.40
Calix		10GE SFP+, 10KM, 1310 nm	12	$ 1,600.00	$ 11,520.00
Calix		10GE SFP+, 300m, 850 nm	12	$ 900.00	$ 6,480.00
Calix		GPON OIM	96	$ 1,300.00	$ 74,880.00
Calix		GE SFP, 10 km, 1310 nm	96	$ 150.00	$ 8,640.00
		1x32 PON splitter and jumper cables	192	$ 1,200.00	$ 138,240.00
		Estimated Installation and Configuration:			$ 96,645.60
				Total:	$ 483,228.00
Combined GPON OLT / Active Ethernet Distribution Equipment (Medium Density)					
Make	**Model**	**Description**	**Qty.**	**Unit List Price**	**Extended Discount Price**
Calix	E7-2	E7-2 chassis, 1 RU with redundant power supplies	43	$ 800.00	$ 20,640.00
Calix	GPON-8	OLT Line card with 8 GPON and 4 GE interfaces	86	$ 9,796.00	$ 505,473.60
Calix		10GE SFP+, 10KM, 1310 nm	43	$ 1,600.00	$ 41,280.00
Calix		10GE SFP+, 300m, 850 nm	43	$ 900.00	$ 23,220.00
Calix		GPON OIM	344	$ 1,300.00	$ 268,320.00
Calix		GE SFP, 10 km, 1310 nm	344	$ 150.00	$ 30,960.00
		1x32 PON splitter and jumper cables	688	$ 1,200.00	$ 495,360.00
		Estimated Installation and Configuration:			$ 346,313.40
				Total:	$ 1,731,567.00
Combined GPON OLT / Active Ethernet Distribution Equipment (Low Density)					
Make	**Model**	**Description**	**Qty.**	**Unit List Price**	**Extended Discount Price**
Calix	E7-2	E7-2 chassis, 1 RU with redundant power supplies	3	$ 800.00	$ 1,440.00
Calix	GPON-8	OLT Line card with 8 GPON and 4 GE interfaces	6	$ 9,796.00	$ 35,265.60
Calix		10GE SFP+, 10KM, 1310 nm	3	$ 1,600.00	$ 2,880.00
Calix		10GE SFP+, 300m, 850 nm	3	$ 900.00	$ 1,620.00
Calix		GPON OIM	24	$ 1,300.00	$ 18,720.00
Calix		GE SFP, 10 km, 1310 nm	24	$ 150.00	$ 2,160.00
		1x32 PON splitter and jumper cables	48	$ 1,200.00	$ 34,560.00
		Estimated Installation and Configuration:			$ 24,161.40
				Total:	$ 120,807.00
				Total Implementation:	**$ 2,335,602.00**
				Annual Maintenance:	**$ 350,340.30**

Customer Premises Equipment

Standard Residential ONT and installation (GPON only)					
Make	**Model**	**Description**	**Qty.**	**Unit List Price**	**Extended Discount Price**
Calix	100-04011	Gigacenter 844G Indoor ONT, GPON-only, 2 POTS, 4xGE and 802.11ac client access *(alternatively: 711GE outdoor ONT w/ enclosure and indoor residential WiFi gateway)*	1	$ 280.00	$ 280.00
Calix	100-03893	Standalone UPS, 8 hour	1	$ 50.00	$ 50.00
		Installation and cabling	1	$ 150.00	$ 150.00
				Provisioning:	$ 50.00
				Total:	**$ 530.00**
Standard Business ONT and installation (GPON or GE)					
Make	**Model**	**Description**	**Qty.**	**Unit List Price**	**Extended Discount Price**
Calix	711GE	Indoor/outdoor ONT, GPON or GE service, 2 POTS, 2xGE	1	$ 220.00	$ 220.00
Calix		ONT enclosure	1	$ 30.00	$ 30.00
		Standalone UPS, 8 hour	1	$ 50.00	$ 50.00
		Installation and cabling	1	$ 300.00	$ 300.00
				Provisioning:	$ 100.00
				Total:	**$ 700.00**

Attachment 6: FTTP Cost Model Area Delineations