To: Richard C. Rossi, City Manager, City of Cambridge
From: The Cambridge Broadband Task Force
Date: August 3, 2016
Subject: Phase 1 Conclusion and Recommendations

In October 2014, you appointed us to the Cambridge Broadband Task Force to examine "options to increase competition, reduce pricing, and improve speed, reliability, and customer service for both residents and businesses" for broadband service in Cambridge. Since then, we've met with City staff and expert consultants hired by the City, reviewed case studies of other broadband efforts, conducted two public outreach meetings, and conducted a survey of resident opinions. Some of us have attended industry conferences and local events regarding broadband. We've discussed a wide range of options, various public/private partnerships, business models, and alternatives to a city-wide fiber optic broadband network.

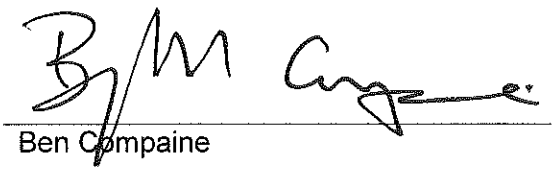
As this phase of study comes to a close, some members have concluded that the best way forward is through a City-owned municipal broadband system, believing it to be the only way the City can be sure of meeting its objectives. Others believe that there are a range of other solutions that could result in achieving a similar end but with less cost and risk to the City. There are two items, however, about which we are unanimous:

- We disagree with the recommendation of the consultant, Tilson, to build a dark fiber network as a way to provide incentives for some corporate entity to finish it. In addition, the option that provides fiber solely to Cambridge Housing Authority (CHA) locations is not accepted by the Task Force.
- Because the scope of the Tilson study was so broad, it wasn't as detailed as it might otherwise have been. If the City is to contemplate a capital expenditure of as much as $187,000,000, (Tilson's rough cost estimate for a city-wide broadband system), it needs more details and assurances than this process has been able to provide.

We recommend that the City proceed to a next phase of planning, a Municipal Broadband Feasibility Study. We intend this phase to be highly focused, broadly inclusive to incorporate better community outreach, and to produce the best possible plan for municipal broadband in Cambridge. This plan should then be rigorously tested against economic realities. In this framework, we would expect to provide you with an appropriately useful analysis of the costs, benefits, and risks of a municipal broadband system so as to allow you to make a fully informed decision.

Attached are our conclusions and recommendations, as well as the report from Tilson. We wish to thank you for appointing a Broadband Task Force to examine this important community issue and we look forward to Phase II of this process.

Submitted to the City Manager by the Cambridge Broadband Task Force



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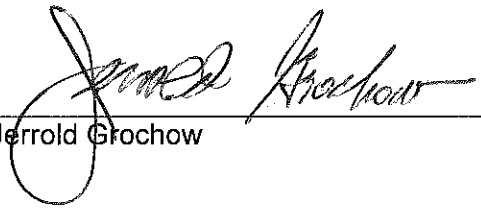

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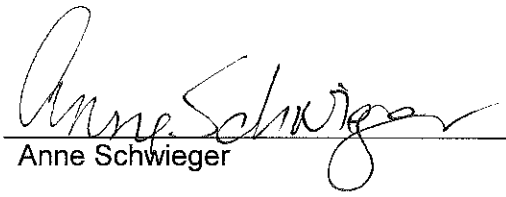

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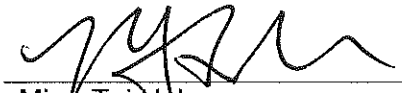

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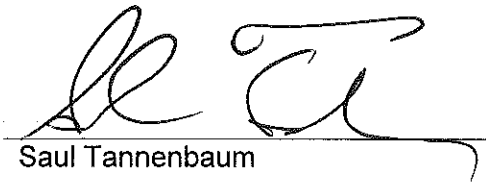

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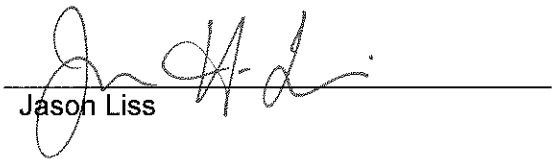

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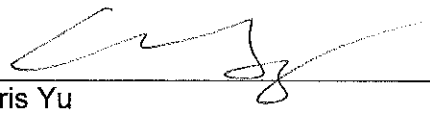

Chris Yu

PHASE 1 CONCLUSIONS AND RECOMMENDATIONS OF THE BROADBAND TASK FORCE

Highlights Learned in Phase I

Through Tilson's research, a randomized telephone survey, two community outreach sessions, attendance at conferences, and the discussion of the Task Force, we have learned:

- About two-thirds of households surveyed felt that their Internet service was of average or better value.
- Based on the survey, only 5% of City residents are frequent users of public Wi-Fi. Another 16% use it "occasionally."
- More residents considered "reliability" of greater importance than the cost or the speed of the service.
- Slightly more than half the respondents would be very or somewhat willing to pay more for faster service.
- According to participants in our outreach efforts, business and institutional users in Cambridge generally have the service they need directly from third party vendors. There is no evidence that data service issues are causing them to either leave Cambridge or not locate in Cambridge.
- Dozens of municipalities have implemented their own broadband service, often including cable TV. Hundreds of municipalities have government-owned networks of some kind, with many permutations of ownership and control. They range from totally municipally-owned and operated systems to municipal ownership of the underlying fiber backbone with private ownership and control of actual premises connections and the provision of services.
- Motivation for municipally-financed systems include the need to wire areas that private providers have neglected, to create better services in order to attract business to the area, and to offer services at lower prices than existing providers.
- In the overwhelming number of cases where local government has been successful in creating a municipally-owned broadband entity, the municipality had already owned the electric utility, providing ready access to conduits as well as operating experience and efficiencies in financing, billing, and account management for the add-on broadband service.

Goals and Objectives

Affordability and Equity

In 2015, the Mayor's Blue Ribbon Commission on Income Insecurity in Cambridge reported that the cost of internet was a major concern of residents who participated in its focus groups. Phase II of planning must directly address digital equity and inclusiveness, seeking the advice of residents who have not adopted broadband in the home or who have, but find the expense burdensome. The next phase should also incorporate targeted outreach to, for example, low income communities, the school system, and Cambridge social service agencies. Cambridge, with its wealth of resources, can provide a model for how cities should deal with digital inclusiveness.

Therefore, based on Phase I findings, a few questions arise:

- How much would a municipal broadband build-out improve access to affordable broadband for residents and small businesses (with the term “affordable rates” defined for 100Mbs and 1Gbs service)?
- How much would a municipal broadband build-out provide a better service at lower cost to all residents than the current levels of commercial service?
- How much would a municipal broadband build-out ensure that access programs solve real problems experienced by low income households?

Choice & Competition

Based on Phase I findings on the number of broadband providers in Cambridge:

- What is the likely impact on broadband pricing for business and residential customers with municipal broadband as the new competitor?
- What is the likelihood, and under what circumstance, might a private competitor enter the Cambridge market? Would that undermine, obviate, or reinforce the need for a municipally-financed system?

Supporting Entrepreneurs & Small Businesses

Based on Phase I findings on broadband availability and pricing in Cambridge:

- What would be the level of improvement to access to >100Mbs broadband for entrepreneurs and small businesses?
- What new opportunities might be afforded to entrepreneurs and small business by improved access to >100Mbs broadband?
- How can enterprise quality broadband be assured to be available throughout Cambridge?

Innovation & Excellence

The Task Force recommends that Phase II include broad outreach to the commercial, entrepreneurial, and institutional sectors of the Cambridge community. Institutions like Harvard and MIT have internal high speed networks and seek the highest speed connections for their worldwide research collaborations. We have a burgeoning biomedical industry that needs to move vast amounts of data for its business purposes. We also have a legion of entrepreneurs eager to find digital business opportunities.

As Cambridge aims to be a global leader in health care, services for the elderly, smart cities applications, and city efficiency, high quality broadband is critical. Further investigation of these areas will be required in Phase II.

How a robust municipal broadband infrastructure could help spur innovation and access to opportunity across Cambridge, as described in Tilson's Appendix G: Outreach Session #1 Issues and Recommendations needs to be explored.

Local Control

Based on the experience of communities currently running municipal broadband networks

- What have been the observed benefits of local control?
- What is the range of local control that might be realized under various business models, as all the way from city-owned and operated to city-financed but leased out to operators?

Considerations for a Municipal Broadband Network in Cambridge

Among the key potential benefits of a Cambridge-owned network would be, first, control over pricing and services and, second, the flexibility to make decisions based on social need rather than business needs.

Those of us who support municipal broadband take note of the City's previous efforts to solve these problems. The City has applied for Google Fiber and invited telecommunications companies to build a network in Cambridge. We believe, as do many experts, that the nation is experiencing a widespread market failure in the telecommunications industry. We agree with President Barack Obama[1] who has called high speed municipal networks "good for business, communities, schools, even the marketplace because they promote efficiency and competition." We also agree with Federal Communication Commission Chair Tom Wheeler who said, "When commercial providers don't step up to serve a community's needs, we should embrace the great American tradition of citizens stepping up to take action collectively."[2]

The Tilson report documents some of the successful municipal broadband projects. Tilson has provided a rough cost estimate for building a full broadband network in Cambridge, placing it in the cost range of a new school, an investment in the community that the City makes routinely, albeit carefully. Building a fiber optic broadband network is a complex but well understood skill. If Cambridge were to undertake such a project, it would be selecting from among the same consultants and contractors as would the private sector. Cambridge's advantages are two. Because of its outstanding AAA credit rating, it has access to less expensive financing. And, when the build was over, Cambridge would own a network as an asset and be able to chart its own destiny.

Although a city-funded broadband network has attractive attributes, the evidence suggests that it could be a high cost endeavor with substantial financial risks.

[1] https://www.whitehouse.gov/the-press-office/2015/01/14/remarks-president-promoting-community-broadband

[2] https://apps.fcc.gov/edocs_public/attachmatch/DOC-332988A1.pdf

The Tilson study included a telephone-based scientific survey of Cambridge households. Tilson's survey and surveys from the Census Bureau confirm that Cambridge has a considerably higher rate of household broadband connections than the national average.

The Tilson report included a number of case studies of other municipalities that have built cable or broadband-only networks. Few, if any, are directly comparable to Cambridge. There are precious few cases of build-outs that are financially viable without ongoing subsidies. Many were built on top of existing municipally-owned electric utilities, which provide some economies of scale and scope. In most cases the motivation for municipal ownership was to wire homes and businesses that the private carrier had not, which does not apply in Cambridge. A common motivation found in the case studies was to create an infrastructure that would attract and retain businesses and institutions and,thereby, employment.

Future technologies, such as 5G wireless, must be incorporated into the assumptions for municipal broadband. Any broadband system built today would be with fiber as both a backbone and to the premises, promising far greater bandwidth than current services.

Municipal Broadband Feasibility Study: Questions that require answers

Decision makers will need to know how a full municipal broadband build-out might enable the City of Cambridge to meet its goals for broadband, as laid out in Phase I. Phase II should seek to provide this information by answering the following questions:

- Building the network
    - What will be the full cost of building a full municipal network? Are there neighborhood-by-neighborhood variations in the cost profile considered in Tilson's report?
    - Can the construction of a network be phased so that each phase of work has its own value to Cambridge?
    - What's the best plan for funding a network build-out given Cambridge's general practices for capital expenditure?

- Operating the network
    - What's an appropriate legal structure for Cambridge to build and operate a broadband network?
    - How many Cambridge households and small businesses will sign up as customers? Will that projected "take rate" cover both operating and construction costs?
    - Is Cambridge willing to offer cable television and voice service bundles in order to acquire a significant number of customers? If so, what additional cost and complexity will that add the effort? Are there additional reasons/benefits for doing so?

- Should Cambridge seek full cost recovery from a network “business” or is it prepared to use tax revenues to cover some of the costs? If so, how much of the costs?
- How would the incumbent players, particularly Comcast, respond to a competitive player? This could result in desirable changes such as accelerating system improvement or lowering prices. On the other hand, such results may undercut the economic assumptions underlying the take rate and revenue projections for the municipal system.
- What is the shape of evolving technologies? Any substantial building of plant and equipment at the end of this study will likely be coming on stream no sooner than widespread implementation of 5G is expected.
- Can a stand-alone data-only service reasonably compete with existing services that bundle video and data services together over a plant that has similar costs?
- How large a role does “profit” play in the prices households now pay for data and video services?
- Short of building physical plant, are there other programs that could achieve the goal of providing quality broadband to the relatively small number of households that have economic need?

Municipal Broadband Feasibility Study: Expected Results

It is the intent of the Task Force that Phase II provide sufficient quantitative and other information for the City Manager to make a decision about whether and how to pursue a municipal broadband network. We believe the following information is required in order to accomplish this goal:

1. Street-by-street and neighborhood-by-neighborhood cost analysis to build the fiber network.
2. The “cost to connect” to the fiber network for a particular premises.
3. Take rate assumption requirements (revenue streams) to support the build-out. How many households would subscribe to the service? For the network to be competitive, would the City also provide telephone and television services?
4. Given the build-out and take rate assumptions, the capital requirements and operational costs to support the fiber network.
5. Development of a flexible implementation plan that considers external factors.

The answers to these questions will allow the City to estimate the amount of coverage/reach of the network and the associate upfront and recurring operating costs.

Municipal Broadband Study
for the
City of Cambridge, Massachusetts

Submitted to:
The City of Cambridge, MA

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1. Glossary of Terms

Term	*Definition*
Download Speed	Measured in megabits per second, it is how fast a user can pull data or conduct online activity from the server to their device. Examples include loading web pages and streaming videos.
Last Mile	Components of a network that provide broadband service to an end-user's premises or devices through an intermediate point of aggregation (e.g. remote terminal, fiber node, wireless tower, or other equivalent access point).
Live Broadcast Video Services	Subscription-based television services, usually provided by both analog and digital cable and satellite television.
Middle Mile	Network components that provide broadband service from one or more centralized facilities (e.g. central office, cable headend, wireless switching station, etc.) to an internet point of presence.
Mobile Virtual Network Operator (MVNO)	A wireless communications services provider that does not own the wireless network infrastructure over which the MVNO provides services to its customers.
Open Access	A network management policy by which multiple service providers can offer services over the same physical network.
Point of Presence	A physical location that houses servers, routers and switches, and is an access point to the internet. It allows two or more different networks or communication devices to build a connection with each other.
Take Rate	The percentage of potential subscribers who are offered service that actually do subscribe.
Telecom	The exchange of information over significant distances between two circuits by electronic means. Each circuit contains a transmitter and a receiver.
Throughput	The amount of material or items passing through a system or device.
Upload Speed	Measured in megabits per second, it is how fast a user can send data from their device to others. Examples include sending files via email and video-chatting.

2. Executive Summary

The City of Cambridge's Broadband Task Force engaged Tilson to help it identify a strategy for attaining world-class broadband in the City. Working with Tilson, the Task Force has identified five goals for the eventual solution:

1. Affordability and Equity
2. Choice & Competition
3. Supporting Entrepreneurs & Small Businesses
4. Innovation & Excellence
5. Local Control

Tilson has conducted an evaluation of current service offerings in Cambridge, solicited residents' input via surveys and public meetings, and worked closely with city personnel in evaluating a range of options.

Tilson has evaluated three potential options for a fiber optic network. Fiber optics provide the greatest bandwidth capability and the greatest potential for coping with technological and user pattern changes. Tilson has examined three levels of fiber-build out through a high-level network design. Each of these potential fiber networks illustrates strategies that the City could pursue, although any ultimate City fiber build-out may depart from these examples in some of the particulars. Each strategy represents a different level of financial commitment, operational responsibility, and adherence to the above goals:

1. **A "Targeted" build** connecting only the 22 premises owned by the Cambridge Housing Authority and providing these facilities with connectivity as an extension of the City's existing fiber optic network. At $5.5 million, this is the lowest cost solution that represents the least departure from "business as usual" for Cambridge, but does not address all of the Task Force's goals.
2. **A "Partial" build** consisting of a dark fiber platform routing fiber to all neighborhoods in the City, but relying on third party Internet Service Providers (ISPs) to provide services to end users. This is a medium cost option, at $7.0 million, whose satisfaction of the Task Force's goals would depend on the City's ability to negotiate agreements that satisfy the goals, and on the response of service providers.
3. **A "Full" Fiber to the Home Network** where fiber is run to substantially all premises in the City and services are provided by either the City itself or its designated ISP. This is the highest cost option by far at $130-187 million, depending on the percentage of premises along the route which are connected. It represents the greatest operating responsibility and greatest departure from "business as usual."

Given the City's limited experience owning and operating a consumer broadband network, Tilson recommends that the City build a limited but expandable initial network and seek partners to use, manage, and operate the network. The City should regard this initial network as a first stage in its efforts and a test of the willingness of market participants to engage with the City on favorable terms and extend and expand on its broadband effort. We recommend that this initial stage effort be kept small enough that operating expenses and a very limited financial return on the capital investment would be tolerable. As the City gains experience owning a network and working with third parties for the network's maintenance and operation, it can embark on a path of controlled expansion in stages, where costs and projections are clearly understood before committing financial resources.

3. Introduction

City of Cambridge Manager Richard R. Rossi appointed a Broadband Task Force to examine broadband service in the City, evaluate the City's internet infrastructure, analyze alternatives for improving the internet infrastructure, and develop potential projects (network designs, specifications, and estimates). The Task Force was established through Policy Order O-9, whereby the "City Manager is requested to appoint a task force composed of experts, residents, the Cambridge Housing Authority, and representative from the local universities charged with developing a municipal broadband proposal for Cambridge, potentially also including extension of city fiber into public housing properties."[1] The purpose of this report is to support the work of the Task Force and to better inform the City about its options for action to address its broadband goals. The analysis and recommendations contained herein are Tilson's, not those of the Task Force.

City of Cambridge Broadband Goals

Tilson worked with the Broadband Task Force to ascertain how the City leaders envision their community when it comes to broadband improvements, and what the specific goals should be in order to achieve that vision. As a result, the Task Force developed the following five broadband goals:

1. **Affordability and Equity.** Access to service should be without regard to income, size of business, or geographic areas of the city.
2. **Choice & Competition.** Cambridge residents should have a variety of providers to choose from for internet service. Increased competition will result in lower prices for all and can spur better service as service providers compete with each other to attract customers.
3. **Supporting Entrepreneurs & Small Businesses.** The proposed solution should support local small businesses and entrepreneurs. Access to world-class broadband connectivity will empower local businesses to act on a global scale by eroding geographic constraints. It can also attract entrepreneurs to Cambridge, already known as a high-tech city.
4. **Innovation & Excellence.** Cambridge is well-known as a high-tech city and is home to world-leading universities and provides forward looking services to its residents. The solution should create and provide a pathway to innovation, thus nurturing new business ventures, attracting further entrepreneurs to a city already known for seeding startups, creating civic engagement, and smart City services. Pervasive access to best-in-class connectivity can encourage the sort of idea-sharing and communication that are key to achieving and maintaining entrepreneurship in innovation hubs like Cambridge. In addition, an innovative solution will show that the City is forward-looking and committed to investing in its future.
5. **Local Control**: City officials and their designees should play an active role in planning the available services. The City should also retain significant influence over capital and operational investment decisions including network construction, expansion, and connectivity.

Despite the City of Cambridge's reputation as an innovation hub, it has a highly concentrated telecommunications market with limited competition. Comcast dominates the market with greater than 75% market share in the residential and small business segments, while Verizon, RCN, and netBlazr have limited presences. Other carriers include XO Communications, Wicked Bandwidth, and MegaPath. There is a bifurcation of broadband connectivity in Cambridge, based largely on income: less well-off residents spend a proportionally much larger share of their income on broadband. Broadband is increasingly seen as a necessity, not a luxury, and this can impose a real hardship on those less able to afford high rates.

In this report, Tilson will provide a comprehensive overview of existing telecommunications services in Cambridge, with a focus on broadband. Broadband, wireline, and wireless carriers will be discussed. The report will then discuss actions taken to date around community outreach and establishing the community's perceived needs, which included a survey. Next, the report will provide a definition of the

[1] http://www2.cambridgema.gov/cityClerk/PolicyOrder.cfm?action=search&item_id=42262

service gap: lower income residents can experience a significant hardship at the cost of service driven by a less-than-optimally competitive market.

Tilson understands that the Cambridge Broadband Task Force has largely settled on a solution involving a fiber optic network reaching some, if not all, portions of the City. Deploying broadband via wireless technology in a dense area such as the City of Cambridge will not achieve the desired results. Microwave radio links require a clear line of sight to function at an optimal level when transmitting and receiving signals. With the amount of obstructions in a city environment, these design requirements cannot be met effectively. And the obsolescence of wireless technology is at a much higher rate than that of fiber, while yielding the same or lower throughput speeds. There is a technological lock-in where the existing wireless technology is relevant for three to five years prior to infrastructure upgrades taking effect.

The report will discuss business models of a municipal-scale fiber network, including both capital strategies involving "full" to "targeted" builds, and operating strategies that determine what other parties the City may choose to bring into the network, and how revenues, risks, and costs are allocated among the involved parties. Funding and financing models will also be addressed.

Next, the report will present three main capital expense models and preliminary designs as baseline models from which Cambridge can select and further customize. Termed Small, Medium, and Large, these present progressively larger commitments. The Small build is a targeted option that will reach 22 Cambridge Housing Authority buildings and could function as either an extension of the existing City network or as a quasi-independent network run by a private partner. The Medium build is an example of an infrastructure platform, consisting of a backbone fiber network that reaches all City neighborhoods, but on which service is provided by private operating partners. Lastly, the Large build envisions a City-wide Fiber to the Premise buildout. It is by far the most ambitious option and presents the greatest cost, complexity, and risk. Should Cambridge choose this type of solution, it will almost certainly need to do so with an experienced operating partner. Indicative operating expenses for all three solutions are outlined in their own section.

After discussing the three potential capital models, the report will present case studies of successful (and not so successful) municipal broadband networks, with further highlighted projects supporting low income residents specifically. Case studies highlight the reasons for success or failure of each network, and key takeaways for Cambridge.

The report closes with a discussion of lessons learned from other municipal projects and a brief analysis of the regulatory and public policy aspects around building municipal networks.

4. Existing Broadband Services

The City of Cambridge is a highly concentrated market for residential telecommunications services. Internet, voice, and video services each have two to three providers competing for market share, but the subscriber rates are not similar among them. For small businesses, however, it is a fairly competitive market for telecommunications offerings.

The data in this section were collected at various points beginning in October 2015. Although the data was revisited in February 2016, providers do change their non-promotional pricing from time to time, and may change them in the near future.

Carrier Offerings Summary

As Table 1 illustrates, residents, small businesses, and enterprise customers have some degree of choice regarding plan offerings and pricing. The listed providers have varying degrees of availability in the City.

Provider	Residential Internet	Small Business Internet	Residential Voice	Small Business Voice	Wireless Voice & Data	Live Broadcast Video Service	Enterprise Level Internet	Dark Fiber
Comcast	X	X	X	X		X		
Verizon DSL	X	X	X	X				
Verizon FiOS	Limited	Limited	Limited	Limited				
netBlazr	X	X						
DISH						X		
AT&T d/b/a DIRECTV						X		
MegaPath		Limited		X			X	
Verizon d/b/a XO Comm.		Limited		X			X	X
RCN Business		X		X				
Wicked Bandwidth		Limited					X	
Verizon Wireless					X			
AT&T					X			
Sprint					X			
T-Mobile					X			
Lightower							X	X
Last Mile Solutions								X
Level 3 Communications							X	X
Sunesys							X	X
Zayo							X	X

Table 1: Cambridge Telecom Service Offerings Landscape

Residential Offerings

Residents in the City of Cambridge have in general three companies to choose from when shopping for internet, wireline voice, and/or broadcast services: Verizon and netBlazr for internet and wireline voice services only, and Comcast for all three services.

It must be noted that Verizon offers two types of broadband services – DSL[2] and FiOS – that differ greatly in their underlying technologies, capabilities, and reach within Cambridge. Verizon DSL is a city-wide offering while FiOS is limited to the neighborhoods of Cambridgeport, North Cambridge (only in new buildings), West Cambridge, and Porter Square. Even so, not all households within these four neighborhoods have the option of subscribing to FiOS. Verizon has remained consistent over the years that it has no plans to invest in further FiOS network expansion across Massachusetts. Thus, the

[2] Verizon markets its DSL product as "High Speed Internet," as opposed to FiOS.

residential and small business offerings analysis will include FiOS product offerings, but will not compare them to the city-wide offerings.

Internet

Comcast, Verizon, and netBlazr provide residential internet services in Cambridge. Each of these companies uses different technology to reach residences. Refer to Appendix A to view each company's product offerings and pricing structure. It must be noted that Comcast and Verizon provide package bundles that include internet and phone at the minimum, with a marketing strategy that bundling is a cost savings to the consumer. netBlazr does not offer product bundles, however, and focuses exclusively on providing wireless internet. Table 2 lists each of the internet providers in Cambridge by their respective target markets.

Business models can be broadly broken down into four main types:

- Cable franchises historically provided broadcast services, but have generally expanded to offer phone and internet service over their existing infrastructure.
- Wireless ISPs provide service via a fixed (not mobile) service that provides internet access to customers who use a compatible wireless modem.
- The Incumbent Local Exchange Carrier (ILEC), is the traditional "phone company" in a given place. ILECs have a service area defined by law and FCC regulations, and are legally required to provide voice service to all customers in their service area who request it. This is also termed as being the "provider of last resort." The ILEC in Cambridge is Verizon.
- Competitive Local Exchange Carriers (CLECs), are alternative providers of traditional phone and data services, but can choose the areas and customers they wish to serve.

Target Market	Provider	Business Model	Technology	Maximum Advertised Download Speed	Maximum Advertised Upload Speed	Cost per Megabit of Fastest DL Tier
Residential	Comcast	Cable Franchise	DOCSIS 3.0	150 Mb/s	20 Mb/s	$0.53
Residential & Small Business	Verizon	ILEC	DSL	7 Mb/s	0.75 Mb/s	$6.43
Residential & Small Business	netBlazr	Wireless ISP	Fixed wireless	50 Mb/s	50 Mb/s	$2.00
Small Business	Comcast Business	CLEC	DOCSIS 3.0	150 Mb/s	20 Mb/s	$1.67
Small Business	RCN Business	CLEC	DOCSIS 3.0	110 Mb/s	15 Mb/s	$1.03
Enterprise	MegaPath	CLEC	DSL	20 Mb/s	2 Mb/s	$4.75
Enterprise	Wicked Bandwidth	CLEC	Ethernet	1 Gb/s	1 Gb/s	$2.00
Enterprise	XO Communications	CLEC	Ethernet	100 Mb/s	100 Mb/s	$21.28

Table 2: Internet Service Providers in Cambridge

Cambridge residents who are solely interested in the fastest internet speeds offered would subscribe to Comcast's "Blast" package that provides up to 150 megabits per second (Mb/s) download speeds, with varying upload speeds. Comcast does not publish upload speeds, and states that they will vary from resident to resident, as will download speeds.

Comcast is in the process of deploying a fiber to the home product called Xfinity Gigabit Pro. This will provide up to 2 gigabits per second (Gb/s) download speeds to customers within $^1/_3$ mile of a Comcast fiber line. This limited availability at the outset will expand to a city-wide gigabit offering by 2018, which may or may not be fiber based. Priced at $299.95 per month and requiring a 2-year agreement, Xfinity Gigabit Pro further demonstrates Comcast's competitive response to similar offerings from Google Fiber and AT&T U-Verse GigaPower.

Wireline Voice

Both Comcast and Verizon offer residential voice services in Cambridge. Each of these companies provides a basic and an enhanced product offering. Refer to Appendix B to view each company's product offerings and pricing structure. It must be noted that independent phone packages from Comcast and Verizon are not the best option for residents; internet and phone bundling would yield a higher value.

Wireless Voice

Tilson analyzed wireless carriers that own physical network infrastructure and not virtual carriers, or Mobile Virtual Network Operators (MVNOs), that contract for capacity on another carrier's network. Refer to Appendix F for a complete list of carriers and their respective phone plans. Subscribing to a wireless carrier's network can provide relatively higher speed internet access, while also obtaining mobile voice, and video through streaming services. Mobile data plans often include caps on the amount of data included, however, with steep overage fees.

Live Broadcast Video Services

Comcast is the sole cable operator in Cambridge. Dish Networks and DirecTV are alternative live broadcast video service options available to residents provided they are willing to forego a hard-wired connection for satellite service. Comparisons cannot be made between these companies, as they have different business models and network infrastructure. For example, Comcast is the only live broadcast video service provider that markets a double play offer. Dish Networks and DIRECTV recommend – or partner with – a third party company for internet and voice bundling solutions. Refer to Appendix D for a complete list of product offerings in the City of Cambridge from each of these cable providers.

Verizon FiOS does not offer live broadcast video services in Cambridge. Its business strategy and marketing efforts focus solely on internet and phone offerings at this time. A FiOS Internet offering is a mark of progress from Verizon's initial strategy of deploying FiOS exclusively in the suburban areas of Massachusetts. But it remains to be seen as to whether a FiOS live broadcast video service play will ever be an option to the residents of Cambridge.

At the time of this report, the pay-tv industry is experiencing an upheaval in how content is delivered to subscribers. Over the top (OTT) video and Streaming Video on Demand (SVOD) – accessible anytime and anywhere – is quickly surpassing traditional scheduled television programming in terms of value to viewers. By 2018, the OTT market will total $8-10 billion, as 30% of North American smartphone owners now watch full length television shows on their smartphones, and 20% watch full length movies.[3] The underlying reality of this shift is that consumer viewing habits have migrated to a "whatever, wherever, whenever" experience, and in turn, have taken control of the content delivery methods that the cable operators used to have. Cable companies' business models are rapidly evolving to allow them to serve content to people via networks they may not control. For example, Comcast offers "Stream TV", a mobile-first IPTV service that focuses on broadband-only customers without impacting their Xfinity internet plans. Cord cutting – subscribing only to internet, but not broadcast services or phone, and instead streaming video online – is becoming the dominant trend in video services.

Small Business Offerings

Small businesses in the City of Cambridge have varying options for obtaining internet service depending on the desired speed and their allocated telecom budget. There is small business-class internet, providing guaranteed bandwidth, and enterprise-class internet, providing bulk dedicated bandwidth and more specialized services like metro Ethernet. The majority of these internet service providers offer voice services as well, typically through VoIP.

City-wide Internet

The city-wide, small business class-service providers are Comcast Business, Verizon DSL, RCN Business, and netBlazr. Refer to Appendix E for the small business internet service providers' product offerings in Cambridge. It is important to highlight the distinction between "RCN" and "RCN Business." Both are subsidiaries of RCN Telecom Services, LLC, but RCN does not provide residential telecom services in Cambridge.

As with residential offerings, Comcast Business provides the fastest download speeds with a 150Mb/s tier. But unlike residential, Comcast requires small businesses to commit to a one-year agreement. RCN Business also requires a contract but offers a maximum of 110Mb/s download.

Small businesses looking strictly for the lowest price for internet access would select Verizon DSL's "Starter" package at $29.99 per month. This provides a maximum download speed of one megabit per second, but is far and away the highest unit cost. RCN Business provides significantly higher speeds for a modest incremental cost.

[3] Ooyala *State of the Broadcast Industry 2016: OTT Moves to Center Stage*

Refer to Appendix E for the small business internet service providers' product offerings, specific to the City of Cambridge.

Voice

Voice products for small businesses are offered by the Internet Service Providers, whether it be through VoIP or a physical connection. Though offered as *à la carte* options, phone services are typically bundled with an internet plan due to the cost savings.

Enterprise Class Services

Enterprise-class services consist of services provided with a committed throughput rate and are designed to be used at or near that rate most of the time. These are specifically targeted at certain large customer types. Customers of enterprise services typically have many users on-site and require dedicated bandwidth. Unlike other service classes, enterprise internet services are designed to use a large proportion of their nominal capacity on average. Thus, enterprise service is characterized by dedicated, reserved bandwidth. This type of service typically requires a Service Level Agreement (SLA) that describes the service ordered, guarantees the throughput speeds, and contains a service restoration clause, guaranteeing response times, should the connection be interrupted. Subscription fees for enterprise class service offerings are significantly higher than other service classes.

There are many providers offering enterprise-class internet service in Cambridge, but availability is mostly concentrated in Harvard Square and Kendall Square where the majority of enterprises are located. For simplicity's sake, this section will focus on four providers whose offerings can be taken as generally indicative: netBlazr, MegaPath, XO Communications[4], and Wicked Bandwidth. The service is custom ordered, and customers are often responsible for the cost of connecting their premises to the provider's network. Wicked Bandwidth and XO Communications both require a fiber deployment into the building, which must be custom installed if not already present for an existing enterprise within the same premises. MegaPath provides long distance Ethernet (often called Metro Ethernet) over copper, and netBlazr provides fixed wireless. In general, advertised enterprise offerings range from 1.5Mb/s to 1 gigabit per second. Higher speeds are possible, and prices are generally negotiated separately for each connection.

It is also useful to note that providers can have markedly different terms for the same service. Wicked Bandwidth and netBlazr both offer gigabit service. Wicked Bandwidth costs $2,000 per month and requires a one-time installation fee of $1,000 as well as a minimum contract of three years. In contrast, netBlazr's published rate is $4,499.95 per month, but does not charge for the installation nor require a contract.

Institutions and businesses that are interested in enterprise class internet at the lowest price possible have limited options. Typically, enterprise class internet commands a premium rate due to the dedicated bandwidth component of the service. The lowest cost enterprise class internet plan is MegaPath's 1.5 Mb plan at $64.00 per month, a surprisingly high cost per megabit. MegaPath's lowest tier offering provides the lowest cost and speed, but not the lowest unit cost of the providers surveyed.

Dark Fiber

Dark fiber refers to the lease of existing fiber strands to enterprises for their exclusive use. The exclusivity can be to the physical strand (the lessee's traffic is the only traffic on the leased strands) or multiple lessees can share a strand, but each has dedicated bandwidth from it.

Point to point connectivity can encompass two main use cases. It can represent connectivity for a large enterprise between its various locations or can be connectivity between two network points of presence for a carrier. These connections can be made over fiber that the enterprise owns or via dark fiber. Dark

[4] As of February 2016, Verizon has acquired XO Communications.

fiber, in this context, refers to the lease of specified fiber strands. Dark fiber customers lease dedicated bandwidth (individual strands or specified wavelengths on shared strands), often taking the form of an indefeasible right of use (IRU). This is a contractual agreement that allows the lessee the exclusive use of the specified fiber or capacity for any legal purpose. Customers of dark fiber can either be enterprises or network operators themselves seeking to establish a raw connection between their points of presence. These points of presence could be on opposite sides of a state, country, or ocean. This type of enterprise service is designed to provide direct internet access to end users or to link geographically disparate places on a carrier's network.

Cambridge has several dark fiber providers with varying coverage in different parts of town depending on where their fiber is located. Customers for dark fiber are typically large enterprises that require scalability and high bandwidth, and have the in-house expertise to operate their own network. In addition, dark fiber services are different than standard internet services. Typically, dark fiber providers provide a range of low-level network transport services that establish basic connectivity between various customer locations along the fiber route, and leave it to the customer to actually provide higher level connectivity between the locations. The following are the main dark fiber providers active in Cambridge:

- Lightower
- Last Mile Solutions
- Level 3 Communications
- Sunesys
- XO Communications
- Zayo

Maps of these providers' routes are shown in Appendix K.

5. Community Outreach Sessions Analysis

Tilson and the Task Force conducted a series of community outreach sessions. This section provides takeaways from and summaries of these sessions.

Outreach Session #1 – Residential Community

Date: October 14, 2015
Location: Cambridge City Hall

The first outreach session consisted of lively discussions by several dozen residents of the City of Cambridge in regards to their broadband internet needs. Though most participants identified as solely residents, there were a few who were both residents and small business owners. The community input forum began with a brainstorming session centered on the following question: "What about broadband service in the City of Cambridge do we want to see improved?" A synthesis of participants' responses includes:

- Affordability
- Choice and competition
- Local control
- Innovation and excellence
- Supporting employers and small businesses

Next, participants formed affinity groups around these issues based on each individual's primary interest, and proceeded to discuss ideas and follow-on thoughts in each interest. Refer to Appendix G for the various inputs within each of the affinity groups. Following a thorough discussion on the impacts of these issues in Cambridge, a volunteer from each affinity group reported to the larger group about the issue clusters, recommendations, and their impacts on the community.

The session ended with a prioritization exercise, where the participants voted on final recommendations. Participants were given 3 colored dots to cast multiple votes based on their affiliations. Voter classifications can be found in Appendix H. Virtually everyone agreed that existing offerings were not satisfactory given the cost and low quality of both broadband service and customer service. A majority agreed that the City should play a major role in improving the state of broadband access to its residents. Refer to Appendix H for a complete breakdown of the recommendations and votes cast.

Aside from competition and choice, many residents also expressed frustration at a perceived lack of affordability of internet access, with significant support for increasing affordable internet access to low-income residents. Though Comcast currently offers an "Internet Essentials" program that targets this demographic, people expressed their belief that this program is not working effectively due to somewhat tight restrictions in eligibility. In summarizing and concluding the forum, residents voiced their opinion that a municipal, government-funded broadband network could address these issues.

The session concluded with participants' feedback on their experience within the session and their takeaways from interacting with other residents in the Cambridge community. Many participants believed that the City of Cambridge should own and manage its own broadband network to address the existing equity and autonomy issues.

Outreach Session #2 – Business Community

Date: October 15, 2015
Location: Cambridge Innovation Center (C.I.C.)

The second outreach session consisted of a diverse group of 15 professionals from Cambridge businesses and institutions. In attendance were representatives from Lesley University, Novartis, Microsoft, local entrepreneurs, City representatives, and Cambridge Public Schools among others. The first group exercise, "Broadband Brainstorm", had the participants address the following question: *How does better broadband across the City of Cambridge support my organization and its work?* Participants provided a diverse set of answers, including examples like these:

- Supports economic development and City's leadership in the tech economy
- Opportunities to collaborate with K12 schools
- Addresses digital divides (economic & geographic)
- Colleges are more attractive to students
- Supports quality of life
- Makes properties more marketable
- Access to great infrastructure without multiple digs
- Addresses City's affordability issues for residents
- More affordable options for business & institutions
- Applications—cloud apps, smart buildings, sensors, video, "homework at home"

Refer to Appendix I for the complete list of responses from the participants in regards to this question. Following the brainstorming session, participants formed into two groups to address the following questions:

- What is the problem with broadband available to my organization?
- What isn't the problem with broadband available to my organization?
- What is the problem with broadband available across the City as a whole?
- What isn't the problem with broadband available across the City as a whole?

Table 3 and Table 4 below provide a range of participant responses to illustrate the diverse feedback to these questions.

Is the Problem	*Is Not the Problem*
Poor competitive choices	Comcast raising speeds without raising prices
Lost opportunities when digging up streets	Use of city conduit (if available)
Wi-Fi quality in many public spaces	Kendall and Harvard Square Wi-Fi Collaborations
Planning for fiber and conduit in new construction	High demand for great broadband

Table 3: Sample Participant Responses to State of Broadband

Is the Problem	*Is Not the problem*
Inconsistent levels of access to best service	Metro A Loop connectivity to Summer St.
Access to conduit between locations in the City	Good fiber options in some locations
Upload ability	Working with the city
Number and diversity of devices	Basic broadband access
1 Summer St. vulnerability	Kendall and Harvard Square Wi-Fi collaborations

Table 4: Sample Participant Responses to Problems with Broadband for Them

Refer to Appendix I for the complete list of participant responses recorded in both groups for each of the above questions.

City-wide, the existing broadband offerings to small and mid-size organizations are limited in scope, and the costs are not aligned with the quality of service. But in locations where fiber is present, internet speeds are suitable for organizations and are not a problem. In addition, the current collaboration between the City, MIT, and Google to provide Wi-Fi in Kendall Square is a high visibility project that can potentially serve as the model for other deployments around Cambridge.

A group exercise entitled "Blog Post from the Future," produced interesting remarks from the participants regarding how they envisioned their future selves would describe how better broadband arrived in Cambridge three to five years from now. Table 5 below provides notable remarks around process and outcomes.

Process	***Outcomes***
"City talked to carriers and business partners to find out what they wouldn't do regarding broadband offerings."	"Public utility: City-owned conduit"
"Decided appropriate role for City."	"Decided that this was infrastructure with limited private business case."
"A comprehensive plan was made."	"Services that are more reliable and of higher quality."
"Broadband plan with multiple service levels."	"Broadband access regardless of users' ability to pay."
"Collaboration amongst public schools, private universities, providers, and local businesses (small, medium and large)."	"Students have better, more equal opportunity at success."
"Presented a compelling business case to carriers / business partners."	"Better employee recruitment."
"Spent time talking to residents and businesses alike regarding digital divide."	Competitive pricing has lowered costs to residents

Table 5: Notable remarks around process and outcomes

Refer to Appendix I for the complete list of participant responses recorded in both groups for the "Blog Post from the Future" exercise.

The session concluded with participants' feedback on their overall experience within the session and their takeaways from interacting with other business professionals on the topic of broadband internet in the Cambridge community. Many participants remarked that with the collaboration between the City, private institutions, and large organizations, a city-wide, scalable broadband network can be made possible.

6. Survey Results

Opinion Dynamics, a full service market research firm with headquarters in Waltham, MA, conducted a telephone survey with 403 households in Cambridge between October 15, 2015 and October 31, 2015. There was a margin of error of ±4.8% at the mid-range of the 95% confidence interval. The objective of the household survey was to collect the residents' views on telecom services – internet, voice and live broadcast video services – offered in the city. This method of surveying achieved statistical randomness in identifying:

i. What service residents are currently using and how much they pay;
ii. An assessment of the adequacy of current service, with a focus on the quantity and distribution of unserved and underserved residences;
iii. Service option residents would like to have to meet their current and projected needs;
iv. Resident willingness to pay for improved broadband service

There were many key findings and interesting statistics, which will be explained in this section. Refer to Appendix J for the Opinion Dynamics Survey Results.

Key Findings

383 households, or 95% of all households who participated, have internet access at home (excluding cellular data plans). Only 7% of households subscribe solely to mobile data plans. A side-by-side comparison of these results can be seen in Figure 1 below. In a 2015 national survey by Pew Research Center, 67% of households have adopted broadband internet.[5] At 95%, Cambridge far surpasses this national benchmark. Keep in mind that the Opinion Dynamics survey sampled people to ask about household characteristics, while the Census sampled households to ask about household characteristics.

It is interesting to note that the 2014 American Community Survey of the US Census estimated that 83.1% of Cambridge households have a broadband subscription. The difference between the ACS and Opinion Dynamics is likely due to differences in methodology and response populations between the two surveys. The ACS uses phone, online, mail, and in-person questionnaires, and responses to it are legally required. The Opinion Dynamics survey, in contrast, was entirely voluntary and conducted only over the phone. Compared to the overall City demographics reported in the ACS, the Opinion Dynamics survey respondents were significantly more likely to be ages 26-35 with post-graduate degrees. In addition, it appears that more Opinion Dynamics respondents belonged to higher income tiers than would be representative of the City as a whole. Twenty-two percent of Opinion Dynamics respondents declined to provide income information, so the actual income distribution of the respondent population is not certain.

[5] Pew Research Center, *Home Broadband 2015*

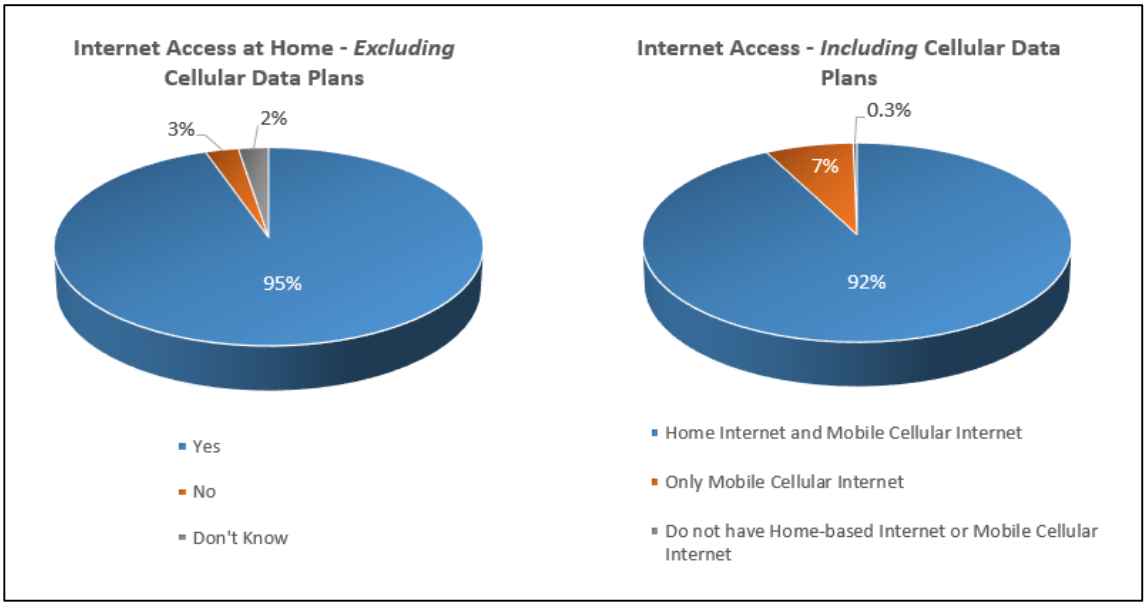


Figure 1: Internet Service at Home & Cellular Data Plans

As can be seen in Figure 2 below, 83% of respondents have Comcast service. Verizon only accounts for 9% across their FiOS and DSL offerings. Most households who subscribe to Comcast have selected the Triple Play package – internet, live broadcast video and voice services. But when households were asked to assess the *value* of their internet service on a scale of 1 to 5, the results were mixed, with a mean of 2.96 (see Figure 3 below). In fact, the data show a fairly large variation of satisfaction level with overall quality of internet service at the household level and neighborhood level in Cambridge. Figure 4 shows a wide dispersion of opinion on the *overall quality* of internet service at home, with a mean of 5.96.

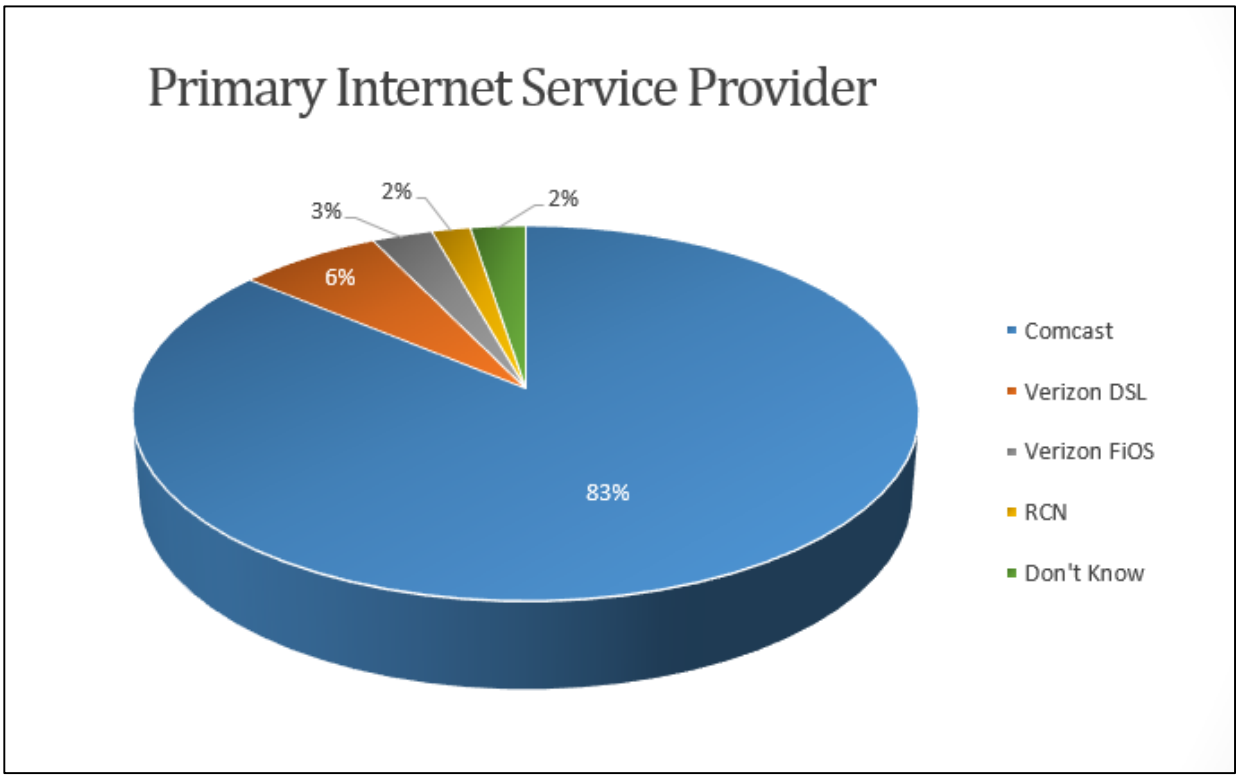


Figure 2: Primary Internet Service Provider

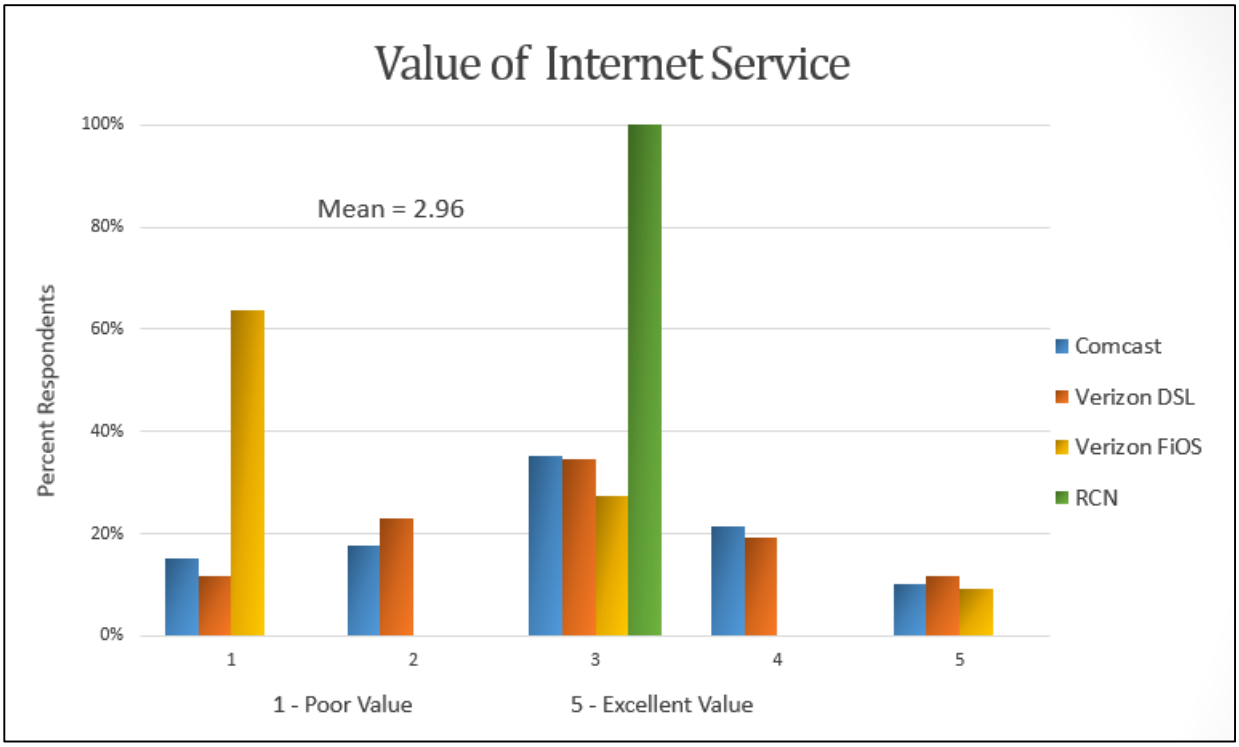


Figure 3: Value of Internet Service

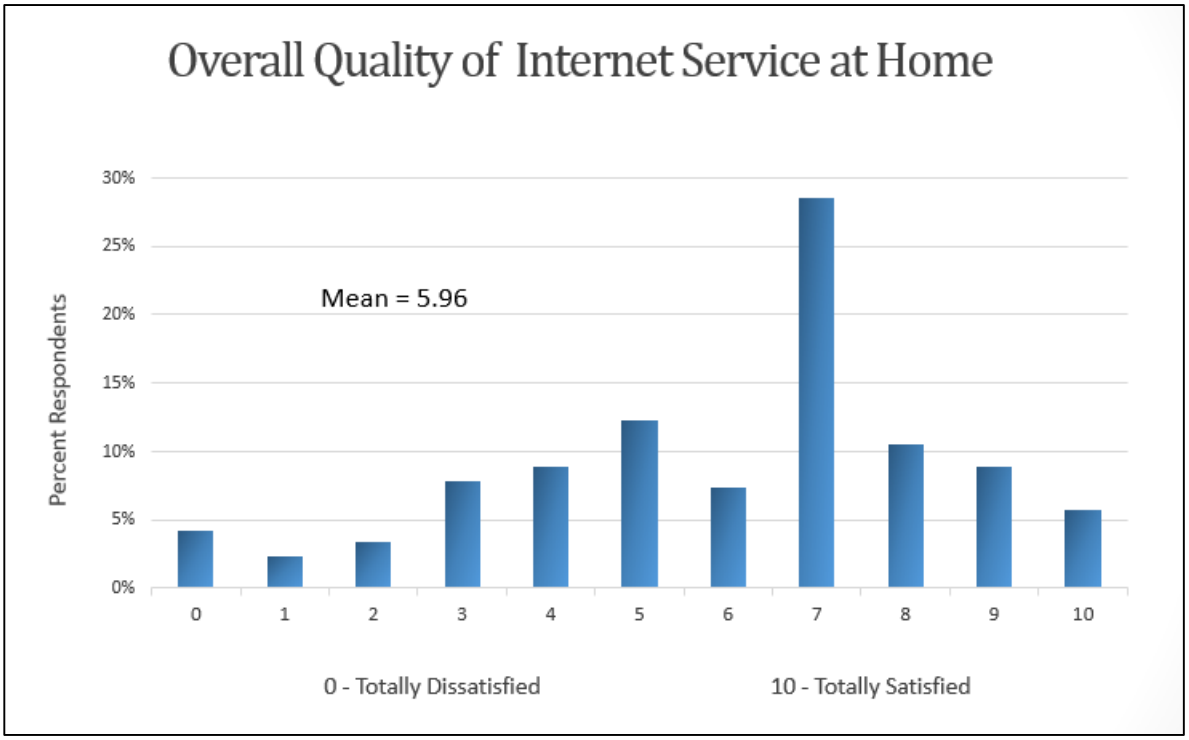


Figure 4: Overall Quality of Internet Service at Home

The quality of home internet service is an important factor for the majority of households. When asked a hypothetical question about moving and the importance of the quality of home internet service has on ultimately deciding on a particular house, apartment or condominium, 81% responded within "somewhat important" to "very important" (see Figure 5 below). This finding is aligned with the households' response to the top issues that they would recommend to the city leaders in improving overall internet services in the city: better internet service and competition. See Figure 6 below for a breakdown of all responses. The third most recommended issue to address is the city's public Wi-Fi

network. Seventy-six percent responded that they rarely or never use the city's public Wi-Fi network (see Figure 7 below).

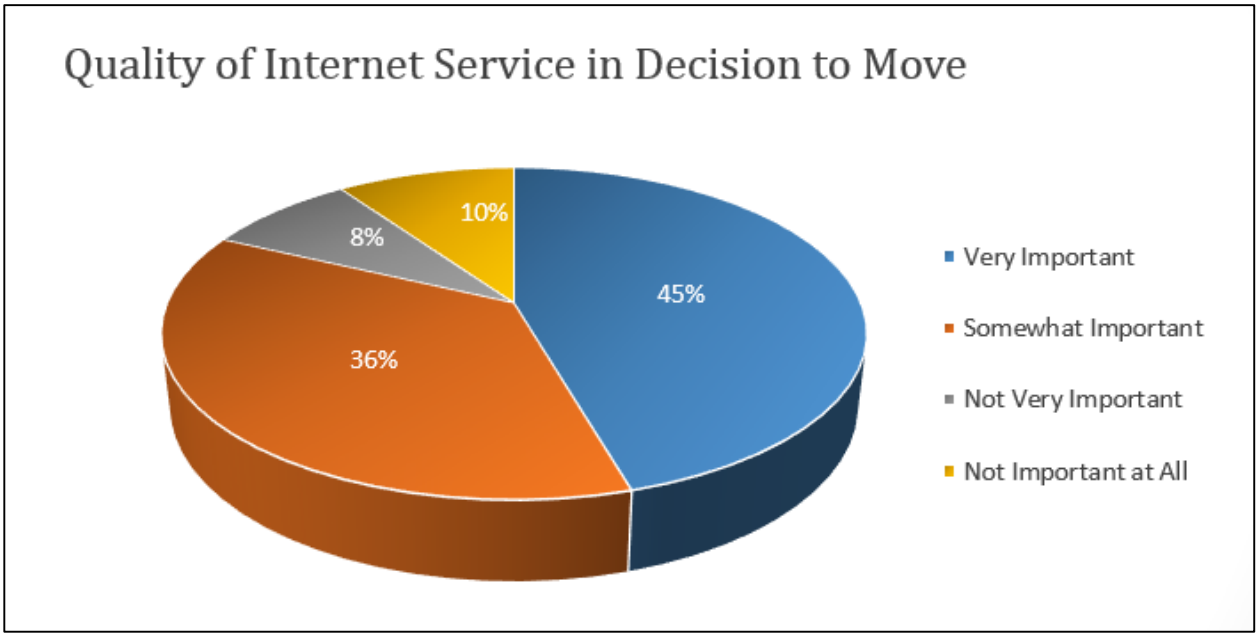


Figure 5: Importance of the quality of Internet Service in Decision to Move

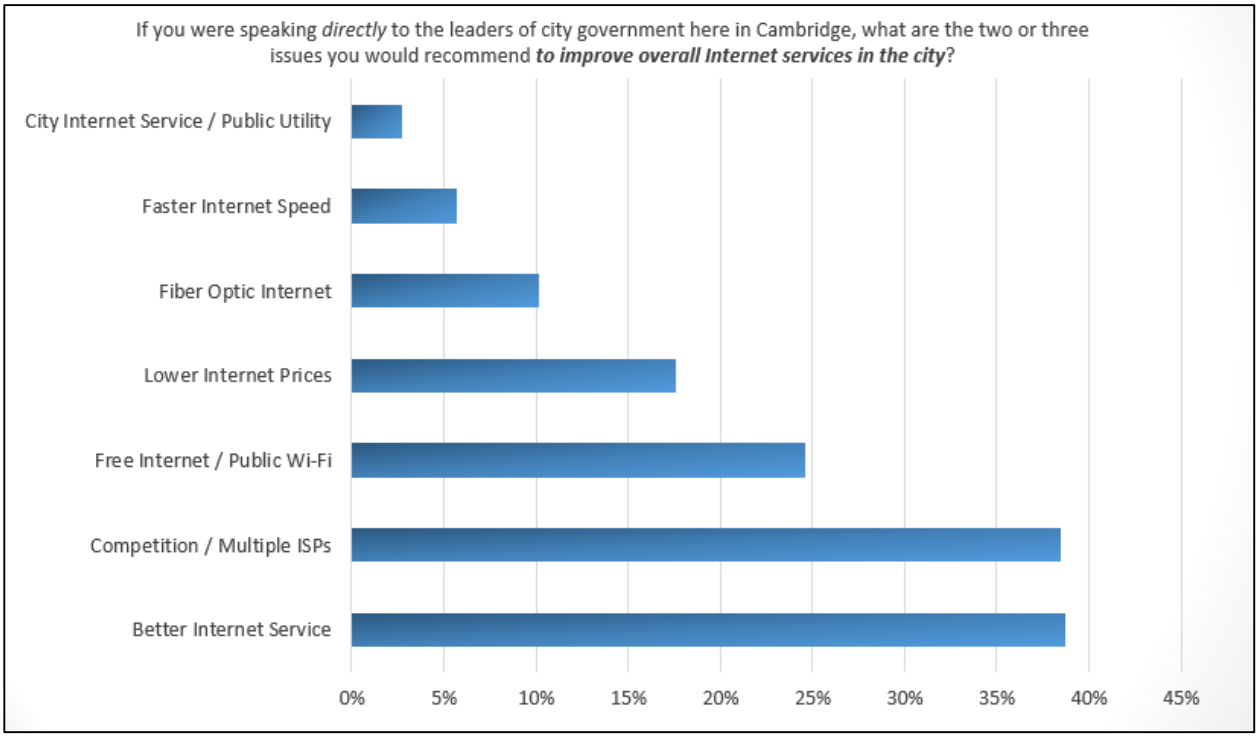


Figure 6: Recommendation to Improve Overall Internet Services in the City

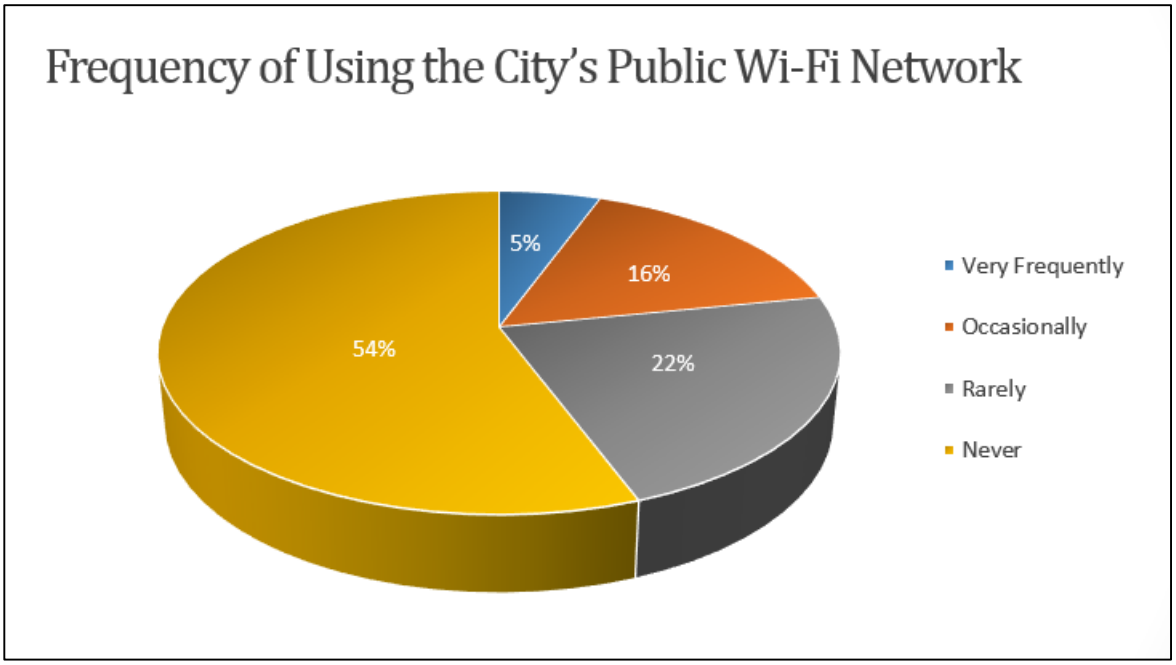


Figure 7: Frequency of Using the City's Public Wi-Fi Network

Another key finding was the household's view on the cost of internet service. Seventy-four percent responded that this is a very important matter to them, while 21% responded that it is somewhat important to them (see Figure 8 below). In fact, Figure 9 shows that the only attribute a majority of respondents did not describe as "very important" was the ISP's ability to provide all services on one bill. It seems that people view virtually all surveyed aspects as of paramount importance. But when households were asked to estimate their download speed, 75% of respondents did not know or were unsure (see Figure 10 below).

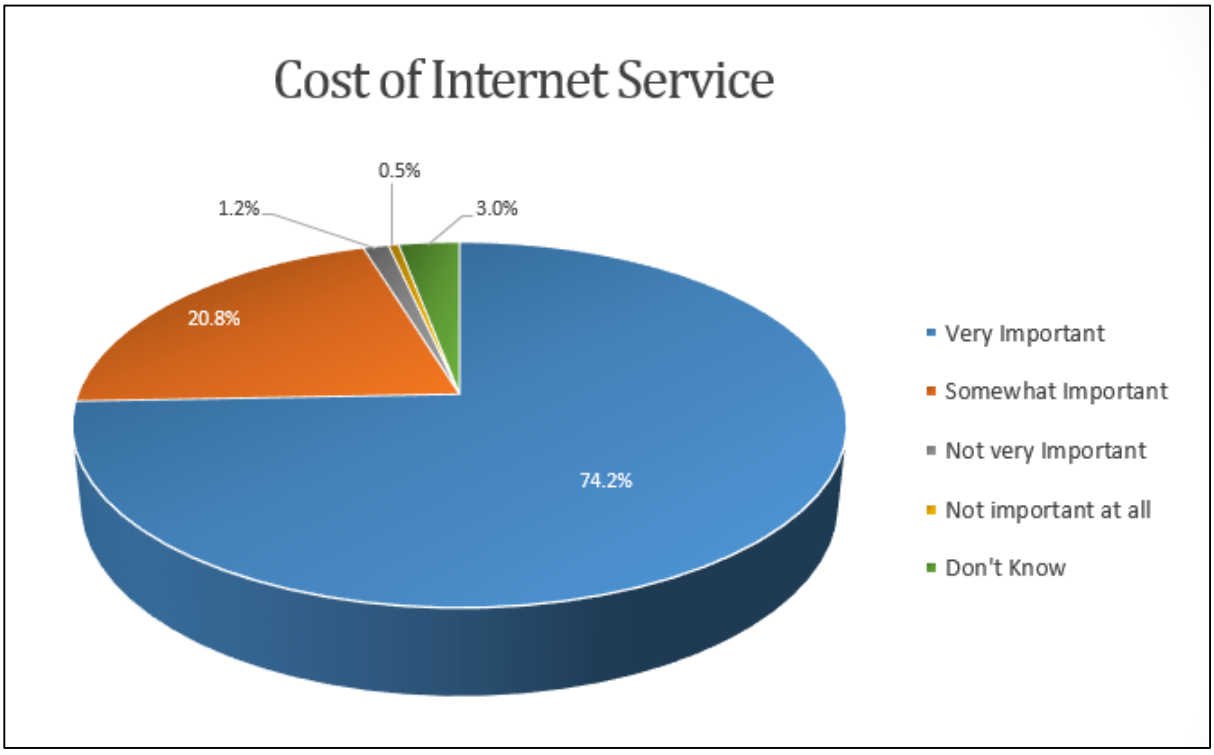


Figure 8: Cost of Internet Service

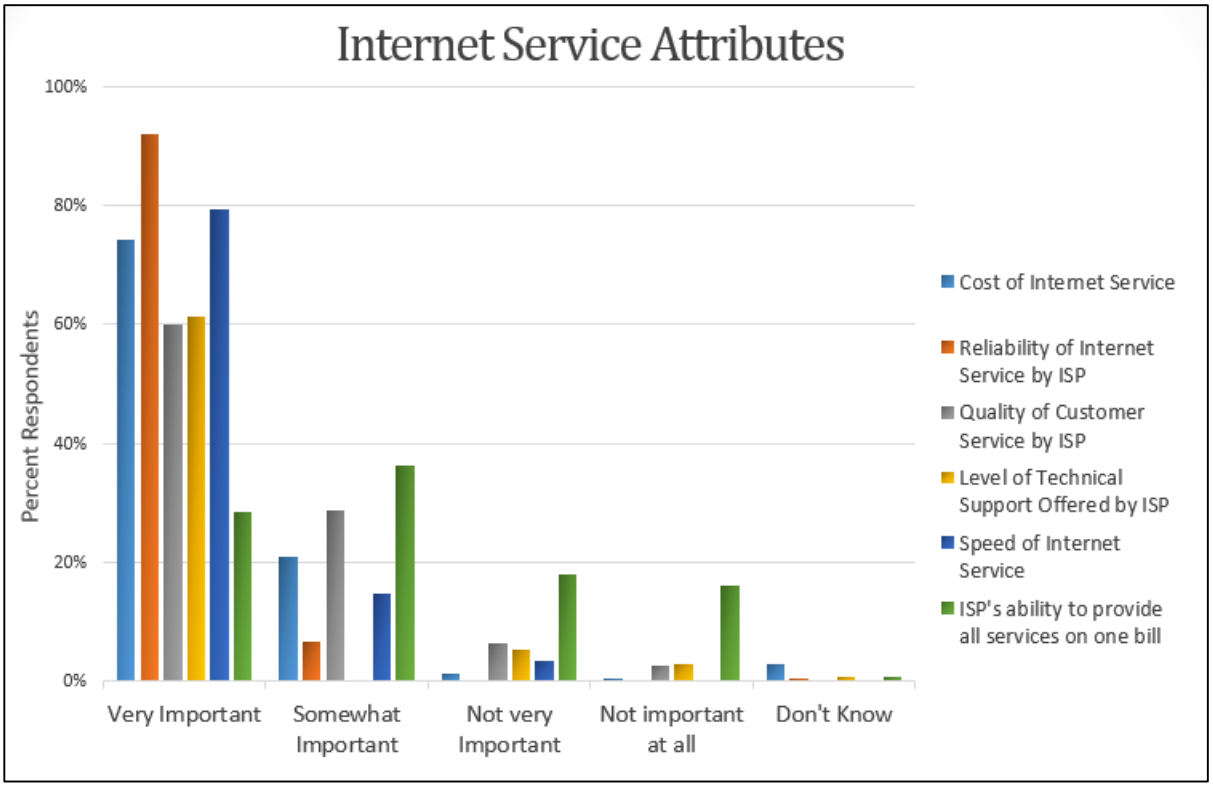


Figure 9: Importance of Internet Service Attributes

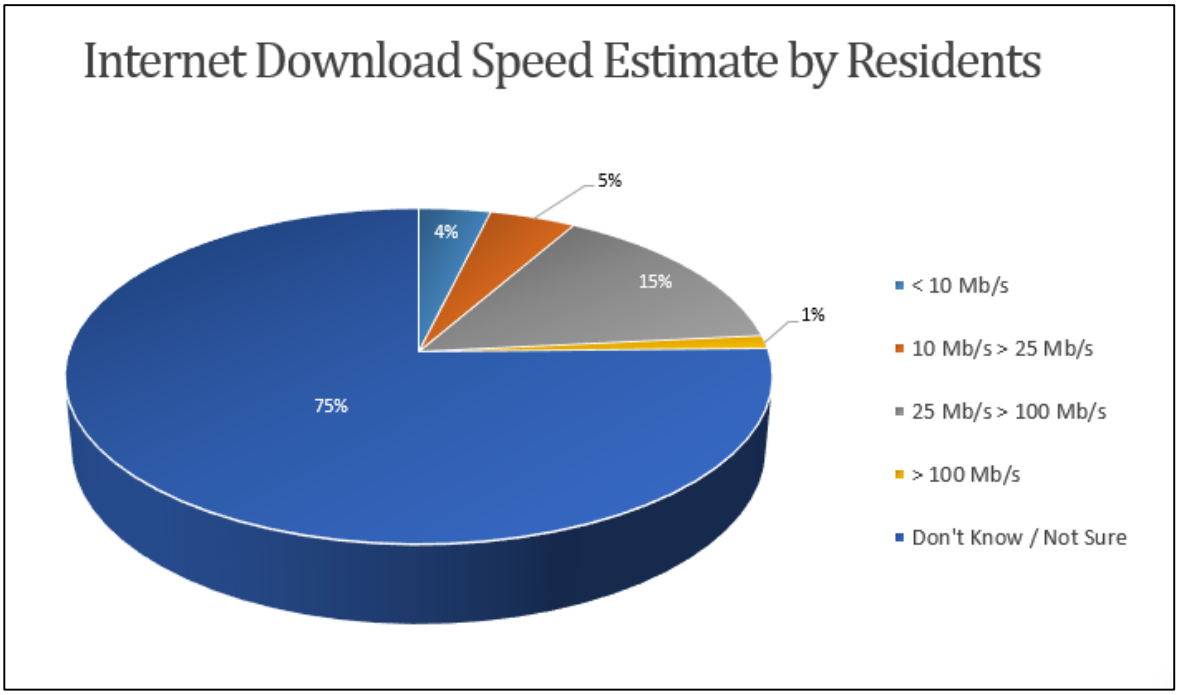


Figure 10: Internet Download Speed Estimate by Residents

Cost being one of the highest-profile concerns for the vast majority of respondents after reliability and speed, 54% of respondents described themselves as being “somewhat willing” to “very willing” to pay more for faster internet. Figure 11 shows the breakdown of self-reported price sensitivity to internet speeds.

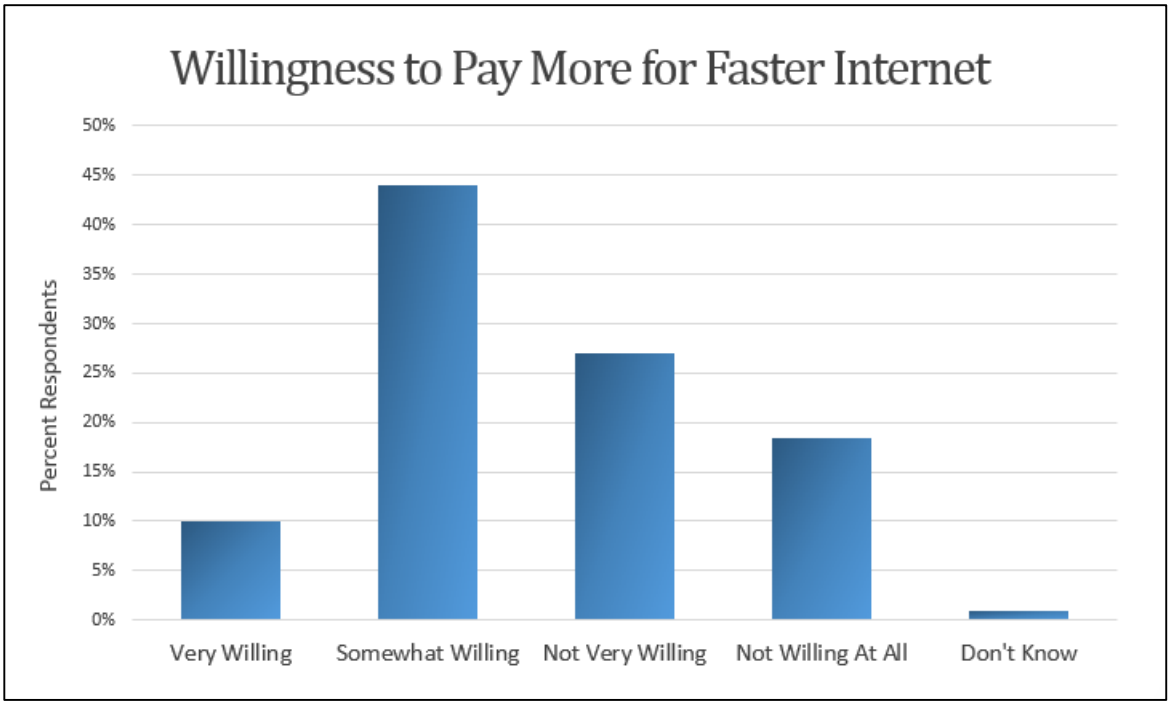


Figure 11: Willingness to Pay More for Faster Internet

The proportion of Cambridge residents who work from home is approximately double the national average. Gallup's annual Work and Education poll in 2015 showed that 37% of U.S. workers say they have telecommuted, up slightly from 30% in 2008.[6] Furthermore, telecommuters work from home two days per month, on average. 24% of the respondents in the Gallup survey telecommuted more than 10 days in a typical month (20 work days). In comparison, Tilson's survey of Cambridge households shows that 78% have telecommuted, while 22% have never telecommuted. Of the Cambridge telecommuters, 57% said they frequently worked from home.

As the frequency of working from home increases, fast and reliable broadband connections become more and more necessary. An improved broadband environment would have the most impact on the city's goal of innovation and excellence, but would also support entrepreneurs and small businesses. Having the flexibility to telecommute promotes increased productivity at the firm level, and potential increased job satisfaction among employees.

Several themes emerged from the survey that can be related to a few of the city's goals. Most notably, these themes are inhibiting the Task Force's goals from being achieved. From an affordability perspective, the cost of internet service is important – or very important – to 75% of respondents, and a majority estimate that they spend $150 or more per month on telecom services. However, a majority responded that they would be somewhat or very willing to pay more for faster internet service.

With respect to choice and competition, Comcast dominates the market. On average, people are only marginally satisfied with their current internet service but do not have much of a choice in provider. Most households also report that reliability and speed are important considerations, but most of them do not know what speed they are subscribed to. Lastly, we see the potential for innovation and excellence from households recommending that the city address better internet service, curbing the lack of competition with an increase in ISPs, and improving the city's public Wi-Fi network. The potential for innovation and excellence can also be seen by the work from home frequency of 57%, and the comparable productivity levels of working at home or in the office.

[6] http://goo.gl/NwrRyz

7. Defining the Service Gap

Given the existing broadband offerings within Cambridge, there is a large service gap to address. This section will explain those gaps as they relate to the city's goals.

Cambridge prides itself as one of the top innovation locales in the world, but the broadband offerings from the dominant provider are comparable to their general offerings nationwide. Cambridge envisions itself as leading the pack, not a member of it.

Affordability and Equity

As a key finding of the survey results, approximately 74% of residents view the cost of internet service as a very important attribute in their evaluation of internet service. An interesting discovery of the households whose total income is less than $20,000 is that 79% subscribe to plans ranging from $125 to $249.99 per month. In other words, up to 15% of their gross income is being spent on telecom services. Of the households whose total income ranges from $20,000 to less than $50,000, 45% subscribe to plans ranging from $75 to $149.99 per month, or up to 9% of their gross income. Of the households whose total income ranges from $50,000 to less than $100,000, 55% subscribe to plans ranging from $150 to $249.99 per month, or up to 6% of total income. It is important to note that these expenditures are not categorized by the type of telecom service a household is subscribed to, i.e. internet, live broadcast video services, phone, or all three. Still, one can draw two main conclusions from this. First, broadband demand is relatively inelastic: people are willing to pay for internet access at a minimum, even when it accounts for a significant proportion of household expenses. Second, lower income residents are essentially being forced to pay a significantly higher – and material – proportion of their income for telecom services. In the modern economy, broadband is a necessity much like electricity.

There are also certain neighborhoods of Cambridge that do not have the same options for broadband services that other neighborhoods have. While Comcast service is available throughout the City for residents and small businesses, Verizon FiOS is only available in certain buildings in certain neighborhoods. Where FiOS is available, it is an added option to Comcast service in that building, since Comcast's franchise agreement with the City allows it access to all residential premises. This means that some households benefit from competition and choice, while others are served by essentially a monopoly if they want true broadband speeds, which DSL generally cannot provide.

Choice and Competition

Currently, the broadest range of service offerings – for both residents and small businesses – is provided by one company, and is the only relevant offering today. Verizon's DSL product offering is available city-wide, but is outdated technology in terms of throughput and reliability. Verizon built its FiOS network in only a few neighborhoods – Cambridgeport, North Cambridge, West Cambridge, and Porter Square – that had demonstrated demand and ability to pay. Even so, not all households within these four neighborhoods have the option of subscribing to FiOS. Verizon stopped building out the FiOS network in Massachusetts in 2010, suggesting that the cost to deploy fiber infrastructure to new households outweighs the return on investment. netBlazr, an area wireless ISP, received a capital infusion through a private investor in 2015, and is attempting to increase competition on residential and small business offerings throughout Cambridge by way of their fixed wireless technology. Subscribers to netBlazr are scattered throughout the city.

Supporting Entrepreneurs and Small Businesses

In a technologically renowned city like Cambridge – home to one of the world's leading technical universities, one of the world's leading research universities, and innumerable technology companies – the Task Force no doubt expects more and better connectivity than that provided by the local cable monopoly to nurture the next Akamai or Novartis, let alone Facebook or Google.

Fifty-four percent of the 25 largest employers in Cambridge are in a technical field. With the exception of the startup companies and small businesses at the Cambridge Innovation Center (CIC), the tech startup community is currently doing more with less. The CIC has alleviated some of the existing service gap by providing speeds of roughly 100 megabits symmetric over wired and Wi-Fi connections within its building. But in order to do this, the CIC purchased enterprise-grade fiber service and operates its own network.[7]

Innovation and Excellence

Cambridge has comparable network infrastructure and services to many other parts of the United States. Comparable, however, does not satisfy the goals of innovation and excellence. Many, many cities and towns have an incumbent phone company providing DSL and a local cable monopoly providing internet service. In order to innovate, Cambridge needs to provide residents and businesses the kind of connectivity platform on which they can devise new ways of doing things and new services to offer. On the residential side, innovation can be supported by giving residents best in class connectivity – thus helping to erase geographic boundaries and providing an entire city of global citizens. Innovation and excellence in broadband infrastructure can also encourage entrepreneurship, civic engagement, and development of entirely new applications for the infrastructure. In addition, an innovative approach that encourages net neutrality – where the broadband infrastructure does not differentiate between different types of traffic – can further support development of new applications and of myriad coexisting services.

Achieving excellence in broadband is relatively straightforward, at least on the surface. The easiest metric is speed, but speed is only one component of the whole. Network reliability is also of paramount concern. Fiber provides the most reliable solution, as wireless and DSL have their own limitations. It is only when innovation and excellence are achieved that the City can close the gap on the digital divide within the community. Though any effort will improve the situation relative to the status quo, the most creative strategies towards innovation and excellence will yield significant benefits while avoiding inflated costs.

Local Control

The City of Cambridge currently has minimal control when it comes to telecommunication services. The majority of households are being served by a three main internet service providers. Only one of them provides true city-wide access. Verizon has not built out higher-speed FiOS, and DSL has significant speed and distance limitations. netBlazr's wireless service can work, but coverage is spotty and can be affected by terrain, buildings, and even weather. Lack of effective competition is the main driver behind Cambridge's average connectivity and higher prices.

[7] Source: Interview with Michael Herman, Senior Systems Engineer at the CIC

8. Fiber Designs and High-level Cost Estimates

The City of Cambridge engaged Tilson to support a Phase I broadband planning effort undertaken with the Cambridge Broadband Task Force. Part of the work of this phase is to produce a high level cost estimate and network design for a potential expansion of the existing municipal fiber network, with an eye to improving broadband service in underserved areas and population segments. Tilson has estimated the costs of three potential expansion plans, ranging from extending service to all Cambridge Housing Authority sites to a full Fiber to the Home deployment for all premises in the city.

The three designs presented in this section are not intended to be three specific recommended build options from which the City would choose. Rather, these designs are intended to illustrate types of networks that the City might consider building in order to advance the discussion. If Cambridge does choose to build a fiber network based on one of the high level designs presented in this section, Tilson would expect one of the first steps to be a process to further define objectives. The City's final solution may very well incorporate elements of all three build options.

Existing Facilities and Conditions

Prior to creating these designs, Tilson worked to examine the potential to use existing conduit, poles, and the existing city fiber network.

Conduit

An existing City ordinance requires utilities[8] that utilize the city street to install extra conduit that is reserved for the City's use. The City in fact utilizes such conduit for its existing municipal fiber network. However, a number of factors could limit the City's ability to use this infrastructure for a project to construct a fiber network intended to serve the public more broadly:

1. **Conduit availability.** While utilities are required to provide spare conduit, there is no guarantee that this requirement has been consistently followed, or that existing conduit is in good condition. Spare conduit may have been utilized and not recorded as such. Records on file with the City may be inaccurate or incomplete. While the City could seek redress, this likely would be a time-consuming process that could delay a project.
2. **Physical access.** Existing access points, such as manholes, are not necessarily spaced in a manner to facilitate the access that would be required for a project to serve a large number of premises along a fiber route. Existing City fiber using utility conduit runs between City buildings and isn't intended to be accessed along route.
3. **Change in use.** Very limited use of conduit for municipal purposes with limited need for access is well established in Cambridge. Use of these facilities by the City for serving the general public is not.

Clarifying and resolving these issues will take time and resources, both for physical inspection and for legal work to clearly establish and assert the City's rights. And depending on street-by-street conditions, it may or may not make sense to try to use existing conduit. At a minimum, it will be worth investing the resources in a physical inspection of any existing conduit that the City has the right to use along a prospective route prior to detailed design and layout of a network. For these high-level cost estimates, however, we have assumed that new conduit would be required along any underground routes.

Poles

Conditions on existing utility poles are more readily determined, and aerial construction would in fact provide the more cost-effective method of construction along most City streets. Tilson sampled and field-inspected 100 utility poles across the city. "Make-ready" is the term for the process of readying poles to receive new facilities, moving existing lines on the pole as necessary to make space, and in some cases replacing poles that are too short or would not be sound. Generally, the sampled poles indicate

[8] Here companies such as Verizon, Comcast, and Eversource are all lumped under the heading of "utility."

that poles in the City would require a medium to heavy level of make-ready work, which is not surprising for an urban environment like Cambridge, and also not a fundamental barrier to use of existing poles. We assumed for our cost estimate that the City would pay for make-ready using the same rates as a commercial competitive telecommunications provider. The sample has informed the level of make-ready costs included in our estimate.

City Fiber

The City has an existing fiber optic network across the City connecting dozens of City buildings, and it is reasonable to consider how much this existing network might be used in a project for the City to provide fiber access to residents and businesses generally. The answer, unfortunately, is that this network likely has very limited usefulness for this purpose. The reason is that the existing network is designed with very different objectives in mind. If the City were to seek to provide fiber access to its residents and businesses very broadly, this would require a fiber network with cables containing high numbers of individual strands and frequent access to the fiber cable. This would in many cases require supplementing the existing fiber even where the City has excess strands. An even bigger issue, however, would be that the existing City network has been intentionally designed (as a security measure) to provide essentially no access to the fiber cable outside of the connected buildings. Reaching a large number of premises not already connected to the City fiber would likely involve installing new fiber cable with the appropriate level of access, even routes where the City has existing fiber.

In our high-level network design, therefore, we have not assumed the use of the existing City fiber network except in the Small design, which represents a targeted build-out from existing City buildings to a very limited number of new locations.

General Design Parameters

Tilson has laid out and analyzed three separate alternative fiber designs, termed Small (Partial), Medium (Targeted), and Large (Full). The parameters for each of the designs were chosen in consultation with the Broadband Task Force and City staff. Each of the three designs illustrates one of the Capital Cost Strategies discussed earlier in the report. The estimates in this section assume that any given design is built from scratch, not based on a smaller initial buildout.

The two lit network designs presented, the Small and Large Designs, use a Gigabit Passive Optical Network (GPON) architecture, the most common fiber-to-the-premise network architecture deployed in the United States today. In a passive network, fibers are split so that multiple premises share a single beam of light. While it is possible to split fiber cables so that up to 64 premises share one beam of light, Tilson has designed a 1:32 split ratio as the best balance between cost and performance.

Tilson also used a few assumptions that were common among the treatments of all three network options. We assume that a construction contractor will add an approximately 20% premium to the network's baseline cost as its profit margin. The specific contractor's markup will vary as the bid process unfolds, but the 20% figure is indicative. Furthermore, we assume a 30% contingency as recommended by the City based on its experience with other construction projects. Finally, we have made conservative assumptions around sales tax, applying the stock Massachusetts 6.25% sales and use tax to the broad project costs. The City may very well be able to reduce the sales tax burden in an actual project.

Small Network: Fiber to Cambridge Housing Authority Locations

Key Assumptions

The Small network option is a Targeted Network build-out. This design envisions building fiber into Cambridge Housing Authority locations only, along with other premises along the fiber route. Distributing connectivity via inside wiring or via wireless within multi-tenant buildings is not within the scope of this study, but would be a very important part of delivering service to residents. Depending on the condition and availability of existing wiring, extending connectivity from the demarcation point to

residents could increase capital costs significantly. This design has the lowest capital cost of the options examined.

Network Design

As can be seen in Figure 12, the proposed small buildout connects Cambridge Housing Authority properties to the existing City of Cambridge fiber network. It also provides connectivity to the 250 premises Tilson has identified that are adjacent to the proposed fiber lines.

The Small network design totals 4.4 miles of fiber, approximately 2.7 miles of which are routed underground. The aboveground portion is carried on utility poles. This network connects to Cambridge's existing municipal fiber network.

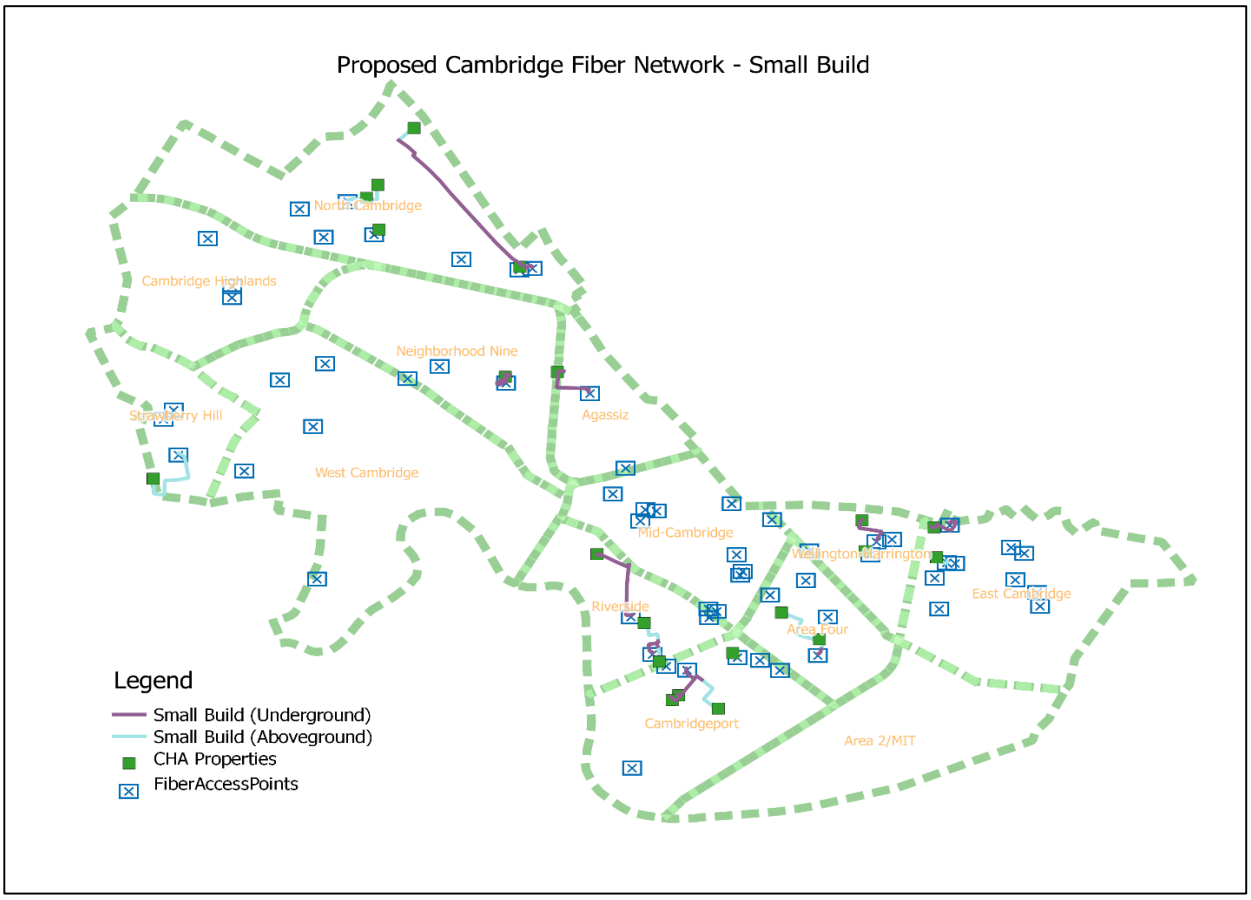


Figure 12: Small Network Buildout

Capital Cost Estimate

The total estimated capital expense for the small buildout is $5.5 million. This includes connection to CHA-owned multi-unit properties (a total of 22 buildings connected, containing a total of 2,694 housing units) and construction of the additional fiber runs necessary to connect with existing Cambridge municipal fiber. It also assumes this project would be built in a manner consistent with this being an early phase of a larger build-out to reach a broader audience. Therefore, it also assumes that the fiber is built with connections to 250 premises along the routes needed to reach the CHA locations. A breakdown of the major cost categories can be found in Table 6. Connecting the 250 non-CHA premises accounts for approximately $306,000 of the below costs, including allocations for margin, contingency, and sales tax.

Make Ready	$119,855
Outside Plant Materials & Labor	$2,576,700
Police Detail	$269,655
Network Electronics	$124,590
Engineering and Drafting	$309,080
Contractor's Margin	$618,160
Contingency	$927,240
Tax	$1,205,415
Total Project Cost	$5,474,580
Underground Cost Proportion	68%
Total Underground Distance	2.7 miles (61.6%)

Table 6: Small Build Option Capital Breakdown

Medium Network: Multi-Neighborhood Dark Fiber

Key Assumptions

The Medium design is a partial network build-out intended to provide a dark fiber pass along routes that pass through city neighborhoods. The general approach of the Medium buildout is to provide fiber to multiple key neighborhoods in the city. Private internet service providers would then be invited to connect to the fiber in each neighborhood, run service to individual premises, and provide full Fiber to the Home service.

Network Design

The dark fiber network consists of 17 miles and extends to all city neighborhoods. Aerial construction consists of approximately 14.98 miles, while 2.02 miles of fiber is placed underground. The 88% of fiber running on existing poles aboveground minimizes costs; in fact, routing along roads with poles where possible was a design criterion for this option. Figure 13 displays a map of the proposed network buildout.

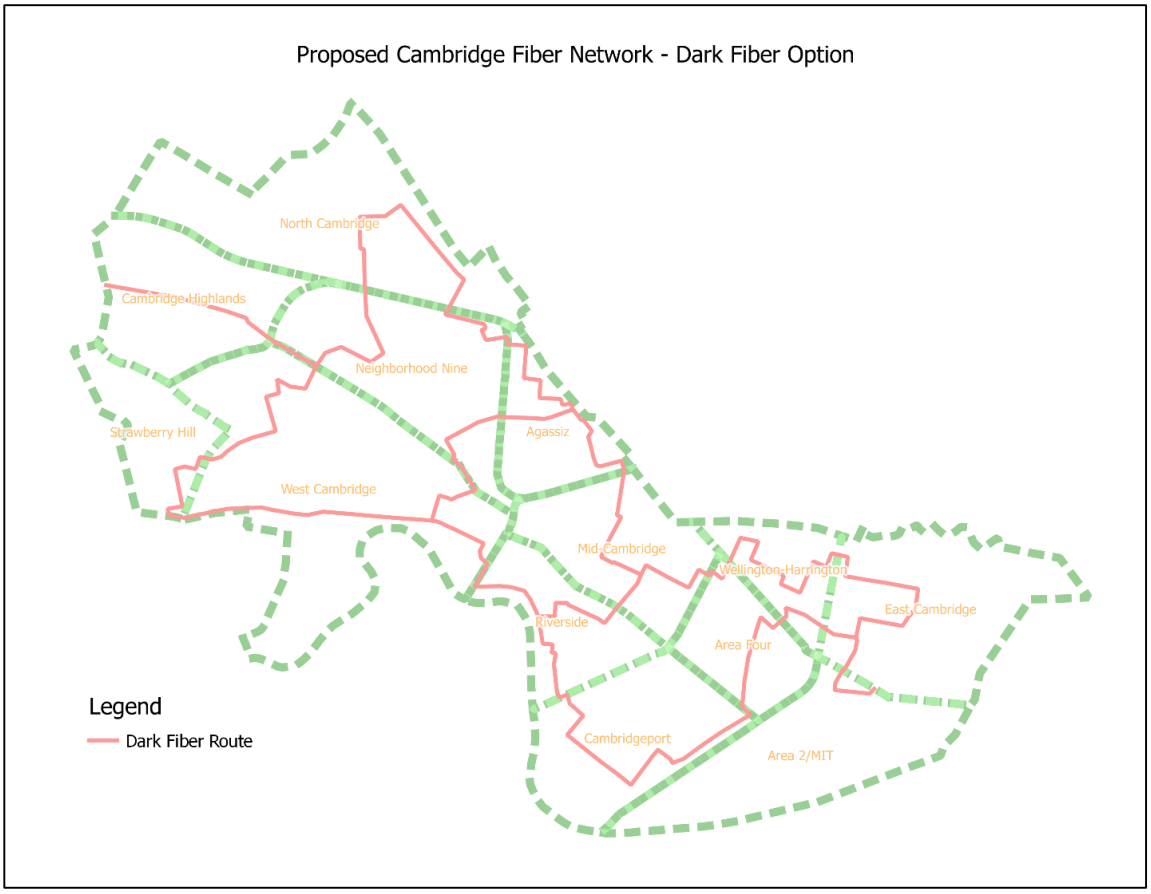


Figure 13: Dark Fiber Network Map

Capital Cost Estimate

Construction of this dark fiber only solution is estimated to cost approximately $7.0 million. In addition to the cost factors discussed in, this includes materials and construction costs at prevailing wages, as well as installation of a Point of Presence where service providers will connect with other networks. Note that this does not include any network equipment, as service providers will install and maintain the equipment they need in order to provide service. A breakdown of major categories of cost is in Table 7.

Make Ready	$491,890
Outside Plant Materials & Labor	$3,115,240
Police Detail	$335,715
Network Electronics	-
Engineering and Drafting	$394,285
Contractor's Margin	$788,570
Contingency	$1,537,710
Tax	$320,355
Total Project Cost	$6,983,765
Underground Cost Proportion	67.5%
Total Underground Distance	2.0 miles (12.0%)

Table 7: Medium Build Option Capital Breakdown

Large Network: Fiber to All Premises in Cambridge

Key Assumptions

The Large design is a Full Network build-out for fiber to the home at all premises in the city limits—approximately 148 miles of fiber. The model assumes approximately 29% of the cable will be run underground via new trenches dug to minimize impact to existing city facilities. For this design, Tilson has assumed that existing underground conduits will not be available to the project. To the extent that the project can use existing underground facilities, the project's cost will decrease.

Network Design

The network extends to all premises in the city, as shown in Figure 14 below.

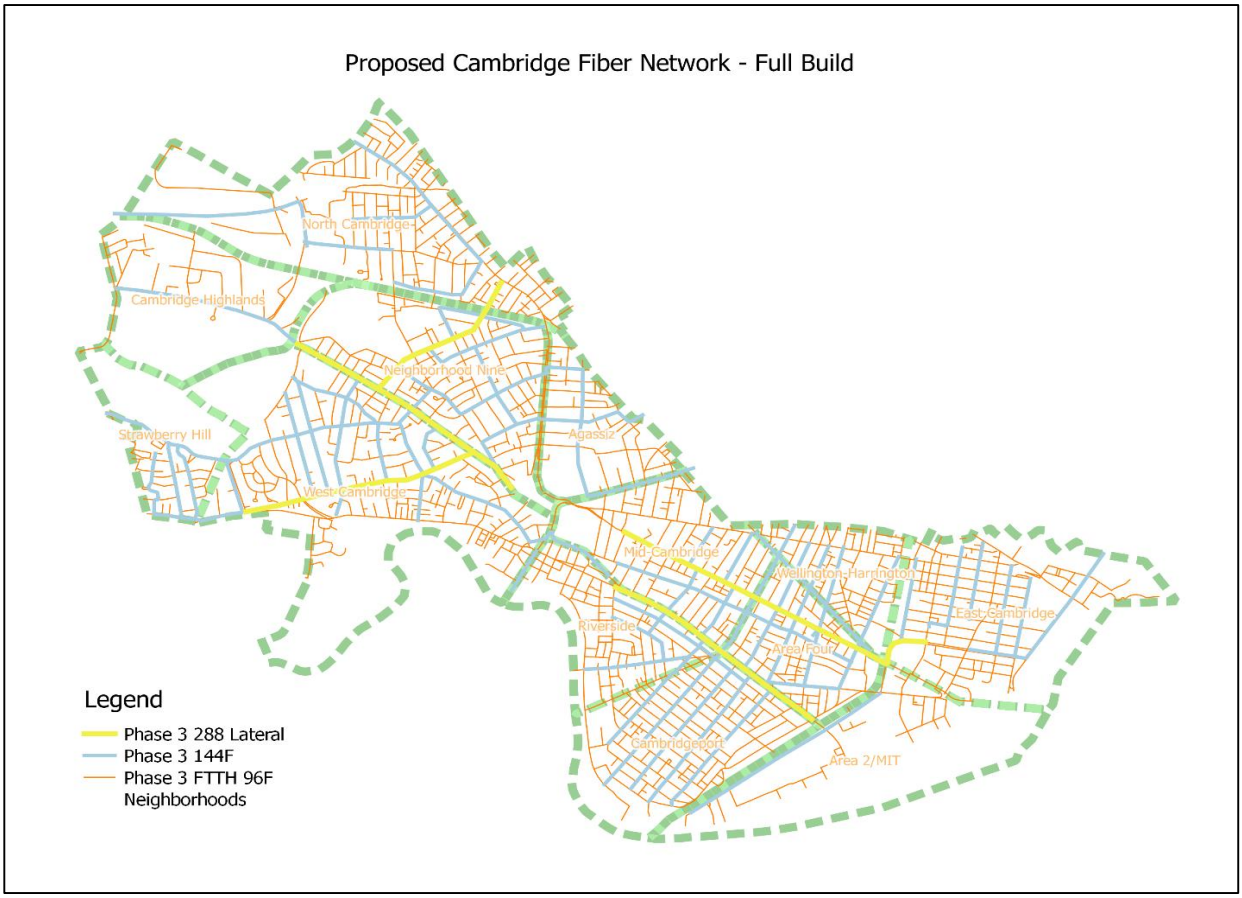


Figure 14: Large Network Buildout Map

Capital Cost Estimate

Capital costs were estimated as both lit and dark networks. That is, Tilson evaluated the network as both a dark network, with other entities providing service on it, and a lit network where network electronics necessary to provide service are included. In addition, the capital cost of a network will vary depending on the proportion of the premises passed are connected. Table 8 below shows capital cost estimates for dark and lit networks at four levels of assumed percent of passed premises connected: 25%, 50%, 75%, and 100%. As can be seen, costs associated with the underground portions of the network, including trenching and manholes, comprise a large amount of the overall cost. Since take rates only affect the relatively small number of underground fiber drops, the amount of underground work is minimally affected by take rate, increasing by only $92,000 when adjusting the take rates from 25 to 100%. Drop costs are included in the "Dark Network Build" line item in Table 8.

The critical metric in understanding the finances of any broadband network is that of *take rate,* the proportion of potential customers who actually take service on the network. The actual minimum take

rate required for a prospective Cambridge network to cover its costs, or earn a profit, would depend on many factors and assumptions that the City has not yet evaluated. It is also important to note that the take rates are shown in Table 8 to illustrate how capital costs vary with take rate. They are not intended as a prediction of what take rates would actually be. Actual take rates for a Cambridge network will depend greatly on the competitive landscape for broadband in the City, on the prices charged for service, and on the incumbent providers' competitive response to a municipal network. High take rates (i.e., 70% or greater) can reasonably be expected in a location where there is no other broadband option, but are highly unlikely in a competitive environment like Cambridge. A baseline assumption for take rates in Cambridge would be more in the 15-25% range. Further market research would be required to arrive at a more accurate figure.

% of Premises Passed Connected	25%	50%	75%	100%
Dark Network build	$60,490,219	$65,250,358	$70,010,497	$74,770,636
Network Electronics	$7,049,532	$12,528,760	$18,007,988	$23,487,216
Engineering/ Drafting	$7,358,877	$8,430,415	$9,501,953	$10,573,492
Contractor's Margin	$14,717,755	$16,860,831	$19,003,907	$21,146,983
Contingency	$28,699,621	$32,878,620	$37,057,618	$41,236,617
Sales Tax	$5,979,088	$6,849,712	$7,720,337	$8,590,962
Police Detail	$6,049,022	$6,525,036	$7,001,050	$7,477,064
Total Cost	**$130,344,114**	**$149,323,732**	**$168,303,350**	**$187,282,969**
Total Underground Cost	*$44,109,479*	*$44,140,279*	*$44,171,079*	*$44,201,679*
Underground Cost Proportion	*77.4%*	*71.5%*	*66.4%*	*62.1%*

Table 8: Full Build-Out Capital Costs

Table 9**Error! Reference source not found.** shows capital costs per connected premise at the same take rates. Higher take rates yield significant economies of scale.

% of Premises Passed Connected	25%	50%	75%	100%
Dark Network Subtotal	$4,155	$2,241	$1,603	$1,284
Network Electronics	$484	$430	$412	$403
Engineering/ Drafting	$505	$290	$218	$182
Contractor's Margin	$1,011	$579	$435	$363
Contingency	$1,971	$1,129	$849	$708
Sales Tax	$411	$235	$177	$148
Police Detail	$416	$224	$160	$128
Total Cost	**$8,953**	**$5,129**	**$3,854**	**$3,216**

Table 9: Full Build-Out Capital Costs per Premise Connected

9. Business Models

This section provides a discussion of various business model aspects to consider in developing a citywide broadband network. The three main points of consideration are:

- **Capital Cost Strategies.** How will the developer select the breadth of network to be built? Will the network service all premises in the city, or will it only serve a subset of premises? If the latter, will the network be scalable to add more connectivity in the future?
- **Funding and Financing Models.** As with any large, capital-intensive project, it is important to determine how the project will be funded.
- **Operating Models.** There are several possibilities, depending on who owns the network and who provides service on it.

Capital Cost Strategies

This section provides an overview of strategies for matching the magnitude of capital costs desired with the best fit type of network for a given cost magnitude. In deciding between a "full" network build, "partial" build, or "targeted" build, the overarching question facing the City is how much capital cost it wishes to commit to. This study should be conducted early on in the planning process amongst the community resources and stakeholders in order to make the project economically viable.

Full Network Builds

In a full network build-out, the City would take on the full capital costs of building out a network on a broad (or universal) scale throughout the city. These costs include the *pass,* the *drop,* and the electronics. Briefly, the pass is the fiber optic cable that runs by the premises to be connected, usually along a road on a pole, or buried underground, and connects to a central aggregation point through which services can be provided. The drop is the fiber that is spliced into the pass and connected to the individual premises. Electronics that enable the passing of data on the network are installed at individual customer premises and at the central aggregation point, or node.

Opportunities

For a city looking to address broadband needs of its residents, businesses, and institutions, this level of commitment allows the City to ensure that a complete and fully integrated network is deployed. Uncertainty about the type of services that will be available, and where they will be available, is reduced. This type of network also has the greatest opportunities for producing revenues from users.

Operating Implications

This option produces a network with the greatest level of operating responsibility. It requires maintenance and management not only of the physical infrastructure, but also of the data network that rides on it. It is the largest scale and most complex operation to manage, relatively speaking.

Risks

The level of risk is highly correlated with the required level of capital and operating expenses. This option amongst the three has the greatest level of complexity, and has the potential to produce high levels of execution risk at the construction and operating stages. Thus, it has the greatest capital and operating cost requirements.

Partial Network Builds

The city may elect to develop only part of the network infrastructure to deliver improved broadband, and offer access to it on favorable terms. The objective is to make it easier for more or alternative broadband service providers to enter the market than if they had to construct an entire network themselves.

"Partial" as used here refers not to building only to a small subset of users (see "Targeted" Network Builds, below), but constructing a network consisting of some network elements, and not others. For example, a dark fiber network consisting only of the fiber pass (either along all city routes, or only key routes) would be an example of a partial network. Such a network would rely on service providers to invest capital in constructing drops (and perhaps lateral routes off of the key routes), as well as network electronics in order to provide a complete "lit" broadband service. A partial network can include a greater or lesser number of elements. For example, a dark fiber network that delivers a fiber drop to every premise would still be a partial network (but a more expensive one). A partial network might also involve no fiber at all, but only some of the supporting infrastructure for deploying fiber, such as underground conduit.

Opportunities

Partial networks can be constructed at a fraction of the cost of a full network build-out, and therefore may present a lower fiscal hurdle for the city to clear. They also lend themselves more readily to building relationships with multiple service providers. Because a partial network by itself does not deliver broadband services to retail customers, it is less likely to be in direct competition with broadband service providers. However, this does not mean that no incumbent providers will see such a network deployment as a competitive threat.

Operating Implications

The very nature of building only parts of a solution requires that the city develop relationships with one or more broadband service providers who are willing to use the city's infrastructure and invest their own additional capital. Turning these relationships into improved services is key to realizing benefits from this type of build-out. Partial networks are also operationally less complex to manage. They involve far fewer direct customer relationships for the city to manage, and the city would not be required to manage the network electronics that light the network.

Risks

Partial network build-outs run a greater risk that geographic coverage and broadband service objectives will not be fully realized, and the more partial the network, the greater the risk. Simply put, the City cedes a degree of direct control over how (or whether) the direct network elements it does not control will be developed and operated, and the services that will be offered. This risk can be mitigated by negotiating for requirements or offering more favorable terms for those companies that use the City's network elements to deliver the types of additional investments and services that the city is seeking.

Targeted Network Build

A targeted build out delivers service to a small geographic area or a certain class of users. Examples of user classes could include low income users or neighborhoods, small businesses, families with school-age children, households with a resident over the age of 55, or any other group identified as in need of network access.

To a large extent, the City of Cambridge already has a targeted network, as it has over time developed its own fiber facilities connecting city buildings. The Information Technology Department has connected over 1,000 users across 40 municipal buildings. Extensions of this targeted network would be additional targeted network builds.

Opportunities

Targeted build-outs provide a lower capital and operating cost than larger network builds. In some cases, they have a built-in business case, as existing spending on telecommunications networks can be re-directed to support the cost of building out a network that the city owns. Some cities have used targeted network builds as an early-stage way of developing a core network and developing operational expertise on small scale before later expanding to serve a broader base of users.

Operating Implications

Targeted network build-outs are more likely to be successfully managed internally by a small IT or network services department. Their smaller number of users makes them less complex to manage.

Risks

One of the biggest risks of this type of approach is that the demand from the targeted users becomes "siloed" and does not contribute to the overall business case of a wider network. This is not inevitable, but can happen unless explicitly guarded against. In particular, new fiber network facilities built to serve targeted users must be engineered and built in a manner that allows additional users along or off the route served to be added with a modest incremental investment. This will raise the cost of a project compared to one that only serves the targeted users, but will be lower than the cost of constructing additional fiber routes on top of the initial investment.

Operating Responsibilities and Capital Strategy Models

Full, partial, and targeted build implications are summarized in Table 10 below.

	Targeted Network	Partial Network	Full Network
Physical maintenance	Smaller network, less to maintain, still may require rapid-response capability	May be larger, but "dark" network; still requires rapid-response capability	Greatest level of maintenance; both glass and electronics
Marketing and customer acquisition	Limited user base; customers may even be captive	Small number of wholesale, institutional, and enterprise users	Requires reaching out to a large volume of potential customers.
Billing	Small number of users to bill; billing may be aggregated	Small number of users, relatively simple billing	Large volume of bills; many have many types of services
Customer service and technical support	Smaller number of users; easier access to internal helpdesk	"Dark" network, less to trouble-shoot; must be able to handle interconnection requests	Large number of customers to support; many may not be technically sophisticated
Network management and monitoring	Smaller number of users; closer to internal network management	"Dark" network requires little active management	Requires active, continual monitoring capability

Table 10: Operating Responsibilities of Capital Strategies

Operating Models and Responsibilities

Following is an overview of operating models. In this section we will examine these options and their compatibility with the Task Force's goals. Each approach comes with its own operating costs, varying risks, and level of control. The three models discussed are:

- Municipally owned and operated networks.
- Municipally owned network operated by a private partner or contractor
- A municipality agreeing to "anchor" a privately-owned and operated network.

These three categories are provided as guideposts, but the boundaries between them are not sharp and absolute. For example, a municipality "operating its network" can itself include a range of possibilities. It can mean setting up internal operations (e.g. hiring City employees, buying bucket trucks, operating customer service centers, etc.), or some or most operational functions can be provided by a contractor or contractors. Use of contracted services doesn't necessarily mean that the City doesn't operate its network in some sense. However, arrangements to use a primary contractor to provide a turnkey operational solution have many similarities to a public-private partnership where an Internet Service Provider operates and delivers its service over a City-owned network.

In thinking about the operating structures involving private partners, it is vital to bear in mind that the parameters of these agreements are open to substantial negotiation. There are myriad ways to structure these agreements. These can address, for example, responsibility for paying operating costs, revenue sharing, payment arrangements, service levels, speeds, network build-out, prices, or other factors that help the City address its goals. For example, the City could make bulk purchases provide free or discounted service to low-income residents. It could also require the operator to offer low-income residents certain tiers and pricing of services, or to build a minimum standard of connectivity available to all premises in defined areas of the City. Another important consideration is payment structures. Cambridge could also agree with an owner or operator on how each entity gets paid, for example a set fee, minimum or maximum amount, percent of revenue, or no revenue sharing but using the City's negotiating leverage to achieve the best deal for residents.

Table 11 provides the parameters of each operating model. Each of these operating models implies differing levels of municipal responsibility and ownership. In addition, the City's level of operational responsibility is a function of both the capital cost strategy and the operating model. For example, the City will have a considerably less complex set of duties to perform with a "Partial," dark fiber network, even one that it owns and operates itself, than it would operating a full FTTP network. That said, there isn't any fundamental reason that any of these operating models could not be combined with any of the capital cost strategies outlined in the previous sections. Cambridge's leaders, in consideration of residents' needs and desires, can determine each model's suitability for the city's needs and comfort with risk and ownership profiles.

Model	Ownership	Who operates facilities	Who takes operating risk	Who gets revenue
City Operator	City	City	City	City
Private Operator on City Network	City and (and possibly Private Partner)	Private Partner	Private Partner (and possibly City)	Private Partner (and possibly City)
Private Owner/Operator; City is Anchor	Private Partner	Private Partner	Private Partner (and possibly City)	Private Partner (and possibly City)

Table 11: Parameters of Operating Models

Municipally Owned and Operated Utilities

Under this operating model, the City owns and operates the network itself. The City would have total responsibility for all aspects of the network and its operation. Cambridge would need to ensure that it has staff (or to a degree, contractors), facilities, and processes in place to operate an internet service provider business capable of supporting a significant fraction of the City's population.

Operating Costs

The municipality assumes the fixed costs of operating the network. This model involves the highest level of operating costs and responsibility, where physical maintenance and operation of the fiber, as well as customer-facing operations are present. However, user subscription fees can decrease, or even offset these costs.

Risks

With a municipally owned and operated network Cambridge would also be exposed to the entirety of the project's operating and financial risk, and would need to ensure it has a thorough understanding of the business model on which it is embarking. This includes, but is not limited to, revenue projections, capital and operating expenses, financing, and likely increased competitive pressures. The greatest risk a municipality faces stems from the fact that cities are often not in the broadband business. Depending on how the project is financed, the city runs a very real risk of not being able to pay its costs from user fees if an insufficient number of customers sign up for service. Also, most cities are inexperienced in being internet service providers to the general public and may have significant problems suddenly becoming competitors in the marketplace. Lastly, incumbent providers are aggressively raising the stakes: in 2015 every major incumbent – covering over 80% of the U.S. population – announced plans to deliver mass-market gigabit service within the next few years.

Control

The municipality can be in complete control of the network under this operating model.

Municipally Owned, Privately Operated Network.

In this scenario, the City partners with an existing service provider, who then becomes the primary provider of network services (or in the case of a dark fiber network, the manager of the fiber assets). This provider could provide both retail and wholesale services or just retail or wholesale services. If a provider only provides one type of service, another ISP on the network could support other types of customers. In some but not all cases the operating partner also has some responsibility for capital investment or development. For example, the partner may have responsibility for supplying the network electronics on a lit network, or building extensions of the network, over and above what the City is prepared to do.

Operating Costs

Partnering with a private firm as the network operator typically involves shifting all or some of the operating costs on to the private partner (along with some corresponding amount of the revenue derived from the operations). The amount of cost sharing would be determined in negotiations.

Risks

Once the contract is in place between the municipality and the network operator, the private entity accepts most of the risk in running the business in exchange for increased control. A municipality can mitigate their risk of a partner's non-performance by structuring the contract so that frequent renegotiations take place. It can also make payment under the contract partly contingent on the network operator's successes or failures of particular as measured by established metrics. Although working with a private operator can shield the City from a degree of risk that operating costs will be greater than expected or revenues lower, it does not take these risks completely out of the equation.

Control

Risk and control are highly correlated in this type of partnership. A municipality who relinquishes control and transfers risk generally stands to benefit from the network operator's business acumen. Network provisioning, maintenance, customer support, and billing are key activities that a municipality does not have the experience or reputation on, whereby relinquishing control to the private entity allows for the opportunity to earn and sustain revenues.

Privately Owned and Operated Network with City as Anchor User

In this scenario, the City partners with an existing service provider, who then builds, extends, or delivers service over a network that it owns and operates itself. In exchange for the operator agreeing under contract to build facilities and/or deliver services to meet City goals, the City agrees to guarantee a certain amount of revenue to the private operator over the life of the agreement. There may be variations on the privately-owned dimension as well. For example, the private party may agree to provide some or all of the network constructed to the City at the end of the contract, or it may provide long-term exclusive rights to the City to use part of the network capacity.

Operating Costs

Under this model, the City is generally not directly exposed to the operating costs of the network. Generally, its ongoing financial obligation is converted into a fixed (or at least maximum) obligation to make payments to the network owner/operator.

Risks

This type of agreement tends to be designed to greatly reduce uncertainty to the City about what its This type of agreement tends to be designed to greatly reduce uncertainty to the City about what its future costs will be. The degree of uncertainly can be fodder for negotiation, ranging from a fixed cost to some amount of risk and reward sharing in the financial performance of the private partner. Like other partnering agreements, this type of model does contain risk that the partner will not perform as expected, and a well-written contract is important. Partner agreements where the private partner owns the infrastructure tend to be long-term agreements, and provide fewer opportunities for re-negotiation due to the partner's ownership of the asset. In the short run, there may be little practical difference in the outcomes from a well-written partnership agreement, regardless of who owns the underlying network. In the long-run, however, there is a greater risk that the interests of the parties may drift apart, if for no other reason than because it is harder to foresee what or how those interests might change over longer periods. Table 12 below highlights the risks associated with each operating model.

Control

As in the prior model, in this model the City relinquishes control and transfers risk to the partner, but to an even greater extent. While directing (or if necessary, changing) a network operator under contract for a City-owned network is not always necessarily easy or painless, operating contracts typically provide

more opportunities to make adjustments in expectations over time than agreements where the partner owns the underlying network.

Municipally Owned and Operated	Private Operator on a Municipal Network	Privately Owned and Operated Network; City is Anchor User
• Municipality's capacity to execute on a commercial venture • Financial risk from competition and execution	• Performance by the selected partner • Financial risk from private partner's lack of success (depending on agreement terms)	• Performance of selected partner • Financial risk from lack of success of the private partner (depending on terms of agreement) • Long-term alignment of interests

Table 12: Operating Model Risks

Open vs. Closed Access Models

Operation of a network involves not only who owns and operates is, but how the network is operated and which service providers are allowed to use it. There are two main models for allowing service providers to access the network: open access and closed access.

Open Access Model

In an open access model, the network owner provides nondiscriminatory, transparent pricing for service providers to access the network, with an ultimate goal of market competition. In a pure open access model, the network owner does not compete with retail providers on the network for end user customers. However, some open access models can involve a network operator that offers both retail service and wholesale access to the network.

Open access networks fall into two major categories: dark networks and lit networks. Dark Fiber Open Access Networks sell or lease dark fiber capacity to service providers. In this model, service providers must provide the electronics to light the network and transmit data across the fiber. In Lit Fiber Open Access Networks, a network operator provides electronics to enable connectivity, and allows service providers to provide services using its electronics.

Closed Access Model

In a closed access model, the network owner chooses which service provider or providers to allow on the network. Often, the owner will choose an exclusive provider for the network, who may then market services under its own name. Closed access networks provide the greatest control for the network owner. Through offering exclusivity for a given customer class (e.g., businesses or residential customers), closed access network owners can often obtain higher service commitments or price breaks.

Conversely, a closed model provides less potential for different businesses to expand the number of market niches served by the network. For example, a company that orients itself to providing local residential broadband may or may not be the best company to sell services to large cellular companies or enterprise customers requiring specialized services and customer care. A company that tries to be all things to all users may not succeed in doing so, even with a network that is technologically advanced.

Operating Models and the Task Force's Goals

Not all of the Task Force Goals are equally impacted by the choice of operating model. The goal most impacted is that of Local Control. By definition, entering into an agreement with a partner to own and/or operate part of a network involves surrendering a measure of direct control (although the particulars of the agreement will determine the extent to which that control is ceded). Table 13 below categorizes the level of local control and risk for each of the operating models.

	Municipally Owned and Operated	Publicly Owned Network Operated by Private Partner	Privately Owned and Operated Network; City is Anchor User
Local Control	Greatest Control	Less Control	Least Control
Operating & Execution Risk Undertaken by the City	Greatest Risk	Less Risk	Least Risk

Table 13: Local Control and Risk in Operating Models

Table 14, below, summarizes how each operating model addresses the Task Force's goals beyond local control.

	Municipally Owned and Operated	Publicly Owned Network Operated by Private Partner	Privately Owned and Operated Network; City is Anchor User
Affordability & Equity	Direct City control over services and prices, and build-out	Contract terms on services and prices, City direction or control of build-out	Contract terms on services prices, and build-out
Supporting Small Business	Direct City control over services and prices, and build-out	Contract terms on services and prices, City direction or control of build-out	Contract terms on services prices, and build-out
Innovation & Excellence	Direct City control over level of service offered and integration of broadband into public service delivery	• Private innovation in the use of the network and services delivered. • Contract terms on the level of service offered • Reservation of capacity for integration of broadband into public service delivery	
Choice & Competition	• Any operating model should provide at least one more competitive choice. • Even more choice depends more on whether network is operated on a closed or open basis.		

Table 14: How Operating Models Address Other Task Force Goals

Funding and Financing Models

There are several options for funding and financing the business model of a municipal broadband network. Common funding sources include:

- **User Fees**. Revenue is generated by charging the user for service, typically on a voluntary subscription basis.
- **Re-purposed Municipal Telecom Expenditures**. The municipality redirects funds that would have been incurred for leased circuits to municipal facilities and instead spends them on the amortized cost of the municipality building its own network. This funding model is generally most useful in the early stages of developing a network, but would be insufficient for the full expenditure.
- **Special or Enterprise Funds**. The excess funds from some source other than general tax revenue, such as revenue generated by an existing electric utility, or franchise fees.
- **Grants**. Municipalities in some cases are able to fund a portion of network development through state or federal grant funding. However, grant funding specifically for general broadband

infrastructure development is often not available for areas that do not have large gaps in broadband service availability compared to state or national norms. In some cases, municipalities are able to use grant funds available for a specific purpose to develop communications infrastructure with a dual use at a lower incremental cost than if a general use-network were used.

- **Taxes.** Municipalities may use general tax revenue from residents and businesses to help build and/or operate a municipal network. This can be a controversial revenue source, especially in some jurisdictions that have existing networks and competitors offering broadband service.
  There are a number of municipal networks whose construction was funded by revenue-backed bonds. Networks built by revenue bonds are susceptible to financial pressure if these municipalities fail to gain enough subscribers. Failure to make debt payments resulting from undersubscription is a leading cause of failure among municipally owned networks.
  Anchor Contract. In this model, the municipality selects a partner to provide a turnkey solution. The municipality's only responsibility is to write a check for a contractually defined period of time. The partner develops, constructs, and owns the network. The partner may also operate the network or, more likely, subcontract out the operations and provision of lit services. In return for its payments, the municipality receives a defined broadband service which in Cambridge's case could include CHA properties. The partner would earn extra revenue from the lease of dark strands on the network. Municipalities operating under this model are exposed to very little operation or execution risk (aside from counterparty risk) but also surrender the bulk of their control to the partner except as allowed for in the negotiated contract.

Since broadband networks are capital-intensive, it is common to pay for their costs over time. Again, there are a variety of options. Common strategies include:

- **General Obligation Borrowing**. The municipality borrows against general tax revenue.
- **Revenue Borrowing**. The municipality borrows against future revenues of the network, such as those generated by user fees. Although this has the advantage of not impacting tax revenues directly, it is important to think through the degree to which revenues are assured. If revenues from voluntary sources such as user fees do not materialize at forecasted levels, there can be a mismatch between funding and financing models
- **Pay As You Go.** The municipality makes incremental payments out of current revenues or cost savings realized by offsetting existing telecom spending. This approach is best suited for a targeted or incremental approach to building out a network.

Partnering with one or more private parties can be part of the capital cost strategy, as described in the prior section, and part of the operating model, as described in the next section. It can also be part of the financing strategy.

For example, infrastructure funds, like Macquarie Capital, invest in networks and can act as both developer and financier. Macquarie developed a 3,200-mile fiber network in Kentucky to connect schools and government buildings, and raised municipal bonds to finance the network. In return, the state makes availability payments to Macquarie over a 30-year period. The network is operated by Fujitsu. Typically, funds like this seek underserved areas and larger projects of at least $50 million.

10. Operating Expenses

This section provides an overview of operating expenses, including typical categories and likely magnitudes. The broad categories of operating expenses in a fiber network, which are not present in all capital strategy options, are separated into dark network and lit network costs. The types and magnitudes of costs a given network incurs depends largely on the network's size and the operating activities it takes on itself versus outsourcing. Some cost categories will be present on any type of network, and some are specific to certain business models.

The costs presented in this section are indicative only, and are presented in ranges to highlight their variability at this early stage of planning. They assume a blend of residential, small business, and institutional customers. Whether Cambridge actually needs to incur any of these costs depends on what kind of operating model it chooses. Tilson's base assumption is a municipally owned and operated network, where the City would substantially rely on a private contractor or contractors to provide the actual operating services. Of course, the City could also choose to operate a City-owned network in whole or in part. In that case, the contacted-service model can serve as a reasonable proxy for the costs the City would incur if it were to operate the network itself at this stage. Tilson's recommendations on operating and capital models are at the end of this document.

It is worth highlighting that, should the City choose a public-private partnership model instead of a City owned and operated model, it is possible that the private operating partner would take on the bulk, or possibly even all, of the operating costs. The particulars are subject to negotiation with the operating partner. The essence of those negotiations would be how to share between the City and the partner the costs, risks, and revenues associated with the network.

The network operator, or the City if it were to operate the network, would need to ensure it had access to the required skills and personnel. Some examples include: network operations, fiber maintenance and repair, outside plant maintenance, customer service, technical support, billing, collections, and marketing. Given that the City does not already operate a comparable poles-and-wires utility operation (such as an electric utility), Tilson would advise that the City strongly consider a contracted network operator over a municipally operated model, and consider the latter as a fallback option if it cannot achieve a satisfactory agreement.

Dark Network Operating Costs

Compared to a lit network, operating costs associated with a dark network are relatively simple and revolve around administering a fixed infrastructure asset. Dark fiber operating costs generally consist of:

- **Management and overhead** costs are relatively small for a dark fiber network. These include billing and collection, inventory and fiber request management, insurance, and legal fees. For a dark fiber network of the general scale envisioned for Cambridge, Tilson would expect management and overhead to require at most one full time equivalent employee (FTE). This would probably be spread among multiple people working part-time, as different skill sets would be required that are unlikely to be found in one person. Billing and collection activities are limited to those relatively few customers who buy space on the network. For the same reason, inventory and fiber request management – keeping track of who leases which fibers and of new requests to lease strands – would require limited efforts. Insurance and legal costs would be in line with many small to midsize businesses.
- **Marketing** efforts in a dark network essentially consist of limited outreach to a relatively small set of customers or potential customers. Thus, marketing generally requires less than one full time employee.
- **Pole attachment** fees are paid annually to the pole owner in exchange for leasing space on the pole. Tilson estimates annual pole attachment fees in Cambridge at $20-30 per pole.

- **Maintenance and repair** can encompass anything from repairing cut or broken fiber cables to moving fiber to accommodate required changes in the route (e.g., replacing an old pole). These events are uncommon. A conservative estimate is to expect to spend 1-2% of the network's capital cost on maintenance and repair in a given year. Pole transfers – the required movement of a fiber cable to a new pole, usually because of pole replacement – are included in the general maintenance and repair costs. Analogous to pole transfers is the need to move a buried fiber cable, for example if the City needed to dig up the street to replace a water main. This essentially involves burying a new cable, with all its attendant costs, and splicing it at both ends into the network. Then, the old cable can be removed. In Cambridge, a police detail would also be required for this work.
- **Connection costs** (either to a network or a point) are incurred as new customers (e.g., other networks, businesses, large office buildings, and homes) connect to the network. This work is typically done by a contractor, but the new user can also do the work in some cases. Connection costs are generally passed on to the new customer who wishes to connect, in any case. In a municipal-scale dark fiber network that is designed to provide last-mile services, a well-designed network would include regularly spaced, controlled access points that allow new connections to be made almost modularly.
- **Contractor management** will require a certain number of FTEs that varies with network size and complexity. For the Small and Medium builds, this is likely to be less than one FTE while the Large build may require a full time employee (or more).

Lit Network Operating Costs

Lit networks, in contrast, have a wider variety of operating cost centers. As with a dark fiber network, the costs of providing lit services depend in large degree on the network's size and complexity. General categories of operating costs for providing lit services are shown below, along with ranges of per-subscriber, per-month costs where applicable:

- **Management and Overhead** costs comprise the typical range of costs any business would incur under the heading of "general, and administrative" including:
    - General management
    - Audit, accounting, and payroll
    - Insurance
    - Legal
    - Electric and utilities
    - Rent

Tilson estimates these management and overhead costs as approximately 1-4% of capital expense.

- **Marketing, billing, and customer support** provide the means of interfacing with potential and actual customers. A third-party network operator might charge $20-30 per subscriber per month to recoup these costs:
    - Billing
    - Marketing
    - Customer support

One important component of the above that should be called out is marketing. Marketing of lit services is vital to the success of any proposed network. Other networks have failed to appreciate this to their detriment. This is especially important in a market like Cambridge with incumbent competitors, who will certainly have a competitive response to a new network.

- **Network monitoring and management** costs are incurred in ensuring the network's stable functioning and provision of services. Startup costs for this can be formidable – they include building out and staffing a Network Operations Center (NOC) – but incremental costs once the capital has been spent are in the range of $3-10 per subscriber per month. It is beyond the scope of this document to price out the building of a NOC.

- **Field technicians, billing, vehicle costs**, and **customer support** functions will typically be handled by the lit services operator. A good proxy for these costs would be the cost of hiring a contractor to perform these functions.
- **Bandwidth** refers to actual reserved wholesale bandwidth the ISP contracts for from its provider. Over time, bandwidth costs may be subject to variation. At present oversubscription ratios (the amount of nominal Internet capacity promised compared to all the users on a network to the amount of Internet capacity actually provided to support a network) can be quite high without impacting performance. Over time, the level of utilization can be expected to increase, requiring the provision of more Internet bandwidth to support the network. However, the price per unit of the bulk bandwidth used to supply a local fiber network can be expected to drop.
- **Transport services** provide the connectivity needed to link a prospective municipal network to the internet. Cambridge benefits from the presence of an existing large point of presence within City limits, at 300 Bent Street, where several carriers have a presence. Transport costs would therefore be negligible if the City were to design its network with diverse fiber entrances to this facility. Connections to other area points of presence, like 1 Summer St or 70 Inner Belt, can be added as the network grows.
- **Maintenance and repair** costs will generally be for electronics (at both the customer's premise and the node) and the drops. As with the underlying dark network, Tilson estimates 1-2% of capital costs to be a conservative estimate of these costs.
- **Contractor management** will also require some time ranging from less than one FTE to one or two FTEs, depending on the size of the network. As above, we define an FTE as an all-in cost of $150,000 per year.

Operating Costs for the Capital Models

Each of the build options Cambridge is exploring will result in incurring some mix of the above lit and dark network operating costs. Since so many of the costs would be present among a variety of the different capital models, it may be more useful to specify which costs would not be incurred in a given model.

Small Build

The small build option would not incur significant costs around marketing or transport. Limited network scope and a targeted user base will obviate the need for more than a very limited marketing expense. Transport will be accomplished via the City's existing network. Whether the City chooses to operate this build as an extension of the existing municipal fiber network or hires a private operator to provide lit services to customers will dictate its exposure to the other types of operating costs. Nonetheless, it is Tilson's understanding is that Cambridge has a strong preference for a third party to operate the network. If a private partner were brought in, it would use the City's network as transport to the internet, but this could be logically separated from other traffic on the network.

Table 15 lists the monthly operating costs indicative of the small build option. In general, Tilson estimates the network services provider, whether the City or a third party, to incur approximately $50 to $60 per user per month in operating costs, with take rates ranging from 25-75%. This assumes a total of 2,944 potential subscribers: 250 are non-CHA premises located along the fiber routes, while the remaining 2,694 premises are individual units within the 22 served CHA locations.

Pole attachment	$125-188
Maintenance and repair	$4,560-9,125
Management and overhead	$4,560-18,250
Marketing, billing, and customer support	$14,720-66,240
Bandwidth	$5,000-10,000
Network operations and management	$2,208-22,080
Contractor management	$6,250
Total operating costs	$37,430-132,130
Total operating costs per subscriber	$50-60

Table 15: Small Buildout Indicative Monthly Operating Costs

Medium Build

In the medium build, where the City builds a dark fiber network and brings in one or more partners to provide lit services, the City will not incur any lit services operating costs. Operating expenses for the city will include maintenance and upkeep of the fiber strands and associated buildings, as well as marketing and management costs and annual pole attachment fees.

Table 16 lists the monthly operating costs indicative of the medium build option. Operating expenses for the dark network will consist largely of pole attachment and maintenance, approximately $13,170 to 19,540 per year. Again, we assume one half of a FTE for contractor management, at $75,000 per year.

Pole attachment	$13,180-19,770
Maintenance and repair	$69,840-139,675
Contractor management	$6,250
General management and marketing	$6,250
Total operating costs	$95,520-171,945

Table 16: Medium Buildout Indicative Monthly Operating Costs

Full Build

A full-build broadband solution presents the greatest financial responsibility of any potential business model. Negotiations between the City and its private partner will establish how risks, revenues, and costs are shared. Indicative monthly costs for the below dimensions are in Table 17, with the given ranges again assuming 25-75% take rates.

Pole attachment	$7,700-11,550
Maintenance and repair	$1,872,830-3,745,660
Management and overhead	$1,872,830-7,491,320
Marketing, billing, and customer support	$156,070-312,140
Bandwidth	$7,280-43,670
Contractor management	$12,500
Network operations and management	$43,670-436,720
Total operating costs	$3,972,880-12,053,560
Total operating costs per subscriber	$45-50

Table 17: Large Buildout Indicative Monthly Operating Costs

11. Other Municipal Broadband Projects: Case Studies

Several other municipalities in the United States have already built out FTTH networks encompassing a variety of architectures and business models. This section will summarize a selection of FTTH projects and highlight key takeaways for Cambridge.

Mass-Market Broadband Examples

Leverett, MA

The town owns a town-wide fiber-to-the-home (FTTH) network using Active Ethernet technology, called LeverettNet. All premises in town are connected, but not all subscribe to the service. The town-created Municipal Light Plant (MLP) entity (with a separate budget) is the custodian of the network. Crocker Communications, a local ISP based in western Massachusetts, provides data and voice services with a single one gigabit internet service tier. Holyoke Gas & Electric Telecom provides network operation services.

The Leverett network's construction was financed by tax-backed municipal bonds. Operational expenses are funded solely via revenue from broadband and telecom services. Users of the network pay a monthly network operations charge to cover the fixed operating costs of the network. The more users on the network, the lower that portion of their bill. The Leverett network relies on subscriber revenue, but only to offset ongoing maintenance costs.

The town-created Master Limited Partnership, which has a separate budget, is responsible for overall network operations (outsourced to HG&E Telecom) and assumes the financial risk of operations.

Operating and Financing Models

Leverett has partnered with one ISP, Crocker Communications, to provide the services to subscribers on the network. The Town owns the underlying network infrastructure. The network is financed by general revenue bonds, so its solvency is not dependent on the number of subscribers.

Key Drivers of Success

- Financing the capital cost of the network via tax-backed bonds instead of revenue-backed bonds resulted in guaranteed ability to repay the debt. The town's ability to repay a revenue-backed bond issue would depend entirely on getting enough subscriptions for service.
- Leverett connected all premises in town to the network as part of the initial capital outlay and network construction, whether or not those premise owners had signed up for service. This resulted in significant economies of scale and let the town spread the high fixed costs over a wider group of premises.
- Active political leadership in the town convinced residents to approve a property tax increase in order to pay for the network.

Key Takeaways for Cambridge

LeverettNet started with a focused objective to provide excellent internet access to all 1,800 residents given a dearth of acceptable alternatives. While LeverettNet's scope is much smaller than Cambridge's (aside from perhaps the CHA-only option), the town's goal of universal high quality broadband access is identical. Funding the network from general revenue provides an important backstop against lower-than-forecast take rates, and connections to all premises regardless of subscription ensured economies of scale in construction. Leverett outsourced network operations to an experienced provider, as the town had no experience in utility-style service models. Should Cambridge choose a similar model of municipally operated utility, it should carefully consider the feasibility of entering the ISP business with no prior experience. In addition, it will need to determine whether to connect premises regardless of whether service is used and whether to hire an outside ISP, as Leverett did. A key differentiator between Cambridge and Leverett is the latter's pre-existing municipal utility. This meant that Leverett already had a significant portion of the organizational infrastructure in place to operate as a broadband utility.

Chattanooga, TN

Chattanooga's FTTH broadband fiber network is a model of a successful municipally owned and operated fiber network, with the Chattanooga Electric Power Board (EPB) performing the range of network operations responsibilities, and assuming the financial risk of operations. The citywide FTTH network was originally conceived to provide network connectivity for the EPB's smart meter deployment and is currently operated as a closed network.

The City of Chattanooga, Tennessee undertook the goal of improving broadband access for its citizens through its municipally-owned power utility, the Chattanooga Electric Power Board (EPB). One of the primary advantages of this structure for Chattanooga was that it significantly reduced the cost of constructing the network through lower make ready expenditures. Chattanooga used municipal bonds to provide funding for constructing its 170,000 service location, 8,000 mile network. The service offers tiers of 100Mbps or 1Gbps to residential subscribers and 100Mbps to 10Gbps for businesses.

Operating and Financing Models

The total project cost of the EPB network was approximately $340 million, with $111 million funded through a federal American Recovery and Reinvestment Act (ARRA) grant from the Department of Energy. The remaining cost of the network was funded through the City's passing of a $229 million municipal bond to provide matching funds. The structure of the loan involved EPB's electric division lending EPB's cable/internet division sufficient funds, with the loan being repaid using revenue generated from network subscriptions.[9] Operating cost and risk are assumed by the EPB, as it is the network internet service provider. The network is municipally owned and operated, and closed to third parties.

Key Drivers of Success

- Like LeverettNet, the Chattanooga network was financed via debt whose repayment is not dependent on the number of people subscribing to internet or phone services. In addition, Chattanooga EPB funded a significant portion of the capital cost with grants, which do not need to be repaid.
- Since the EPB network is owned by the local electric utility, it was able to better manage make-ready costs on utility poles.

Key Takeaways for Cambridge

Like Leverett, Chattanooga financed its network via general obligation bonds and is not sensitive to subscription rates for repayment. With a population to serve of approximately 170,000, Chattanooga's network buildout serves potentially significantly more people than even the full buildout option would in Cambridge. Chattanooga's network is an excellent example of a municipal utility taking the opportunity to provide a new service offering to existing customers. It is also important to note that, like Leverett, Chattanooga had a pre-existing municipal utility. The utility was also able to use federal grants from the Recovery and Reinvestment Act to build a significant portion of the network – money that was specifically allocated to electric utilities, not broadband providers. It is unlikely that federal grants will become available again that Cambridge could use to build this network.

Lafayette, LA

Ownership/Operation

LUSFiber is a closed network and wholly owned subsidiary of the municipal Lafayette Utilities System (LUS), which provides electric and water service to the city of Lafayette. LUSFiber is a FTTH provider of internet, digital TV, and phone service with connectivity to all premises in the city. Internet speed tiers range from 3-2,000Mbps symmetric. Prices vary depending on specific services and bundles. The main network was originally built for electric substation management. In 2002, LUS formed LUSFiber and

[9] Information regarding EPB's network was obtained in a phone interview with Danna Bailey, EPB's Vice President of Corporate Communications (baileydk@epb.net).

connected area hospitals and schools to dark fiber strands on the main network. Residential services began in 2009, following several years of legal battles around the city competing with Cox and AT&T/BellSouth.

Operating and Financing Models

The city issued $110 million in revenue-backed bonds to finance the construction of the network. In the event that LUSFiber does not earn sufficient revenue to cover its debt, payment responsibility falls on LUS. The project became cash flow positive in 2012 on operating revenues and expenses, but still has upwards of $100 million in debt. Legally, LUSFiber is a nonprofit entity. It recovers its costs via project revenue only. LUSFiber is a municipally owned and operated network, and is closed to third parties.

Key Drivers of Success

- The core network was already built for utility operations. LUSFiber runs on dark fiber strands that were put in the original core network, and thus did not incur a significant part of the capital cost of the initial buildout.
- LUSFiber received anchor tenancy from local institutions prior to offering residential service. This enabled it to gain ISP experience and an initial revenue stream.
- LUSFiber has achieved a sustainable take rate of approximately 33% of available subscribers.

Key Takeaways for Cambridge

With a population similar to Cambridge's, Lafayette provides an excellent example of a city expanding its municipally-owned utility's service offerings and providing universal fiber to the home. Like Leverett and Chattanooga, Lafayette had a pre-existing municipal utility. In addition, Lafayette undertook a controlled, phased network buildout. It first built a core network with excess capacity, strictly for utility operations. It then used dark fiber strands on that network to begin offering internet service to anchor institutions, and finally began a citywide buildout. Thus, LUS gained experience in fiber network construction, operation, and service provision in stages, building on prior experience with each succeeding stage.

Burlington Telecom

Burlington Telecom is a department of the City of Burlington, Vermont and is 100% municipally owned and operated. However, the City is in a multi-year process to seek a buyer for the system.

Operating and Financing Models

Burlington Telecom financed the capital construction of the network with a capital lease, which it paid off and replaced with two more, larger, leases due to cost overruns. After multiple capital leases, Burlington Telecom was still running an operating deficit, which was paid for out of general city revenues. While the original intent of the City was for network operations to be funded not by general revenue (taxpayer dollars) but instead by project revenue, Burlington Telecom ran out of money and used $17 million from the City Treasury department to support network operations. Such use of general revenue is prohibited by both the City Charter and Burlington Telecom's Certificate of Public Convenience & Necessity. The Vermont Public Services Board ordered the city to stop supporting the network with general funds, at which point Burlington Telecom defaulted on its capital lease.

The Burlington Telecom network is nominally an open access network, but the city directly provides most of the services delivered over the network.

Key Causes of Failure

Burlington has a municipal electric utility, but the Burlington Telecom network was operated as an entirely separate entity. Under Vermont law, cross-subsidization is prohibited. Therefore, Burlington Telecom could not use any of the utility's personnel or systems. Thus, Burlington Telecom was required to learn key processes and organizational models from scratch.

Political infighting and operational mismanagement have been the biggest sources of trouble for the BT network. A former mayor prohibited the network from offering service outside Burlington city limits until all premises in the city were connected to it, despite the fact that the network was designed with excess capacity to serve outlying areas and expected the additional revenues from serving outlying areas in its financial plans. In addition, the city experienced significant cost overruns on the project over the course of several years, which that previous mayor's administration hid from the public. Finally, the network was financed based on projected revenues that did not materialize due to substantially lower take rates within Burlington.

Key Takeaways for Cambridge

A successful fiber to the premises network requires sustained political support and accurate revenue projections. Upon or before committing to a plan, the City should get a reasonable understanding of demand levels and locations. This will help either determine performance of a full-build network, or help the City determine key areas for initial buildout focus if it chooses the dark fiber option. Burlington highlights the risk of starting a municipal broadband utility without having an existing utility organization to leverage. It also highlights the risk of relying solely on user fees and voluntary subscription without a thorough understanding of how many people will sign up for service. Still, there is a limit to the effectiveness of research on likely take rates and other business assumptions. Research can reduce risk but not eliminate it, as even well-planned business ventures can fail.

CityNet (Santa Monica, CA)

CityNet is currently a 100Gbps network in the city of Santa Monica, California, spawned by the City's need to reduce its data access costs. With a similar population to that of Cambridge, Santa Monica's story provides an excellent example of one path the city could take. CityNet serves primarily businesses. After forming a task force evaluating several different approaches, Santa Monica decided to pursue a fiber network in 1998. The first step in developing its fiber network was for Santa Monica to lease an institutional fiber network from the local cable TV operator. That network was expanded to connect 43 city buildings as well as school and college facilities.

When it leased the institutional network, the City funded the network expansion but shared the operations and maintenance costs with the local school district and college. The operational cost savings derived from this shared cost approach reduced the combined telecom costs by $500,000 per year shortly after the network went live in 2002. From here, the City utilized the savings to build its own 10Gbps municipal fiber network, from which it began leasing its excess dark fiber to local large businesses. Because of low monthly fees, these businesses were willing to fund the cost of building fiber from the backbone to their buildings. In this manner, Santa Monica's network was extended at no cost to the city. In 2009, the city made an additional investment in the network in an effort to provide lower cost bandwidth to small businesses in the area. It did this by leasing a fiber connection to a major colocation center in Los Angeles, 15 miles away, and getting transport from a service provider. CityNet was upgraded to 100Gbps in 2014, a move applauded by Santa Monica's large film industry, which regularly transfers large files.

Of particular interest to Cambridge will be CityNet's pilot Digital Inclusion program. The Digital Inclusion program is designed to provide internet access to residents of Santa Monica's affordable housing buildings. Forty-six percent of households in Los Angeles County with annual income under $30,000 do not have internet access at home. Digital Inclusion is designed to bridge this gap. In December 2015, the first affordable housing building was connected to CityNet, providing residents a 10Gbps connection. Depending on the outcome of this pilot connection, the city may expand CItyNet to other affordable housing developments as a prelude to general residential FTTH service.

Financing and Operating Models

CityNet is an example of a pay-as-you-go network, where expansions are built to serve demonstrated demand. The network's revenue is $300,000 per year, which is adequate to fund network operations and maintenance while also supporting a network of 27 Wi-Fi hot spots throughout Santa Monica. The city uses its nearly $200,000 in remaining capital funds as a revolving capital improvement project account. This account funds construction for network expansion, which is repaid by customers as the network continues to expand to their premises.

CityNet's requirement that customers pay for their own connections slows the growth of the network, but short of receiving a stimulus grant, CityNet will continue a policy of expanding based on demand alone. While the city provides internet access directly, it also makes the network available to third-party providers on an open-access basis.

Key Drivers of Success

- Capital costs were largely paid through telecom savings, allowing the city to fund the initial network backbone at little to no additional cost.
- The city uses excess funds for capital improvement and funds network growth directly via new subscribers.

Key Takeaways for Cambridge

A pay-as-you-go model could be worth considering if the City wants to limit large capital expenditures and is willing to accept more incremental progress. It would ensure that fiber is available in areas where there is demonstrated demand, and that fiber could be expanded to other areas as demand materializes. Of course, the City could choose to fund expansion to these other areas itself if it deems such expansion worthwhile to acieve universal access goals in underserved or lower-income neighborhoods.

UTOPIA – Utah

The Utah Telecommunication Open Infrastructure Agency (UTOPIA) is a consortium of 16 municipalities in the Salt Lake City area that builds and owns a FTTP network using active Ethernet. The network is open access, with multiple ISPs operating on the network. UTOPIA also provides public Wi-Fi service in parks and public buildings within its member cities. Each premises to be connected to the UTOPIA network must pay a $2,750 installation fee. Available speeds range from 100-1000 Mbps.

The constituent towns have borne all operating risk for the network. According to UTOPIA's website, annual operating costs are approximately $215,000. Constituent towns have attempted to make up the shortfall by raising property taxes or levying a mandatory utility fee on all homeowners (regardless of whether they are connected to the network). Taxpayers have generally voted down these proposals. UTOPIA is often held as an example of a failed attempt at constructing a viable multi-town broadband network.

At least some of the network's insolvency is due to a far lower take rate than planned: the network currently has only about 11,000 subscribers versus the 50,000 anticipated. FY 2014 revenues totaled $6.9 million, against expenses of $26.8 million and outstanding debt of $241.2 million.

Individual subscribers have a variety of options for funding the $2,750 installation fee:

- Lump sum payment
- 6% financing: $300 up front and $30/month for 10 years
- 7.9% financing: No money down and $25/month for 20 years

The installation fee is for the physical network connection and hardware, and is in addition to service fees that the ISPs charge.

Financing and Operating Models

UTOPIA conducted its initial financing round with a $185 million bond issue in 2004. In 2006, UTOPIA received an additional loan of $66 million from the USDA's Rural Utilities Service to complete the

network buildout. After paying only $21 million of the additional loan, the USDA suspended further payments in 2008, citing materially adverse circumstances in UTOPIA's operations. The network is currently seeking funds to complete the buildout, which was to be completed by 2007. UTOPIA has been in discussion with Macquarie Capital regarding a possible buyout.

The UTOPIA network member cities sought the initial bond funds as a unit, in order to pool their collective bond ratings and tax authority. Cities pledged sales tax revenues as collateral for the bonds. Debt service was to be satisfied by project revenues, with sales taxes making up any shortfall.

UTOPIA is an open access model, and currently has 20 ISPs active on the network. It is worth noting that the incumbent providers (Comcast, CenturyLink, and Frontier) have refused UTOPIA's offer to use the network. In fact, they have actively campaigned against UTOPIA, with considerable success. Many area towns are now prohibited by state law from joining UTOPIA.

Key Causes of Failure

- UTOPIA based its revenue projections on take rate assumptions that, in hindsight, turned out to be wildly optimistic. The network took on debt based on these faulty assumptions that it cannot repay.
- The UTOPIA network intended to cover a very large geographic footprint from the start, thus incurring very large capital expenses up front, and without guaranteed anchor customers.
- Successful lobbying by incumbent providers has prevented other towns from joining UTOPIA, thus constraining growth.

Key Takeaways for Cambridge

While UTOPIA's geographic reach is significantly larger than any buildout Cambridge contemplates, it presents a cautionary tale on the risk of building an entire network oneself and incurring all the associated capital cost, especially without first gaining a thorough understanding of likely demand. UTOPIA leapt to building the most expensive, most demanding buildout option with the expectation of "if you build it, they will come." And not nearly as many people came as the network's owners hoped.

New Hampshire FastRoads: Rindge, NH

The Rindge fiber optic network is part of the larger New Hampshire FastRoads project, an open-access middle and last mile network spanning 22 towns and 220 anchor institutions in western New Hampshire. FastRoads is owned by the New Hampshire Community Development Finance Authority, the Monadnock Economic Development Corporation, WCNH.net, and towns in the Monadnock region.

The towns of Rindge and Enfield are the locations of the initial FTTH pilot project, with initial speed tiers of 10-1,000 Mbps.

Key Issues

- The Rindge network has a variety of anchor customers, thus providing guaranteed revenue for operating expenses
- The project received a grant from the NTIA for the bulk of its construction costs, and thus has no debt to pay off.
- The project has struggled to expand and achieve scale.

Financing and Operating Models

The project has been funded primarily from a NTIA/BroadbandUSA grant of $44 million under the American Recovery & Reinvestment Act of 2009. FastRoads is a sub-project of the broader Network New Hampshire project. Total construction capital was $7.6 million.

FastRoads operations are outsourced to a third party network operator. Costs and risks are borne by the participating communities and the Monadnock Economic Development Corporation. Participating ISPs pay FastRoads a percent of their revenue, based on their network utilization. It is worth noting,

however, that currently only one service provider offers residential service on the network, while three providers offer small business services.

Key Takeaways for Cambridge

FastRoads is an example of a wide-area dark fiber network that struggled to attract service providers. In addition, the FastRoads network was built before securing agreements with service providers, resulting in service providers having significant negotiating leverage when the network was built. FastRoads illustrates the limits to the ability of a small network to attract significant interest from ISPs to provide residential and small business services.

Vermont Telecommunications Authority

The Vermont Telecommunications Authority (VTA), a state authority tasked with improving the state's communications infrastructure, created three regional dark fiber networks in the state.[10]

East Central Vermont

The East-Central Vermont network spans over 100 route miles. Begun in 2012 as the Orange County Fiber Connector, a 36 mile fiber route linking several towns in the area, the network has expanded greatly. It currently consists of approximately 85 miles of 144-strand cable, which was chosen to provide capacity well in excess of any possible forecast need.

VTA offered dark fiber to service providers, utilities, and government entities under two alternative subscription models, detailed below. In both cases, customers were responsible for repair costs, either via self-insurance or taking out insurance to cover such costs.

1. Customers willing to commit before the start of construction were able to take an "Initial Offer" wherein they paid an up-front capital cost proportional to the number of strand-miles they leased, and then a share of operating costs proportional to the number of licensed strands. Initial offerees were allowed to offset their share of capital costs by committing to expand the network via construction of laterals and drops to customers.
2. Customers who did not take advantage of the Initial Offer paid a flat monthly rate for a term of 3-20 years. The rate was priced per strand-mile and intended to recover the operating cost of the dark fiber, plus contribute to the original capital cost.

The largest user of the network is ECFiber, a LLC owned by 23 area municipalities whose mission is to provide fiber internet access in member communities. ECFiber has built its own fiber network to branch off the underlying VTA network, of which it leases approximately 25% of capacity. ECFiber, in turn, has hired a local ISP, ValleyNet, to operate the network and provide service, which is sold under the ECFiber name. Service is available in tiers up to 500Mbps. An alternative use case is that of FairPoint, which leases fiber on the network as middle mile infrastructure to connect DSL remote terminals.

It is worth noting that the spur of the original VTA network connecting the towns of Bethel, Hancock, and Rochester was built despite those communities having service levels that, at the time, the VTA deemed above its minimum threshold of service. The VTA justified this buildout under its second mandate to improve cellular connectivity. A significant portion of that route was part of the VTA's cellular target corridor, in which the VTA determined there was a lack of capacity for cellular backhaul. Thus, the VTA was able to satisfy its cellular mandate while providing enhanced broadband connectivity above and beyond its mandate. This is an example of how a dark fiber network allows the developer to "spend the same dollar multiple times" and underscores the flexibility inherent in dark fiber networks.

[10] In 2015, the VTA and its assets were merged onto the Connectivity Division of the Vermont Department of Public Service.

Putney, Vermont
The VTA built a small dark fiber network of approximately ten miles in the town of Putney. It currently has one customer, Southern Vermont Cable, which bought capacity on the network under the Initial Offer. Southern Vermont Cable delivers services to residents via an all-fiber network, not a hybrid fiber-coax network as is typical of cable operators.

Northeast Kingdom
The Northeast Kingdom, in that remote corner of the state, is home to the 160 mile Northeast Kingdom dark fiber. This network was created in part by VTA construction, and in part by swapping strands on fiber segments built by a local economic development entity. Unlike the other two segments, funding for this network was committed by federal grant and state earmark prior to any commitments from last-mile providers to use the fiber to directly serve homes and businesses. In addition, most of the non-VTA constructed segments were designed and built primarily as middle-mile facilities. For these reasons (and the very low density of end users), the network has not been used as a FTTP network. Customers include:

- Vermont Electric Co-Op, which leases fiber for communication with remote infrastructure
- VTel Wireless, which leases fiber strands for backhaul for an LTE network
- Long-haul connectivity services between Boston and Montreal.

Financing Model
All three VTA networks received their capital via grants from Vermont's capital budget, derived from general obligation bonds on the state's revenues. Thus, there was no obligation for the VTA to repay any of its capital costs. In addition, parts of the Northeast Kingdom fiber network received were built with federal grant funds.

Key Takeaways for Cambridge
The three VTA networks show the inherent flexibility of a dark fiber solution. In East-Central Vermont, the network accomplishes separate goals of improved cellular and broadband connectivity. The three networks collectively support a Fiber-to-the-Premise operator, a DSL solution, a cable, and wireless broadband service. However, if the goal of a fiber network is to spur Fiber-to-the Premise service, the Northeast Kingdom network shows the importance of obtaining commitments from such a provider to use the network up front.

Westminster, MD
Westminster is building an open-access last-mile network using GPON technology, to be completed in 2016. By constructing only the last mile, the town provides within-reach connectivity to all residents without spending the considerable extra sums involved in building drops and providing electronics. Residents interested in connecting to the network work with their selected ISP to build the drop and provide electronics.

The town began with a conservative approach to build its network using the "fiberhoods" strategy: expanding the network in phases to neighborhoods that meet a minimum commitment to service[11]. After an initial pilot project in 2013 connecting an industrial park and retirement community, the town decided to build a further phase of the network. Interest quickly grew, however, and the town resolved, based on pent-up demand, to skip the planned phasing in favor of a full town-wide last-mile network. The full network is expected to be completed in 2016 and will pass all premises in the town.

The pilot project connecting the industrial park and retirement community was funded by a $1.2 million appropriation from the city's rainy-day fund. The remainder of the buildout is being funded by a $6.2 million bond (extensible up to $21 million) to be paid for by project revenues. If revenues are insufficient to cover the debt, however, the city has also appropriated $6.2 million from its tax revenue stream to

[11] http://goo.gl/Pwa6P5

be used to cover any shortfall. The city's self-described "very, very conservative" expectation is that it will be able to cover debt service and maintenance costs within three to five years of project completion[12].

The Westminster-built network is an open access network owned by the town. Virtually all of the network is underground, since other utilities in the area are also underground. A sole ISP, Ting, has been selected to provide service on the network, but other ISPs will be able to participate on the network at a later date. Ting pays the town for leasing its fiber. This reduces the city's exposure to operating risk while guaranteeing a certain revenue profile. Middle-mile connectivity is provided by the existing Carroll County Public Network, a middle-mile network originally built to connect county buildings and schools, but which has recently started leasing fiber strands to private parties.

In developing the project, City Council President Robert Wack noted that Comcast and Verizon also offer service in the city, but there is widespread dissatisfaction with their service quality and availability. The city government noted that fiber to the home was the only way to "take this city into the future."[13]

Key Takeaways for Cambridge

The project's innovative approach regarding minimum demand guarantees and risk sharing with the local ISP showcases the flexibility of a dark fiber platform. In addition, omitting drops and network electronics results in tremendous cost savings to the town by transferring those costs to only the people who wish to pay them.

South Portland, ME

In 2014, the city of South Portland commissioned GWI, a Maine ISP, to build, own, and operate a last mile network serving primarily schools and city buildings. With the city of South Portland as an anchor tenant, GWI self-funded the $150,000 cost of the initial network phase. Over two ensuing phases, the network has expanded to approximately four miles at $300,000 in total costs.

As noted above, the South Portland network was designed mainly to provide connectivity to schools and various municipal buildings. Homes and businesses located along the route can connect to the network for a $300 construction fee. GWI solicits interest from residents throughout South Portland and says it will consider expanding service from the existing backbone into neighborhoods where there is sufficient demand to present an attractive business case.

One interesting aspect of GWI's arrangement with South Portland is that GWI pays 5% of project revenues to the City. GWI and South Portland view this as akin to a franchise fee for a cable operator. In South Portland, GWI specifically agrees to allow other operators access to the network. Nonetheless, Tilson believes this arrangement could expose the City to the risk of allegations of impropriety, since the City is incentivized to maximize GWI's revenues and thus could regulate the market to discourage competition.

Key Takeaways for Cambridge

Third party ownership and operation can provide a route to higher broadband penetration with relatively little risk. But relying on a third party to achieve Cambridge's goals of Equity and Affordability will likely not be satisfactory, as market forces alone will likely not work entirely in the city's interests.

[12] http://goo.gl/RNcyem
[13] http://goo.gl/BRX54H

Targeted Population Examples: Low-Income Housing

Should the City of Cambridge elect to build only a small network serving Cambridge Housing Authority properties, the following examples will be pertinent.

Madison, WI

Overview

The city of Madison is in the process of building a pilot FTTH project in four low-income neighborhoods. Its initial RFP, released in mid-2015, received three proposals; two were for wireless solutions. The RFP specified that the city would prefer a wireless or LTE solution, so there was some surprise that it opted for the sole non-wireless proposal. Madison's mayor, Paul Soglin, has long been a vocal proponent of FTTH, so the move was not entirely surprising. The city will own the network, and ResTech, a local ISP, will be the network operator and internet service provider.

ResTech is building the pilot network and connecting it to Madison's existing municipal fiber backbone, the Metropolitan Unified Fiber Network (MUFN), a 132-mile fiber backbone built with a $5.1 million grant from the American Recovery and Reinvestment Act of 2009. MUFN currently serves hospitals, municipal buildings, and other community institutions.

Funding and Service Tier

The city passed a budget amendment to its initial $150,000 allocation allowing it to pay for the entire project, currently estimated at $512,000. ResTech will provide a single tier of service: 10Mbps symmetric for $9.99/month.

Risks

The city has not analyzed demand for the service in the four neighborhoods, or what the probable take rate will be. Indeed, in a show on the local community radio station, it was said that this is the single largest unknown in the network's development.[14]

Under Wisconsin law, cities that wish to offer municipal broadband must perform a cost-benefit analysis and hold a public hearing, as well as obtain Competitive Local Exchange Carrier (CLEC) certification. Madison states that it will conduct the cost-benefit analysis one year into the network's operation. If the analysis is promising, the city will consider expanding the network to all city premises.

More troublesome for the project, under state law, municipal broadband networks may not offer phone or live broadcast video services; they can only provide Internet service. Being unable to offer additional services cuts off municipal providers in Wisconsin from potentially important alternative revenue streams, making it more difficult to develop a profitable network. The Federal Communications Commission is currently debating new rules that would make it illegal to restrict the types of services municipal broadband networks can offer.

Key Takeaways for Cambridge

Madison is taking a staged approach to a potential wider FTTH buildout. By building a pilot phase first, the city will better understand real-world impacts of the choices it makes, on a smaller scale than a full FTTH deployment. It will also learn more about the suitability for its needs and risk profiles of various ownership/operating models. In addition, by building the pilot phase to serve low income residents, the city can achieve the aims of Equity and Affordability, as well as Local Control, while gaining this greater understanding.

Austin, TX

Overview

The City of Austin has partnered with Google Fiber to receive its symmetric gigabit broadband internet service through a State of Texas franchise. Speeds of 5 mbps download and 1 mbps upload will be free

[14] http://goo.gl/HyCA4T

of charge to 100 community anchor institutions, including the Housing Authority of the City of Austin's (HACA's) properties. The initial plan was for Google Fiber to install broadband internet access for residents at the computer labs of these developments. But the HACA looked to Google Fiber and key community partners to help achieve its two year strategic plan: bringing basic broadband internet into each low-income household. By Google responding favorably and entering into a partnership with HACA, along with HACA receiving a grant from the Community Connections Program, the "Unlocking the Connection" program was rolled out to provide free, basic in-home broadband access for 4,300 public housing residents at 18 HACA properties. HACA's nonprofit subsidiary, Austin Pathways, is the entity charged with seeking funding and implementing the Unlocking the Connection initiatives. The City's project with Google Fiber is divided into three phases, with each phase connecting 6 out of the 18 HACA properties.

Funding

Funding for the initiative is provided in part by the Ford Foundation, the Open Society Foundation, and by key gifts from the following in-kind partners: Austin Community College (ACC), IBM, Freescale, Rackspace, The University of Texas Moody College of Communication, and EveryoneOn.

Capital Costs

The first phase of the Unlocking the Connection initiative is expected to cost $1.4 million. While Google has not disclosed the total cost of its Austin network, industry analysts estimate the per-premises capital cost for its Kansas City network at approximately $560.

Operating Costs

As the network operator and internet service provider, the operating costs are borne by Google Fiber. Additionally, Google Fiber has waived the $300 connection fee per household for all HACA residents. Per the terms of the contract between HACA and Google Fiber, basic internet access will be provided to residents free of charge for ten years.

Risks

HACA and the City of Austin are in a public-private partnership with Google Fiber. In this specific business model, the risks to HACA and the City of Austin are limited, with the primary tradeoff being no control of the network. The other risk – and potential barrier for low-income Austin residents – is the $10 pre-registration fee that HACA or its residents must pay to Google Fiber in exchange for its services. Otherwise, Google Fiber constructs, operates and maintains 100% of the network at its expense in exchange for access to Austin's municipal assets and existing network infrastructure free of charge.

Key Drivers of Success

- A large amount of political support was received early on, with a strong commitment to improve broadband availability. There was strong collaboration among stakeholders, and a thorough planning process was put in place.
- Citywide fiber access is being rolled out in phases by Google Fiber, an experienced developer. Phased development allows for a more orderly project execution, and makes it easier for Google Fiber to scale the network.
- The city allowed Google Fiber to utilize its existing infrastructure in lieu of Google Fiber needing to build its own facilities and pass those costs onto the customers.

Key Takeaways for Cambridge

The Google Fiber case in Austin demonstrates the potential of partnering with a third party ISP who is building a broader network in achieving equity goals. Should Cambridge select a model involving a third party, it should seek opportunities for the third party to support the City's goals. In addition, Cambridge may wish to identify and select private partners who would be willing to subsidize portions of the network for low-income residents for the attendant goodwill.

Fremont, CA

Overview

Eden Housing, an affordable housing developer, opened Cottonwood Place in Fremont, California in 2012. It is a mixed-use development that combines housing and health care services for low-income seniors age 62 and older, and comprises a partnership between Eden Housing, the City of Fremont, and On Lok Lifeways, a senior health services organization. In each of the 98 units at Cottonwood Place, broadband internet access is offered free of charge, with Eden Housing paying the full cost of wired broadband access and providing a free modem to each unit.

Funding

Broadband internet deployment at Cottonwood Place was 100% financed by Eden Housing. However, Eden Housing was able to receive tax credits through California's Qualified Allocation Plan (QAP) application for Low Income Housing Tax Credit (LIHTC), which awards additional points to applicants who offer in-unit broadband access to residents.[15]

Operating Costs

The total cost of service incurred by Eden Housing, Inc. is $190 per month for the entire housing development. Service is provided to all residents free of charge.[16]

Risks

Eden Housing's ISP may raise prices or go out of business.

Key Drivers of Success

- The funding for the project was readily available by Eden Housing, Inc., and they seized the opportunity of taking the California Low Income Housing Tax Credit in the process.
- All operating expenses incurred by Eden Housing at Cottonwood Place are accounted for in their general operating budget.

Key Takeaway for Cambridge

There are potential tax benefits for providing service to low-income or otherwise qualified residents.

Other Low-Income Broadband Initiatives

ConnectHome

While not a specific network, an overview of ConnectHome is in order. ConnectHome[17] is a US government program unveiled in July 2015 by President Obama to expand broadband access to low-income households in 28 communities around the country, including one tribal nation. Under the program, the federal Department of Housing and Urban Development has partnered with eight national and local ISPs, including Google Fiber, CenturyLink, and Cox Communications, to provide low-cost broadband service to low-income Americans, with initial focus on households with children. The program also pays for computer literacy training via a partnership with Best Buy and for reduced-cost computers and tablets via grants from private donors, as well as online course materials including SAT prep.

Existing ISP Programs for Low-Income Customers

Several ISPs offer unpublicized tiers of service for low-income customers. In the City of Cambridge, Comcast currently offers their Internet Essentials Program. Details of selected providers' programs are in Table 18 below.

[15] *Eden Housing's Cottonwood Place*

[16] Ibid.

[17] https://goo.gl/9FGtLM

Provider	Details
CenturyLink	InternetBasics program provides 1.5Mbps service for $9.95/month with a 12 month contract. Qualifications vary by state, but generally require some kind of participation in benefits.
Comcast	Internet Essentials program provides 10Mbps download speeds for $9.95/month to families with at least one child in the National School Lunch Program and who have no outstanding debt to Comcast within the last year. The program requires no credit checks or contracts, and includes a free Wi-Fi modem.
Cox	Connect2Compete program provides up to 10Mbps download speeds for $9.95/month for families with at least one child in the National School Lunch Program and who have no outstanding debt to Cox within the last year. The program requires no credit checks or contracts, and includes a free Wi-Fi modem.
Google Fiber	Basic Internet Plan provides free 5Mbps service but users must pay a $300 setup fee, which can also be spread into 12 monthly payments of $25.

Table 18: ISPs' Low-income Broadband Plans

12. Lessons Learned from Other Municipal Projects

In the course of its consulting work, Tilson has seen many municipal FTTH projects at varying levels of planning, completion, and operation. From this broad experience base, Tilson has identified several lessons learned, all of which are reflected in successful projects. Cambridge is early enough in the planning of its potential project to incorporate these lessons. Some of these lessons learned would be applicable to any broadband project, public or private. This section discusses a range of these factors that any new project should consider. It should be stressed that in all of the successful municipally owned and operated projects, the town had previous experience running the local power utility.

Know Your Objective(s)

A clear, well-defined objective or limited set of key objectives will help any project better navigate its trade-offs and recognize its opportunities. For example, many projects are built out in stages as a way to stretch out their capital costs. Sometimes, a project can face a choice between a network build-out that reaches many but not all of the homes, businesses, and institutions in a targeted area, or a comprehensive build-out that is more expensive in the short run, but perhaps less expensive in the long run—but only if reaching all premises in the area is the project's objective. Clarity will help projects navigate this and other similar trade-offs. With its defined goals, the Cambridge Task Force has a baseline set of objectives in place. In addition, even though the cost of a project isn't captured in a specific goal, cost will always be a constraint to a greater or lesser degree.

Look for Ways to Build Multiple Value Streams from the Same Investment

Many municipalities that have built broadband networks for their entire communities started by leveraging expenditures that they were already making or investments that could be at least partially justified by other city operations, such as running fiber for a smart grid project that was later expanded to include broadband service. In building a network, there are opportunities to build in flexibility for multiple use cases (and multiple potential funding streams) that can be squandered unless the project is designed and operated thoughtfully. For example, one potential other use of a dark fiber platform might be to provide cellular and wireless broadband backhaul services as providers continue their build-outs of distributed antenna systems and small cells in urban areas. A Cambridge fiber network could also provide infrastructure for the City to interconnect City systems for traffic control or CCTV.

Carefully Consider Risks

No broadband project is risk-free. That said, it is possible to mitigate or minimize inevitable risks, and choose the risks that you are best able to tolerate or control. Following is a list of key categories of risks. For each category, it is important to ask each of the following questions:

(i) Do we understand the risk?
(ii) What is our level of exposure?
(iii) Do we have the means to mitigate or avoid it?

- **Cost risk.** In some cases, projects costs more to build and/or operate than originally forecast. Many of the other forms of risk can cause or exacerbate this risk. It is important to understand how conservative your cost assumptions are, and the impact of potentially higher costs. It is also important to understand who bears the risk of higher costs. Failure to understand cost risks can lead to public entities committing to projects that are financially brittle and unravel under financial stress.
- **Execution risk.** This risk speaks to the capacity of organizations to manage and perform the tasks they are called upon to do. It can come into play at either the construction phase or the operational phase. Successful public broadband projects often have these organizations doing those parts of the project that are like activities that they already do successfully. For example, many of the cities delivering broadband as a municipal ISP were previously providing another utility service, such as electricity.

- **Technology risks.** Telecommunications is a field subject to rapid technology change. This represents the risk of making technology choices that turn out to be wrong or just more quickly made obsolete than they can be paid off. Not all types of telecommunications infrastructure, however, is equally subject to technology risk. Electronic equipment in wireless, fiber, and other wired networks tends to become obsolete much more rapidly than some of the "hard" infrastructure, like fiber optic cable, poles, conduit, and towers. In focusing on fiber solutions, Cambridge is mitigating its technology risk since fiber is the most "future-proof" solution for broadband.
- **Market risks**. Any project that relies on broadband users to voluntarily sign up for service faces market risk, especially if those users have other choices for service. Incumbent providers usually do not sit still, but may lower prices or improve services in an effort to retain market share. While some communities consider these to be good outcomes, if a public project has a business case that depends on market assumptions that are no longer valid, or never were in the first place, the result can be unsustainable. Strategies for mitigating this risk are discussed below. This will be particularly of note to Cambridge, with its major incumbent service providers.
- **Political/regulatory risk.** Public entities exist in a political and legal context. Successful projects have had a supportive (or at least sufficiently supportive) political and regulatory environment, and one with support that is deep enough to endure requests to stop, limit, or otherwise constrain a public organization's involvement in broadband projects.

Understand Demand

The level of demand among users for service on a new network is a key factor in determining the success of a project. This includes its financial success, but obviously a network that has limited users also has in some sense limited benefits.

The ability to achieve sufficient demand is a key predictor of financial success. It isn't just the total number of users that matters. It also means having users who will pay enough for services to offset the operating expenses for providing the services, as well as the cost of required debt service from the construction of the network. Some projects can be caught in a bind between the need to charge rates high enough to cover costs and low enough to meet public policy objectives for price and affordability. It is important to determine if rates that are required of a public project are in fact subsidy rates, and if so, where that subsidy is coming from.

Different projects have approached this question in different ways. Some do careful prior assessments of demand, sign up anchor users in advance and/or use presubscription campaigns among residents and only build to where there is sufficient user demand and revenue to financially support a project.

Others, committed to a citywide build-out, have pledged general tax revenues as necessary to fund their projects, or created other mandatory charges on all residents. In essence, these projects create *de facto* 100% subscription level levels, although at the cost of charging people and organizations regardless of their use of the network.

Another aspect of demand is demand for bandwidth. Bandwidth requirements for the average user have moved steadily (and sometimes quickly) up. Cable TV operators are scrambling to deal with the advent of the cord cutter: people who eschew traditional TV and phone services in favor of streaming content and voice over Internet or mobile telephony. If Cambridge wishes to build and/or operate a municipal network, it behooves the City to ensure the network is as future-proof as possible. Fortunately, Cambridge has excellent access to Tier 1 bandwidth providers, and so should not face significant constraints in acquiring ample bandwidth for a municipal network.

Target the Negative Outcomes You Most Want to Avoid

With thought and careful planning, it is possible to reduce the likelihood that a public broadband project will fail to meet key objectives. However, sometimes common goals for public projects come into

conflict, and having a clear set of priorities will help Cambridge choose. For example, here are three objectives that a municipal or other public project might have:

- Minimize any negative impact on taxes.
- Minimize any impact on credit rating or credit reputation.
- Minimize likelihood that non-monetary objectives are missed (for example, we will use extending improved broadband to all parts of the city).

It is not likely possible to optimize all three. For example, a city borrows using a revenue bond to fund a broadband project and it wants to cover the whole city. Hopefully it has a positive business case, has estimated costs well, understands its market accurately, and executes strongly. But if project revenues aren't sufficient to cover the costs of a project, it has to choose. If the project isn't yet finished, it might be able to limit the project build-out to the most profitable areas, impacting its coverage objective. It could make up the difference in the bond using general revenue, impacting its tax objective. Or it could negotiate with the bondholders or default, impacting its credit objective.

Of course, it may be possible to take other steps to mitigate adverse outcomes for all three objectives, but usually only by giving on some other objective, such as contracting with a private partner to take on the financial exposure for delivering and operating the project within defined financial parameters. That is likely to impact other aspects of the project that the public entity may value more or less than what it is gaining, such as contracted cost or degree of control over the network.

Look for Alignment in Public-Private Partnerships

Increasingly, some companies are willing to form Public-Private Partnerships (PPPs) with public entities on broadband projects. These PPPs can have advantages. They can bring operational expertise into a project. They can help create economies of scale for smaller projects by leveraging an existing business's operation. PPPs also provide a means for sharing risk and reward with a private partner.

In considering a PPP, it is important to look for a strong alignment of interests. PPP agreements are often long-term agreements. It is important to understand why the private partner's long-term interests on important items like coverage, upgrades in service, and pricing are more or less aligned with the outcomes you want to see. PPPs always involve surrendering some amount of control to the private parties. If basic interests, while not necessarily the same, are not generally aligned, the objectives of the project can begin to drift away from the reasons that the project was important to the public partner. Strong contracts, while very important, are not a substitute for alignment of interests. Enforcing contract language on an under-performing party can be time-consuming and expensive, and it can put a cloud over the project that is the subject of the PPP. As with any outsourcing venture, of which a PPP can be considered a specialized case, the more that parties are policing contract compliance, the less likely the venture's success.

Finally, be wary of PPP agreements that are favorable to a fault in the direction of the public entity. A private party that discovers that it cannot make money will be less motivated and cooperative.

Looking to the Future

Telecommunications is one of the fastest-changing industries in the world. Only ten years ago, the iPhone did not exist, and few people used streaming video. It is therefore important to have a sense of potential future demand trends for the network. This can be thought of as identifying the best way to future-proof a municipal network. Fiber provides the most robust and upgradeable solution for municipalities that are willing to invest in it. The bandwidth needs of ten years ago are probably as different from today's needs as today's needs will be in ten years. Thus, any potential Cambridge network should be designed to provide the flexibility to adapt to changing needs and use patterns.

The future of wireless communications is also bound together with the development of a dense network of fiber infrastructure. Next-generation "5G" networks, using millimeter-wave spectrum, promises a future where tomorrow's wireless could rival some of the fastest wired broadband services today. However, such networks will operate over relatively short range and require an extraordinary density of wireless nodes. It is too soon to say definitively how much these future wireless technologies will impact the demand for fiber connections to every individual premise. What is very likely, however, is that wireless services that provide fiber-like speeds will require an extensive fiber-to-the-node network. If designed and operated with flexibility in mind, core elements of a fiber-to the premise network can also be core elements of a fiber-to-the-node network.

13. Regulatory and Public Policy Analysis

Generally, the public policy framework for municipal broadband activities in Massachusetts is strong and supportive. There is an established public policy framework that Cambridge could follow whether it decided to operate a municipal broadband utility, or enter into a public-private partnership. By following this established pathway, Cambridge can benefit from other municipalities' experience.

The Municipal Light Plant

Municipal Light Plants (MLPs) were originally a type of organization created to allow municipalities to provide electric generation and distribution. Today, however, MLPs are also a vehicle that can facilitate municipal entry into the delivery of broadband. In 1996 Massachusetts law changed to allow the state MLPs to go into the telecommunications business[18]. Since then, ten (10) electricity-providing MLPs have availed themselves of this option: Braintree, Chicopee, Concord, Holyoke, Norwood, Russell, Shrewsbury, South Hadley, Taunton, and Westfield. Holyoke Gas & Electric (HG&E), one of these MLPs, created Holyoke Gas & Electric Telecom, a fiber optic network to serve community needs, in 1998. It has expanded its offerings beyond that initial project to include the provision of telecom services to local businesses. It also serves as the Internet Service Provider (ISP) for the neighboring city of Chicopee's Electric Light Department (CELD) and for the town of Greenfield, 30 miles away.

MLPs are generally exempt from much of the regulation that Massachusetts would otherwise impose on an electric utility. The rationale is that, since MLPs are directly accountable to voters, an MLP that does not act in its community's interest will soon find itself with new leadership. That said, MLPs are required to provide an annual financial report and to collect revenue to cover depreciation costs. That revenue must be held in a separate account and used only for equipment and other asset renewals.

The use of the MLP is not limited to municipalities that are delivering electricity services. A number of other Massachusetts towns have established MLPs in order to develop their own fiber networks to connect to the state-owned MassBroadband 123 network, including the Town of Leverett, described in the case study section of this report. Holyoke Gas & Electric Telecom also provides network operations support to Leverett's MLP. It is worth noting, as the Leverett example illustrates, that the use of an MLP does not preclude the development of a public-private partnership.

Furthermore, an MLP can join with other public corporations as a cooperative for mutual benefits of all its members. Cooperatives must have a board of at least 3 members, and directors and officers of cooperatives have immunity from liability equivalent to similar for-profit corporations in Massachusetts.[19]

In short, MLPs are now established in Massachusetts as a vehicle for municipalities delivering broadband services, and if Cambridge were to advance its interest in the development of a fiber optic network, it should consider establishment of an MLP as a means for doing so.

Considerations for Public/Private Partnership

One potential limitation to a potential public/private partnership for providing expanded broadband access in Cambridge is the "anti-aid amendment" to the Massachusetts Constitution, which states that public funds cannot be given or loaned to private individuals or organizations for their private purposes:

> No grant, appropriation, or use of public money or property or loan of credit shall be made or authorized by the Commonwealth or any political subdivision thereof for the purpose of founding, maintaining or aiding any infirmary, hospital, institution, primary or secondary school, or charitable or religious

[18] Massachusetts General Laws, Chapter 164, Section 47E
[19] Massachusetts General Laws, Chapter 164, Sec 47C

undertaking which is not publicly owned and under the exclusive control, order, and supervision of public officials or public agents.[20]

Historically, this amendment has primarily been focused on denying public funding for private schools.[21] Some related issues that have been identified are:

1. While governments can't provide grants to non-profit agencies, they are allowed to purchase services from non-profit organizations in the same way they purchase services from for-profit entities.[22]
2. State funds can't be used for improvements to private historical residences, though federal grants are available for such purposes.[23]
3. In some cases, municipalities have eliminated subsiding non-profit programs such as food banks, in response to concerns about violating this amendment.[24]

Given existing precedent for the establishment of public-private partnerships discussed above, this concern seems less likely to present a fundamental barrier, and more likely to be merely a factor to examine in the City's legal review of the structure of a public-private partnership.

[20] Massachusetts Constitution, Article 18, Section 2 as amended by Article 23.
[21] http://paceorg.net/issues-and-advocacy/massachusetts-anti-aid-amendment/
[22] http://www.mass.gov/dor/docs/dls/mflb/opinions/2006-75.pdf
[23] http://www.mass.gov/dor/docs/dls/mflb/opinions/2006-230.pdf
[24] http://www.masslive.com/news/index.ssf/2015/05/easthampton_mayor_invokes_1855.html

14. Conclusion and Recommendations

Cambridge is already comparatively well-served in broadband versus many other parts of the United States. High speed broadband is generally available within City limits, and adoption of home broadband service is very high compared to national averages. Higher speed services are coming; Comcast has announced it will provide gigabit service across all of its national service footprint by 2018. Parts of the City have several incumbent carriers to choose from, at least for certain market segments, such as larger businesses and institutions.

Nonetheless, there is a sense within the City that the current state of broadband connectivity does not reflect Cambridge's ideals of itself as a cutting-edge place that can reliably attract and retain the kinds of businesses, entrepreneurs, and residents who will ensure the City's competitiveness, affordability and attractiveness throughout the 21st century. In particular, Cambridge exhibits a very real digital divide between wealthier residents and institutions who can afford to pay a higher premium for best-in-class connectivity, and other parts of the city that lack affordable yet fast connectivity targeted to ordinary residents and small businesses. In Cambridge, those who want the fastest service can get it – for a price. The cost of these services imposes a hardship on less-affluent Cambridge residents.

A significant source for what Cambridge finds lacking in its broadband choices is the lack of choices. There is very limited competition: 83% of home broadband customers get service through Comcast. A broadband market so heavily dominated by a single national provider offering levels of service similar to many other markets does not advance the Task Force's goals around local control or excellence. This is not to say that the broadband offered in Cambridge currently is necessarily unsatisfactory to everyone, only that it is not especially innovative or exceptional. Cambridge aspires to lead the pack, not be a member of it.

Cambridge also faces significant challenges in developing a best-in-class solution. The City has limited experience providing broadband service or operating a large, distributed fiber network that could provide service to residents. It has limited capacity for taking on such duties under its current organizational structures. Although the level of broadband adoption as well as public outreach and survey data collected for this report suggest that there is a demand for better broadband services and more choices among a significant fraction of Cambridge's population, any conclusions about potential subscription levels for a new market entry from this type of data are necessarily preliminary. Though we would expect no shortage of interest, at this early stage Cambridge has not yet explored who might be willing to partner with the City in building out, running or delivering new services over new network facilities.

The case studies cited in this report provide key lessons for a successful network buildout. Successful networks have a few things in common. First, they partner with an experienced market participant or develop experience themselves over time. This provides technical and operational know-how. Second, they build only what they can afford. Recognizing that the process to a comprehensive solution is a marathon, not a sprint, many successful endeavors have used a staged approach to building or expanding a municipal fiber network where they limit financial and operational exposure by expanding methodically, or they partner with an experienced third party. Third, successful networks amass experience and success on a smaller scale and thus achieve crucial buy-in from stakeholders for further expansion. This allows them to solve practical problems and absorb growing pains. Problems are smaller with a smaller network and are therefore more manageable.

With all the above in mind, Tilson recommends that Cambridge target building a limited, but expandable, dark fiber network and seek a partner or partners to manage and operate it. There are many service providers in Massachusetts who currently operate networks. The general idea is to work with this partner on the initial project, but keep the City's options open regarding further expansion. We believe that the City should use an initial project to generate Cambridge-specific data on questions such

as these, information it can use to make decisions about whether or how it should expand its development of broadband infrastructure and services further:

- If the City were to build a fiber network for use beyond its internal communications, what terms are potential network managers or operators prepared to offer the City to operate or manage the City's fiber?
- What public benefits are potential service providers prepared to offer in exchange for use of City-funded fiber, including in areas such as reduced-cost service to residents, businesses, and institutions, co-investment or other investments to expand the network beyond the City's investments?
- What level of City investment is likely to be required to extend gigabit fiber to all Cambridge premises, vs. investment generated by private entities in response to City investments?
- What level of demand is generated by users in areas of Cambridge that gain access to service delivered over a gigabit fiber?
- If the City were to expand access to dark fiber and/or fiber lit services, what additional network expansion or innovative services would be stimulated from private service providers, including from wireless broadband providers?
- What Cambridge institutions and businesses would be willing to share financially in the expansion of City fiber network in return for dedicated capacity on the resulting network?
- What alternative construction methods are vendors prepared to offer to address special construction challenges, such as the cost of underground construction?
- What relationship does the city have with the vendor (or partner) and what is involved in negotiating the terms of the relationship prior to starting?

It is vital to keep the network as flexible as possible in the early stages so as not to preclude future options, including further expansion of this initial network by the City. For example, the City would probably want to design the network to be capable of serving as a backbone segment for a potential citywide network, but also directly serving some targeted populations as well as premises passed.

This initial network should be thought of as an opportunity for the City to gain key experience and develop key supporting relationships before fully committing to a larger entrance into the broadband space. Cambridge should keep investment in the network small enough so that the project not recouping its costs would be tolerable. If reduced-cost service is not otherwise part of a partnership agreement, the City should examine an aggregated purchase of broadband service on the network that it can then deliver at a discounted rate to disadvantaged citizens. By including private partners, Cambridge will greatly limit its exposure to operating and execution risks.

As Cambridge gains experience in broadband, it should carefully track the market's response. Learning the location and price tolerances of potential customers will provide valuable input into network expansion planning. Also, incumbent operators will likely adjust their pricing structures in an attempt to forestall further development of the municipal network, by taking advantage of their largely sunk capital costs to offer discounts on existing prices.

Finally, underground portions of all three proposed build options comprise a very high amount of the total cost. The City would do well to decrease uncertainty around underground construction costs within City limits. Of particular note would be determining parameters around which the City could use existing conduit, including legal implications and available conduit paths. Tilson also recommends that Cambridge explore other potentially acceptable construction standards that would lower these costs.

By embarking on a carefully planned, staged approach, Cambridge maximizes the likelihood of success in achieving its broadband goals and positioning itself as a world-class, forward-looking city that offers residents, would-be residents, and entrepreneurs a premier place to live, work, and play. The solution

for Cambridge is not solving an engineering problem. It is ensuring that goals are clearly defined, risks are understood, and cost commitments are acceptable.

15. Next Steps

Tilson's analysis assumes that ultimately the City would like to see new City-wide or near City-wide gigabit-capable service from one or more new fiber-based competitors, achieved through some combination of public and private investments. This section provides a roadmap of next steps that the City can take to advance toward this future.

In planning this roadmap, key questions to answer at the outset are:

- Is the City willing to build (or at the very least fund) at least some parts of the network infrastructure required to achieve this objective?
- Is it important to the City to operate what it builds?

The answers to these questions will determine a significant number of the next steps on the City's roadmap. We assume here that the answer to the first question is "yes": Cambridge is willing to build and/or fund some parts of the required infrastructure. We also assume that operation of City-funded or –constructed fiber infrastructure by the City itself is something the City might consider if it needed to, but that sharing the risks of operating a network by engaging one or more private partners is preferred if terms that help meet the City's goals are achievable.

These assumptions mean that the first key tasks Cambridge must undertake are:

1. Developing a more specific scope of the network that the City is willing to build and/or fund
2. Seeking private partners

As part of this roadmap, we assume that an initial project would provide dark fiber access, but that dark fiber access alone wouldn't be sufficient to meet the objectives of the City; the City would want to be assured of at least one gigabit fiber-to-the-premise service provider delivering broadband to homes and businesses using the network. Alternatively, Cambridge may elect a more conservative approach if it wanted to reserve the decision about whether to build out or even deliver services itself until after it had gained some experience through the initial construction period. In this mode, the City could get the limited network up and running prior to seeking a private partner to deliver FTTP services over it and expand the network.

If the City were to opt to build a network that it would operate itself, some elements of the resulting roadmap could still be the same. Items 1, 6, and 7 in the below roadmap would be the same even if the City were to develop and operate its own network.

1. Develop a specific starting network proposal achieving a limited set of initial objectives, but creating a platform for expansion to meet a broader set of City objectives. A limited network would include either the Targeted or Partial network options described in this report, or might contain elements of either one. We suggest that the scope of the starting network not be larger than can be sustained financially by the City using general tax revenue if necessary, less any firm up-front financial commitments by "anchor users".
    a. Identify and involve "anchor users" who may be able to make large early commitments and may also at least partially underwrite the costs. These could include organizations such as the CHA, Leslie University[25], other academic institutions, or telecom companies interested extending/deepening their networks

[25] Leslie University is named in this list due to comments provided by University representatives at the second outreach forum explaining that the University had examined sites within Cambridge for possible expansion, but in some cases limited options for connecting these sites to other Leslie buildings had constrained these expansion options.

in Cambridge. Examples of such telecom companies are dark fiber, oDAS[26], or enterprise fiber-based ISPs. This would likely be direct informal outreach supplemented by an RFI.

b. Develop medium-level cost designs and estimates. Involve potential "anchor users" as partners. Examine the impact of alternative routes parameters/ requirements. Produce scenarios to evaluate the alternatives.
c. Collect detailed data about conduit availability and the ability to provide mid-segment access along routes where underground facilities are being considered. Reach a legal conclusion about the City's right to utilize third-party conduit for commercial purposes.
d. Explicitly document City engineering requirements for new underground construction to the extent that existing conduit is not available or feasible. Solicit engineering opinions about alternative methods of underground construction that could meet City needs at a lower cost or provide more flexibility.
e. If the City chooses to use certain portions of existing City fiber in the new network, it should conduct a detailed inventory of utilization levels of City fiber strands on existing city fiber routes being considered in the starting network scenarios, as well as specific access routes into City buildings that would be required.
f. Identify a specific acceptable point(s) of interconnection along route for service providers. The point or points would be the location of facilities that can house the network interconnect equipment.
g. Include in the designs extra capacity to facilitate expansion/extension of the network (e.g. high fiber strand counts and frequent points of access).
h. Evaluate the estimated total cost against City budget constraints, and re-scope as necessary.

2. Prepare for soliciting involvement of private partners in the operation of the starting network and/or developing additional facilities off of it by taking stock of what levels of City involvement are acceptable to the City. These levels can involve either a maximum, driven by the extent to which the City desires to limit its costs or mitigate its risks, or a minimum, driven by the extent to which the City wants to ensure a degree of involvement and control.
    a. capital spending
    b. operating expense
    c. operating involvement
    d. any minimum revenue requirement that needs to be derived
3. Conduct an RFP-type process for the various portions of network operation and management that the City may wish to outsource:
    a. Network construction
    b. Dark fiber network operator
    c. Lit services operator

    These may be conducted at the same time, and the City may or may not allow or encourage the same company to manage both dark fiber and lit service.
4. The City will need to begin the process of finding an operating partner in accordance with the network design and goals identified in step 1 above. It should develop and begin implementing an RFP process to solicit an anchor FTTP provider(s) and ultimately to enter into an agreement with terms including:
    a. Additional private investment/build-out beyond what the City is providing
    b. Operational responsibilities
    c. Cost and revenue sharing arrangement
    d. Speed and other service quality commitments
    e. Price parameters for services offered

[26] Outdoor Distributed Antenna System, a network of spaced-apart antennae connected to a common transmitter used to enhance cellular coverage in a high-density environment.

f. Open access requirements, if any
g. Upgrade requirements
h. Length of the commitment/termination

5. Detailed engineering with input from operating partner and FTTP provider, if applicable
6. Construction RFP

If the City does not receive responses to its RFP that satisfactorily address its goals for the expansion of infrastructure throughout the City and the delivery of improved services, then the City can re-assess the extent of the network it is planning to build and re-scope and re-issue the RFP, or re-consider delivering service through a city-operated department. It seems unlikely, however that a community like Cambridge would not receive any suitable responses. More likely than no suitable responses would be responses that omit building out to all desired locations or otherwise do not meet all the City's stated goals. Such responses could be addressed by supplementing the City's proposed network build, rather than starting over from scratch.

At the end of these six major steps, each posing its own capital and operational requirements, Cambridge will be poised to begin construction of the first phase of a world-class municipal broadband solution that addresses the Task Force's five goals for improved broadband access. It will likely take the form of a public-private partnership, where the City owns some or all of the infrastructure and its partner or partners operate on that infrastructure. As Cambridge and its partner gain experience and a deeper understanding of the market, the City will have the option to further develop the network. The partnership's experience will prove vital in determining the extent and type of network expansion.

16. Appendix A: Residential Internet Offerings[27]

Error! Reference source not found. provides a comparison of each company's fastest residential internet d ownload speed offerings and associated pricing.

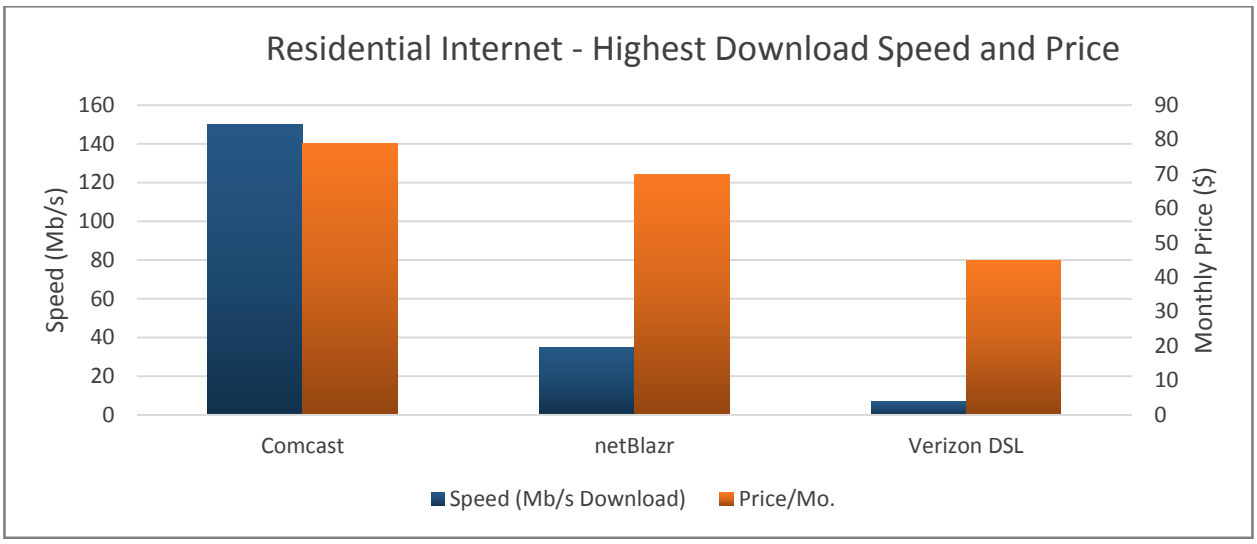


Figure 15: Residential Internet – Highest Speed Offered

Per Error! Reference source not found. below, the next tier of service by netBlazr and Comcast provides 1 5 and 25 times more speed, respectively, for a slightly higher monthly cost.

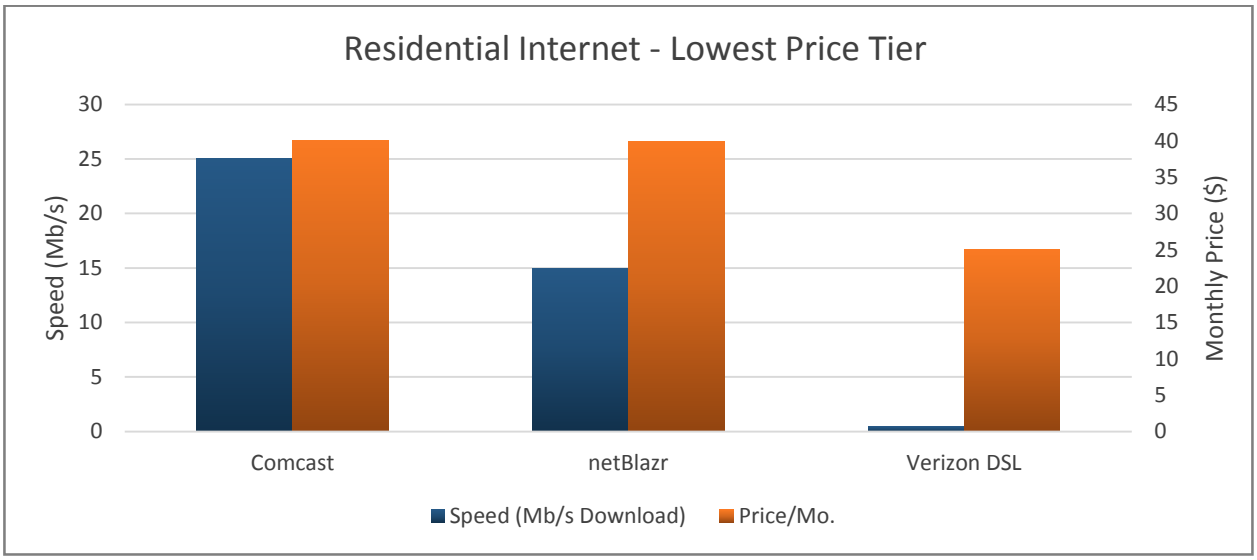


Figure 16: Residential Internet - Lowest Price Offered

Error! Reference source not found. provides a comparison of the cost per megabit for each company's l owest pricing tier. Higher speed tiers, perhaps unsurprisingly, reflect a lower cost per unit bandwidth than lower tiers.

[27] Pricing across all residential internet service providers were obtained in October 2015 and revisited in February 2016 for accuracy.

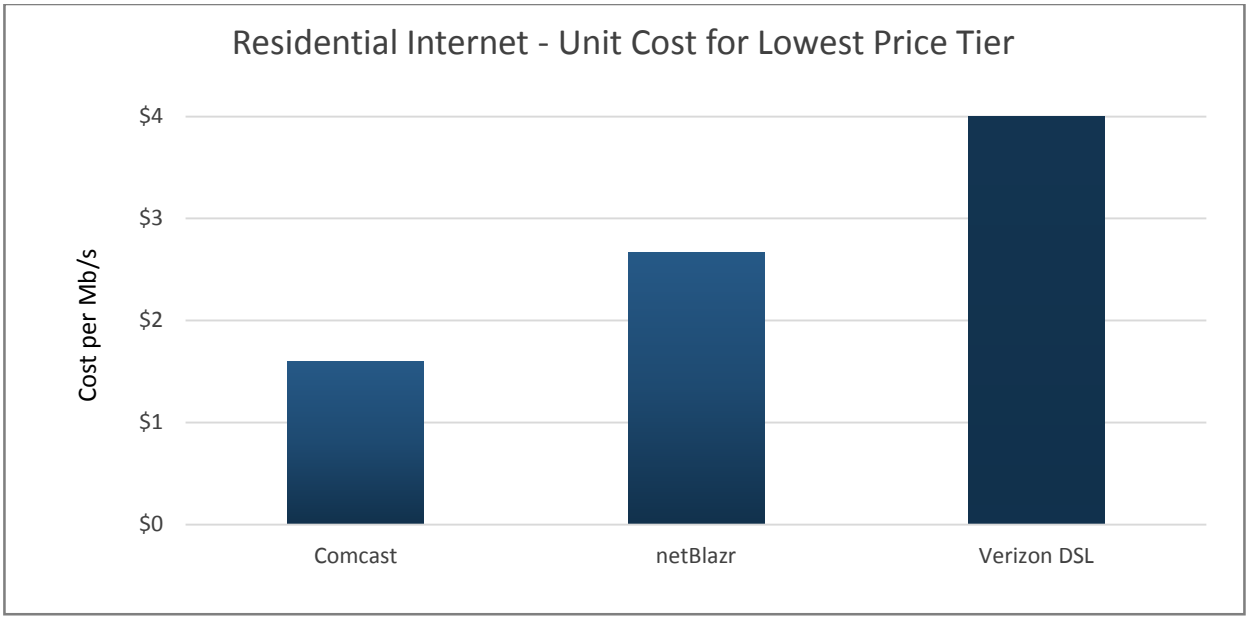


Figure 17: Residential Internet - Cost per Megabit for Lowest Price Offered

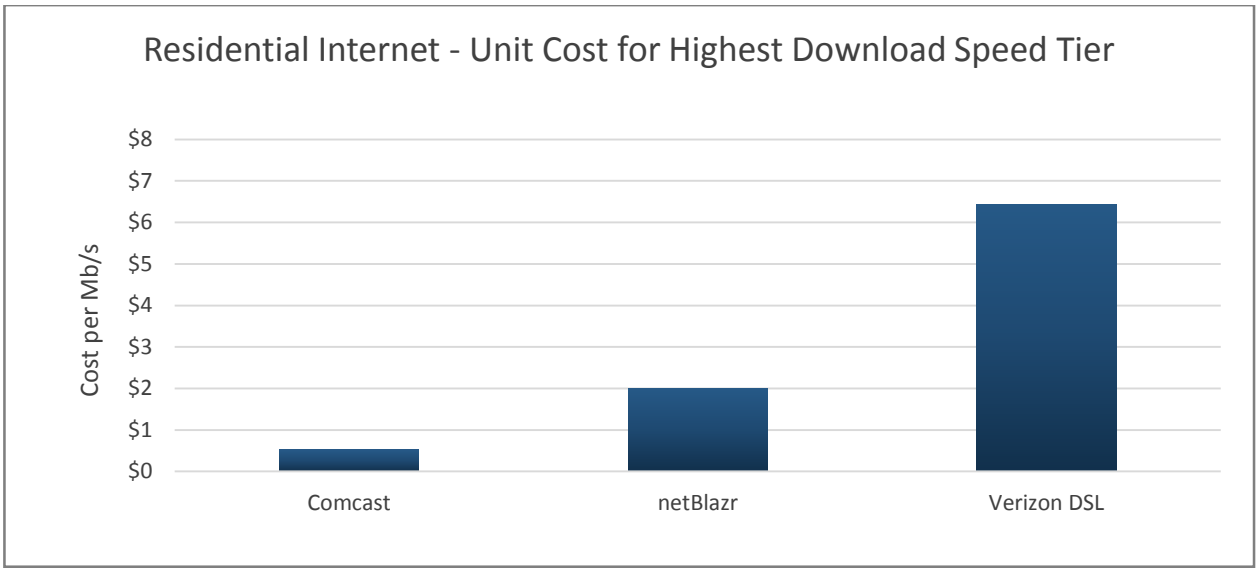


Figure 18: Residential Internet - Cost per Megabit for Highest Download Speed Offered

Comcast

Xfinity High Speed Internet

Name	Monthly Price/Term	Download/Upload (Mbps)	Other
Economy Plus	$39.95/None	3/unknown	N/A
Performance Starter	$49.95/None	6/unknown	N/A
Performance	$29.99/12 months; $39.99 thereafter	25/unknown	Includes hotspot access
Performance Pro	$76.95/None	75/unknown	Includes hotspot access
Internet Plus	$39.99/12 months; $49.99 thereafter	25/unknown	Includes hotspots, HBO, and Streampix
Internet Pro Plu w/ X1	$49.99/12 months; $59.99 thereafter	75/unknown	Includes hotspots, Streampix, and HBO or Showtime
Blast	$78.95/None	150/unknown	Includes hotspot access

Bundles

Name	Monthly Price/Term	Download/Upload (Mbps)	Other
X1 Starter Double Play	$79.99/12 months; $123.90 thereafter	25/unknown	140 TV channels
X1 Preferred Double Play	$89.99/12 months; $123.90 thereafter	75/unknown	220 TV channels incl. Showtime
X1 Starter Triple Play	$89.99/12 months; $147.49 thereafter	75/unknown	140 TV channels, unlimited phone, $100 Visa gift card. Requires 2 year agreement.
HD Preferred Plus Triple Play	$139.99/12 months; $190.49 thereafter	150/unknown	230 TV channels, unlimited phone, $100 Visa gift card, HBO and Starz included. Requires 2 year contract.

Verizon

Internet and Phone

Name	Monthly Price/Term	Download/Upload (Mbps)	Other
High Speed Internet	$24.99/12 months	Up to 1/0.375	Requires home phone line of additional $10-20/month
High Speed Internet Advanced	$34.99/12 months	Up to 7/0.75	Requires home phone line of additional $10-20/month

Internet, Phone, and TV Bundles

Name	Monthly Price/Term	Download/Upload (Mbps)	Other
Option 1	$69.99/12 month contract	Up to 1/0.375	Includes 220 DirecTV channels and HD DVR; “Regional Essentials” phone plan
Option 2	$79.99/12 month contract	Up to 3/0.75	Includes 220 DirecTV channels and HD DVR; “Regional Essentials” phone plan
Option 3	$94.99/12 month contract	Up to 7/0.75	Includes 240+ DirecTV channels, wifi router, “Freedom Essentials” phone plan

FIOS

Name	Monthly Price/Term	Upload/Download (Mbps)	Other
Quantum Internet 50	$44.99/12 months; $54.99 thereafter. Requires 2 year contract	50/50	N/A
Quantum Internet 100	$54.99/12 months; $64.99 thereafter. Requires 2 year contract	100/100	N/A
Quantum Internet 150	$64.99/12 months; $74.99 thereafter. Requires 2 year contract	150/150	N/A

Quantum Internet 300	$164.99/12 months; $174.99 thereafter. Requires 2 year contract	300/300	N/A

FIOS Bundles

Name	Monthly Price/Term	Upload/Download (Mbps)	Other
FIOS Double Play – 25/25	$79.99/24 months; $150 installation	25/25	Includes regional calling
FIOS Double Play – 50/50	$89.99/24 months; $150 installation	50/50	Includes regional calling
FIOS Double Play – 75/75	$99.99/24 months; $150 installation	75/75	Includes regional calling

netBlazr

Name	Monthly Price/Term	Upload/Download (Mbps)	Other
Standard	$39.95; $199 installation	Up to 15/15	N/A
Premium	$69.95; $199 installation	Up to 35/35	N/A

17. Appendix B: Residential Voice Offerings[28]

Comcast

Name	Monthly Price/Term	Activation Fee	Other
Xfinity Voice Unlimited	$29.99/6 months; $44.95 thereafter	$29.95	Unlimited nationwide calling
Xfinity Voice Local with More	$34.95/None	N/A	$0.05/min for long distance

Verizon

Name	Monthly Price/Term	Activation Fee	Other
Freedom Essentials	$63.99	None	Unlimited nationwide calling

[28] Pricing across both residential voice providers were obtained in October 2015 and revisited in February 2016 for accuracy.

18. Appendix C: Wireless Voice Offerings (Postpaid Subscribers)[29]

Verizon Wireless

Name	Monthly Price	Includes	Add'l Lines
Small	$50	1GB for 1 smartphone; unlimited talk/text	$20 each
Medium	$65	3GB for 1 smartphone; unlimited talk/text	$20 each
Large	$80	6GB for 1 smartphone; unlimited talk/text	$20 each
XL	$100	12GB for 1 smartphone; unlimited talk/text	$20 each
XXL	$120	18GB for 1 smartphone; unlimited talk/text	$20

AT&T Wireless

Name	Monthly Price	Includes
300 MB	$45 w/ AT&T Next $60 w/ 2 year contract	300 MB; unlimited talk/text
2 GB	$55 w/ AT&T Next $70 w/ 2 year contract	2 GB; unlimited talk/text
5 GB	$75 w/ AT&T Next $90 w/ 2 year contract	5 GB; unlimited talk/text
10 GB	$115 w/ AT&T Next $140 w/ 2 year contract	10 GB; unlimited talk/text
20 GB	$155 w/ AT&T Next $180 w/ 2 year contract	20 GB; unlimited talk/text
25 GB	$200 w/ AT&T Next $215 w/ 2 year contract	25 GB; unlimited talk/text
30 GB	$240 w/ AT&T Next $265 w/ 2 year contract	30 GB; unlimited talk/text
40 GB	$315 w/ AT&T Next $340 w/ 2 year contract	40 GB; unlimited talk/text
50 GB	$390 w/ AT&T Next $415 w/ 2 year contract	50 GB; unlimited talk/text

T-Mobile

T-Mobile offers the Simple Choice plan. All variants include unlimited calls and texts to North American numbers and free data roaming in Canada and Mexico. Data usage over the purchased allotment is unlimited but throttled. Additional lines are $30 for the first and $10 each after that. All data plans include unlimited free video streaming from HBO and Netflix.

Name	Monthly Price
2 GB	$50
6 GB	$65
10 GB	$80
Unlimited	$95

Sprint

Sprint requires a 24 month agreement on all plans.

Name	Monthly Price	Includes
XS	$65 with 2 yr contract; $50 with lease	1 GB; unlimited talk/text and 2G data

[29] Pricing across all wireless voice providers were obtained in October 2015 and revisited in February 2016 for accuracy.

S	$75 with 2 yr contract; $50 with lease	3 GB; unlimited talk/text and 2G data
M	$90 with 2 yr contract; $65 with lease	6 GB; unlimited talk/text and 2G data
L	$105 with 2 yr contract; $80 with lease	12 GB; unlimited talk/text and 2G data
XL	$125 with 2 yr contract; $100 with lease	24 GB; unlimited talk/text and 2G data
XXL	$145 with 2 yr contract; $120 with lease	40 GB; unlimited talk/text and 2G data
Unlimited	$100 with 2 yr contract; $100 with lease	Unlimited talk/text and high speed data.

19. Appendix D: Live Video Broadcast Service Offerings[30]

Comcast Xfinity

Name	Monthly Price (Promo/After)	Includes
Digital Starter	$49.99/$69.95	140 channels
Digital Preferred	$59.99/$87.90	220 channels
Digital Premier	$69.99/$138.90	260+ channels incl TMC, HBO, Cinemax, etc.

DISH Network

Name	Monthly Price (Promo/After)	Includes
Smart Pack	$19.99/$34.99	55 channels
America's Top 120	$29.99/$59.99	190 channels
America's Top 120+	$34.99/$64.99	190 channels plus sports
America's Top 200	$39.99/$74.99	240 channels
America's Top 250	$39.99/$84.99	290 channels

DISH Network also offers two year contracts for the Top 120, Top 200, and Top 250 plans at $49.99, $64.99, and $74.99 per month, respectively.

DirecTV

Name	Monthly Price (Promo/After)	Includes
Select	$19.99/$299	145 channels
Entertainment	$24.99/$34.99	150 channels
Choice	$29.99/$39.99	175 channels
Xtra	$34.99/$44.99	220 channels
Ultimate	$39.99/$49.99	240 channels
Premier	$89.99/$99.99	315 channels

[30] Pricing across all video providers were obtained in October 2015 and revisited in February 2016 for accuracy.

20. Appendix E: Small Business Internet Offerings[31]

Error! Reference source not found. displays each service provider's fastest download speed package, a nd **Error! Reference source not found.** provides the unit cost for each megabit for this maximum speed tier.

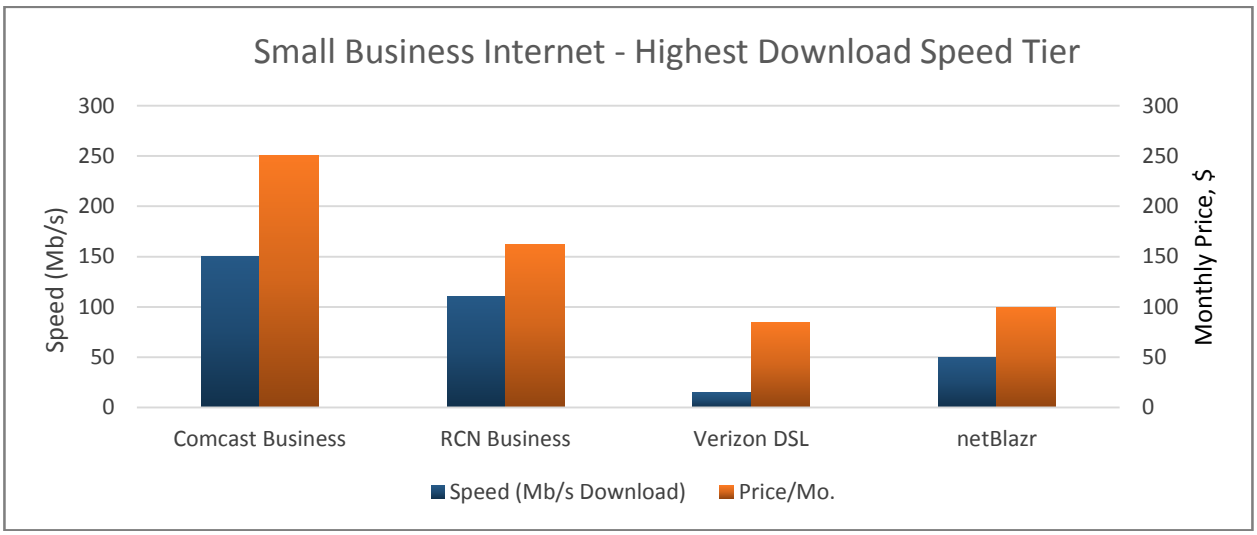


Figure 19: Small Business Internet - Highest Download Speed Tier Offered City-wide

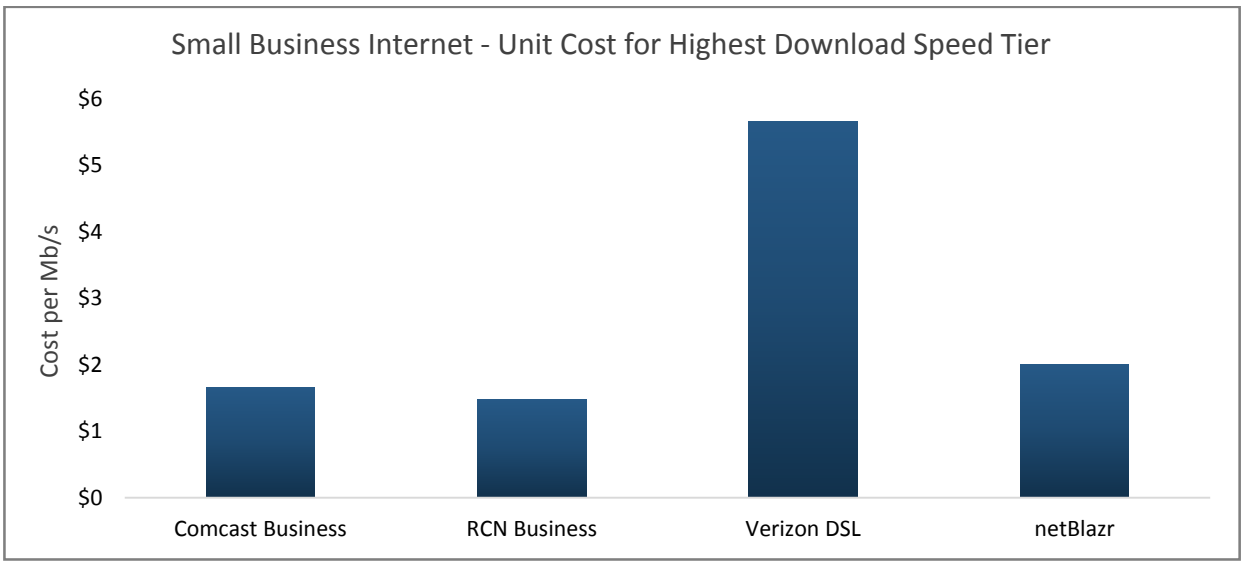


Figure 20: Small Business Internet - Cost per Megabit for Highest Download Speed Offered

Comcast Business

Name	Monthly Price	Download/Upload (Mbps)	Other
Starter	$69.95; $89.90 with phone service	16/3	1 yr contract
Deluxe 25	$99.95; $99.90 with phone service	25/10	1 yr contract
Deluxe 50	$109.95; $119.90 with phone service	50/10	1 yr contract
Deluxe 75	$149.95; $139.90 with phone service	75/15	1 yr contract

[31] Pricing across all small business internet providers were obtained in October 2015 and revisited in February 2016 for accuracy.

Deluxe 100	$199.95; $179.90 with phone service	100/20	1 yr contract
Deluxe 150	$249.95; $209.90 with phone service	150/20	1 yr contract

Verizon DSL

Name	Monthly Price	Download/Upload (Mbps)	Other
Starter	$29.99; $64.99 with phone service	1/0.375	2 yr contract; $49.99 installation
Quick	$37.99; $74.99 with phone service	3/0.75	2 yr contract; $49.99 installation
Fast	$54.99; $74.99 with phone service	5/0.75	2 yr contract; $49.99 installation
Faster	$74.99 with or without phone service	7/0.75	2 yr contract; $49.99 installation
Fastest	$84.99; $74.99 with phone service	15/1	2 yr contract; $49.99 installation

Verizon FIOS

Name	Monthly Price/Term	Download/Upload (Mbps)	Other
FiOS Internet 25	$64.99/24 months	25/25	2 yr contract
FiOS Internet 50	$89.99/24 months	50/50	2 yr contract
FiOS Internet 75	$114.99/24 months	75/75	2 yr contract
FiOS Internet 150	$184.99/24 months	150/150	2 yr contract
FiOS Internet 300	$254.99/24 months	300/300	2 yr contract
FiOS Internet 500	$359.99/24 months	500/500	2 yr contract

In addition, most FiOS plans are available with two bundled phone lines for $30-35/month extra.

RCN Business

Name	Monthly Price With/Without Contract	Download/Upload (Mbps)	Other
25	$45/80 $89.99/139.98 with phone	25/5	1-3 yr contract
50	$90/100 $99.99/159.98 with phone	50/10	1-3 yr contract
75	$115/160 $109.99/219.98 with phone	75/15	1-3 yr contract
110	$155/175 $119.99/219.98 with phone	150/15	1-3 yr contract

netBlazr

Name	Monthly Price	Download/Upload (Mbps)	Other
Internet Service	$99.95	50/50	No contracts. Wireless provider. Up to 1TB/month data transfer.

MegaPath

MegaPath offers many DSL-based plans with download speeds ranging from 1.5-20Mbps and upload speeds ranging from 0.384-2Mbps. Depending on the selected contract term of 12-36 months, monthly prices range from $59 to $95 with installation fees of up to $349.

21. Appendix F: Enterprise and Large Business Offerings[32]

Error! Reference source not found. and **Error! Reference source not found.** show the wide variation in th e four providers' fastest download speed offerings and unit price.

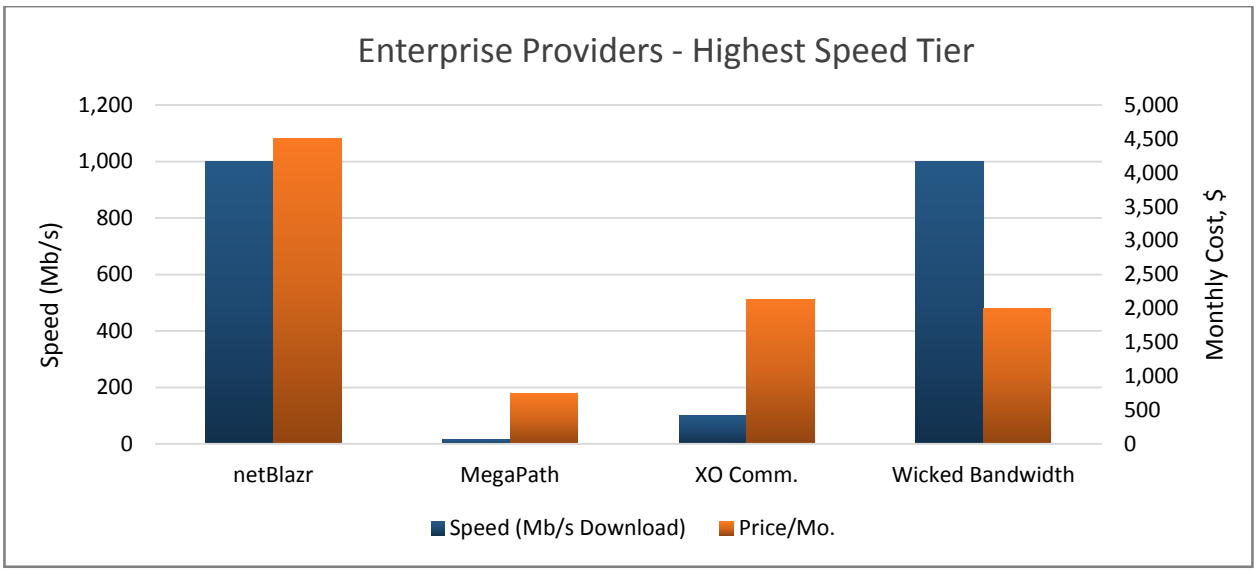


Figure 21: Enterprise Class Internet Providers - Highest Speed Offered

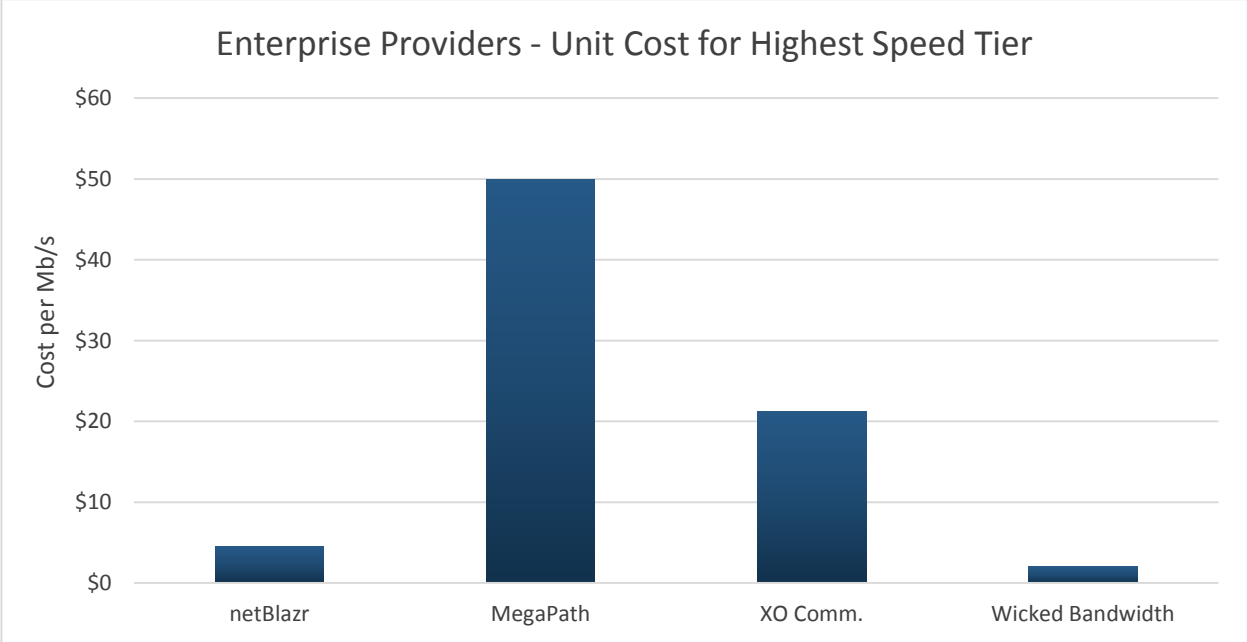


Figure 22: Enterprise Class Internet Providers - Cost per Megabit for Highest Speed Offered

[32] Pricing across all enterprise and large business providers were obtained in October 2015 and revisited in February 2016 for accuracy.

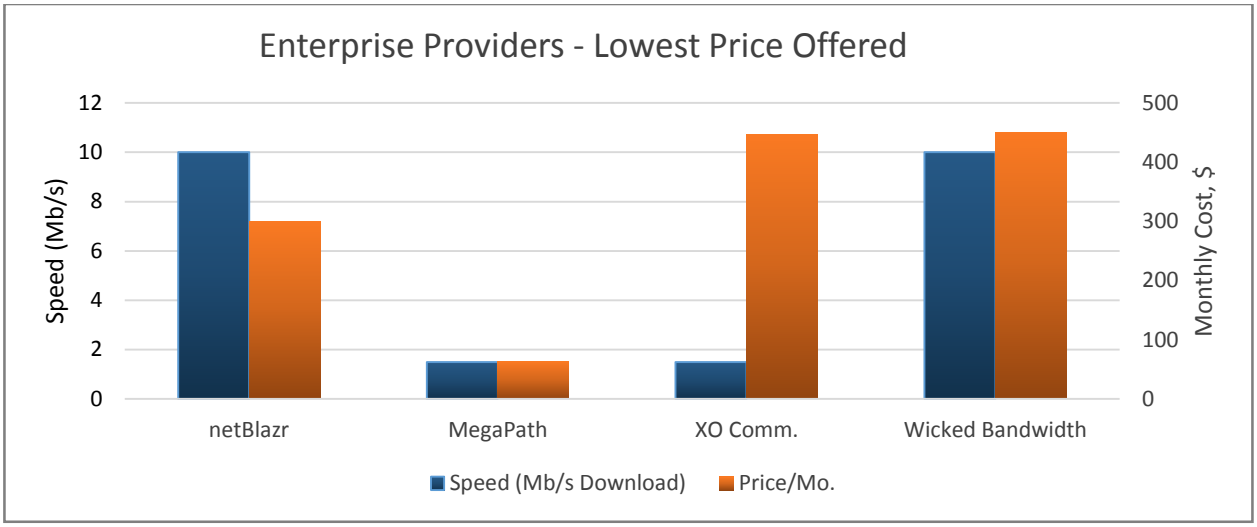


Figure 23: Enterprise Class Internet Providers - Lowest Price Offered

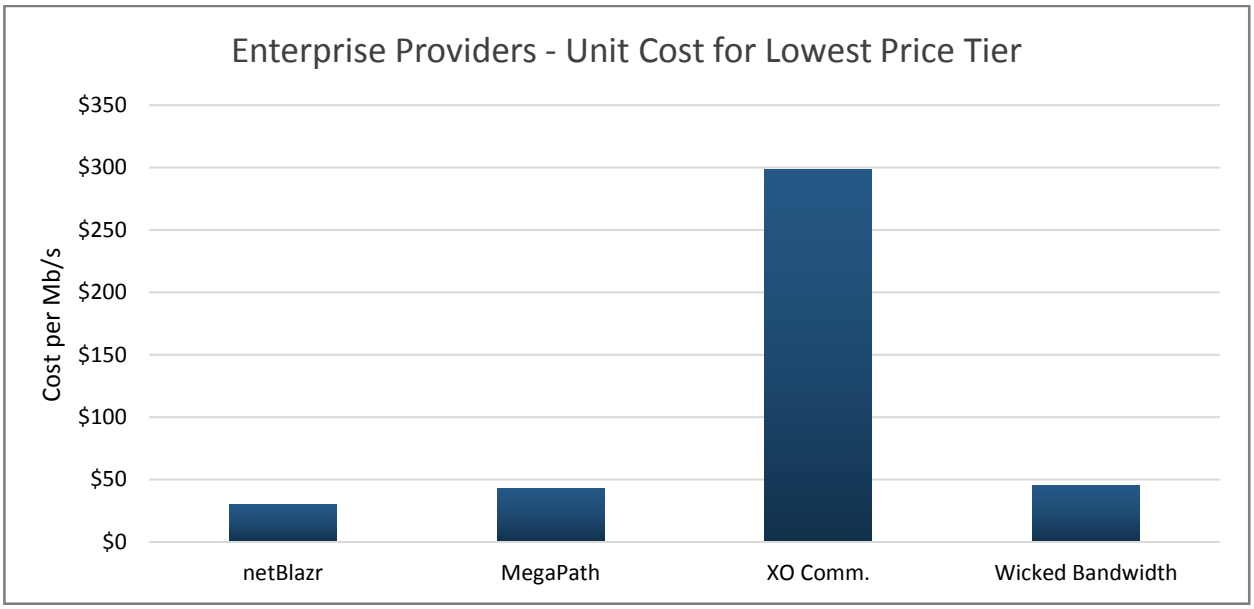


Figure 24: Enterprise Class Internet Providers - Cost per Megabit for Lowest Price Offered

netBlazr

Name	Monthly Price	Download/Upload (Mbps)
10	$299.95	10/10
20	$599.95	20/20
50	$1249.95	50/50
100	$1499.95	100/100
200	$2199.95	200/200
250	$2499.95	250/250
300	$2699.95	300/300
500	$2999.95	500/500
1000	$4499.95	1000/1000

Wicked Bandwidth

Name	Monthly Price With/Without Contract	Download/Upload (Mbps)	Other
10	$450	10/10	3 yr contract; No installation fee
50	$750	50/50	3 yr contract; $1000 installation fee
100	$1050	100/100	3 yr contract; $1000 installation fee

500	$1350	500/500	3 yr contract; $1000 installation fee
1000	$2000	1000/1000	3 yr contract; $1000 installation fee

XO Communications

Name	Monthly Price With/Without Contract	Download/Upload (Mbps)	Other
1.5	$447	1.5/0.375	3 yr contract
10	$971	10/10	3 yr contract
50	$1404	50/50	3 yr contract
100	$2128	100/100	3 yr contract

22. Appendix G: Outreach Session #1 Issues & Recommendations

Affordability

- Providing access for:
  - Low-income students
    - Small investment, big return
  - Low-income residents
  - Low-income senior citizens
  - Public housing residents
- Lower prices, higher speeds
  - Lack of competition and value today
- Free internet structure
  - Public → City provided service
  - Private → Comcast enhances "hot-spots" quality
  - Indispensable
  - Internet is necessary to function in today's environment
- Comcast "Internet Essentials" program is not working
  - There are too many barriers in place

Competition & Choice

- Fiber network needed
- Need a greater choice of internet service providers
- Wi-Fi City-wide
- Include wireless data as competitors
- Municipal system vs. competition
- Public-private partnership
- Internet service is a basic need today

Local Control

- Equity
  - Broadband is essential to everyone and should be available to all households
- Autonomy
  - Cambridge should not be reliant on "outsiders" whose motivation is profits rather than public good
- Public Policy
  - To address equity and autonomy issues, the City should own and manage its own broadband network
  - The City should exert greater regulatory control over other providers
    - Emergency connectivity
    - Internet access for all

Innovation & Excellence

- Innovation
  - WISP Network
    - City could potentially do what NetBlazr is doing
  - Spectrum availability and the rights for the City to utilize it
- Excellence
  - High Speeds + 100% Reliability + Great Customer Service = Excellence
  - "Go Big"
    - Deploy a fiber network to avoid only marginally improving the issue
    - Aiming for capability that will be good for the long run

        - 1 Gigabyte speeds to homes is now normal
    - 1 Gig to homes and a backbone that can support the traffic

23. Appendix H: Outreach Session #1 Voting Results

Issues consolidated with multi-voting structure. Each participant was given three (3) dots, each representing a vote.

Voter Classifications:
- live in Cambridge
- manage a business in Cambridge
- deliver public or nonprofit services in Cambridge

Issue Category	Affinity Group Recommendation	Votes
Local Control	The City should own and manage its own broadband network to address equity and autonomy issues	22 (21 Green, 1 Red)
Innovation & Excellence	"Go Big" - High Speeds + 100% Reliability + Great Customer Service = Excellence. Deploy a fiber network to avoid only marginally improving the issue by providing high speeds to residents that will be sustainable in the long-term	16 (14 Green, 1 Red, 1 Blue)
Affordability	Provide access to low-income students, low-income senior citizens, low income residents, and public housing residents	13 (All Green)
Affordability	Providing access and equity, including price, availability, wireless availability, and a free tier of service	12 (11 Green, 1 Red)
Competition & Choice	Need a greater choice of internet service providers	9 (8 Green, 1 Blue)
Competition & Choice	Fiber network needed	4 (All Green)
Affordability	Free Internet structure	2 (Both Green)
Competition & Choice	Wi-Fi City-wide	2 (Both Green)

24. Appendix I: Outreach Session 2

How Better Broadband across Cambridge Supports my Organization (Outreach Session #2)

Group 1

- Faster connection supporting start-ups. Great connections are not a concern in conducting business.
- Expense for Comcast or the like are too expensive
- Poor symmetric service options
- Poor fiber options between campus locations (Lesley University)
    - Limiting Cambridge expansion
- Opportunities to collaborate with K-12 schools
- Training in maker spaces "frictionless"
- City of Cambridge is a technology ideas leader – practice what you preach
- Digital divide for students – access to online content, bus schedule, etc.
- General affordability issues
- Big issues digging up streets – fiber diversity even for big companies
- More marketable properties for landlords
- Really great infrastructure without multiple excavations
- Conduit infrastructure too expensive for individual users
- Redundant connections
    - Route diversity
    - Carrier diversity
- Ability to access cloud-based apps at home, work, and coffee shops
- Ability to be a smart City – sensors
- More options for video origination throughout City
- Support student learning
- Better informing of the community
- Economic development selling point
- More alternatives to students
- Supporting innovators
    - Growing local economy
    - Solving global problems
- Remaining competitive as innovation economy
- More opportunity for those currently on the wrong side of the digital divide
- Ability for students to do homework at home

Group 2

- Business model depends on users having high quality, affordable broadband
- Need better service from current providers for multiple locations in Cambridge
- Affordable fiber for small business and non-profits
- The number of ISP's is not the problem, it's cost
- Hi-technology business employers expect quality internet
- Broadband internet helps quality of life
- ALL parts of Cambridge need high quality as businesses grow and expand
- Better price/performance
- Robust networks

What Is/Isn't the Problem Exercise

Group 1

Broadband to my Organization	
Is The Problem	**Is not the Problem**
Only copper networks in some areas	Some areas have fiber networks
Number of devices and diversity of services	Metro A Loop that connects to Summer Street
Summer Street vulnerability	
Upload ability for creative digital media	

Broadband Across the City	
Is The Problem	**Is not the Problem**
Highest residential tiers must buy Comcast TV	Comcast raising speeds without raising prices
Limited time Comcast discounts	City, Google & M.I.T. collaboration on Kendall Square Wi-Fi project
Limited access to Verizon FiOS	Harvard Square Wi-Fi project has a supporting coalition
Lost opportunities when digging up streets	Initial capital cost of new networks
Distributing broadband inside CHA buildings	High demand for great broadband
Dedicated support (long-term) for new City projects	
Affordable access at housing authority and Wi-Fi in the squares	
Poorly executed Central square Wi-Fi	
Public spaces Wi-Fi	

Group 2

Broadband to my Organization	
Is The Problem	**Is not the Problem**
New construction	Use of City conduit (if available)
Building codes and landlords need to require fiber into units	

Broadband Across the City	
Is The Problem	**Is not the Problem**
Broadband internet not a public utility like electric and water	Basic access
Uneven levels available	Working with the City
If it's not fiber, it's not sufficient	
Can't always get what's needed	
Lack of dedicated fibers between buildings	

Blog Post from the Future Exercise

Group 1

- City talked to carriers and business partners and found out what they wouldn't do
- Pooling of resources
    - City
    - University
    - Large businesses
- Decided appropriate role for the City
- Broadband internet access regardless of ability to pay
- Students have better, more equal opportunity
- No more snow days
- Higher education opportunities at home
- Access to better tutoring or specialists
- All student content always available
- Better employee recruitment
- "Work anywhere" more possible
- Trained parents as well as students
- Decided this was infrastructure with limited private business case
- Wireless devices have gotten faster
- Better tools
- Better chargers
- No buffering
- Great Wi-Fi ubiquitous
- Gigabyte broadband on municipality not as "Welcome to Cambridge"
    - Local information utility
    - Resource for City
- Kids can do homework at home
- Free internet like free school lunch program
- We made a comprehensive plan
- Plan with multiple services
- Schools, universities, service providers, and businesses were involved
- Started small, but grew
- Hired team of people to cover different services
- Made a compelling business case to carriers/business partners
- Provided a base tier, and additional tiers
- Spent time talking to people on wrong side of digital divide
- City created fiber mandate and vision

Group 2

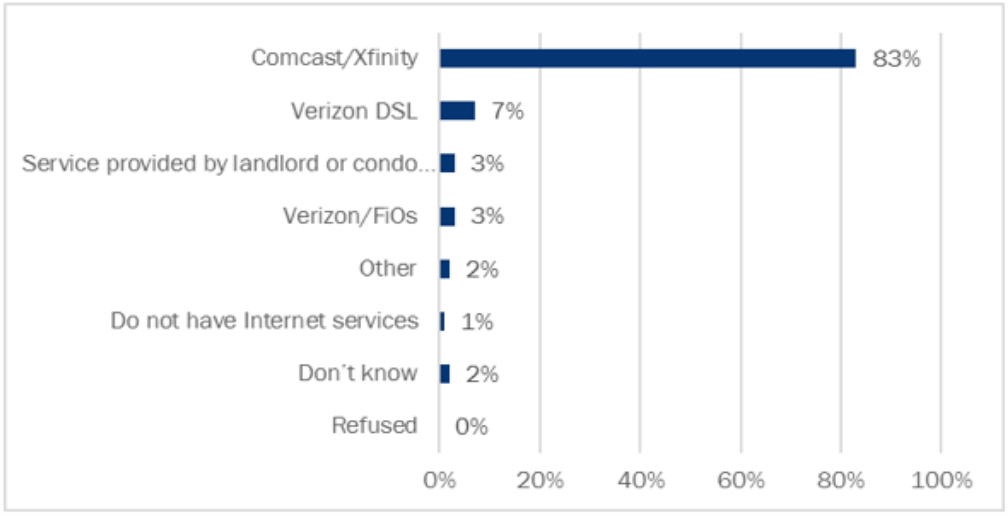
- Competitive pricing has lowered costs to residents
- Capital costs recouped over decades
- Cambridge becomes an even more attractive place for residents and businesses
- Greater use of "the cloud"
- Students are happier and more productive
- Attracted smaller ISP's
- High quality video streaming
- More reliable
- Public utility – City-owned conduit
    - Large capacity conduits

- Public Wi-Fi across the City
- Leased ONT's
- New developers must connect into City network

25. Appendix J: Opinion Dynamics Survey Results

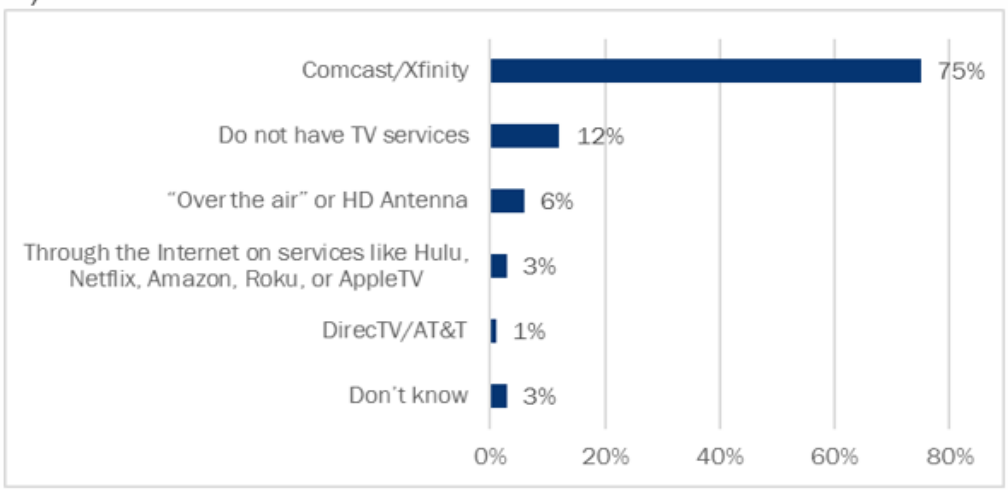
Primary Internet Service Provider

What is the name of the ***primary*** provider of Internet services for your home? (n = 403)



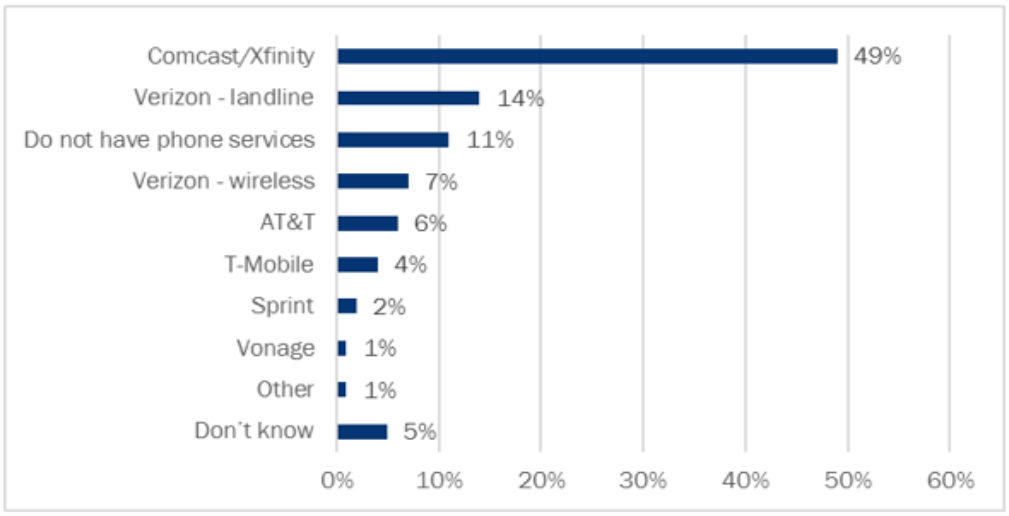
Primary TV Service Provider

What is the name of the ***primary*** provider of TV services for your home? (n = 403)



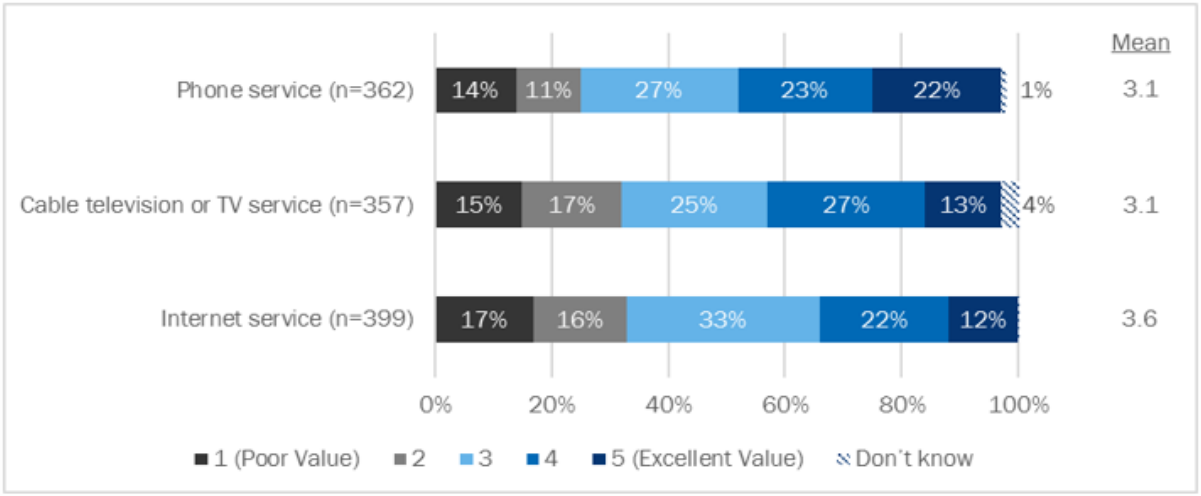
Primary Phone Service Provider

And, what is the name of the ***primary*** provider of phone services for your home? (n = 403)



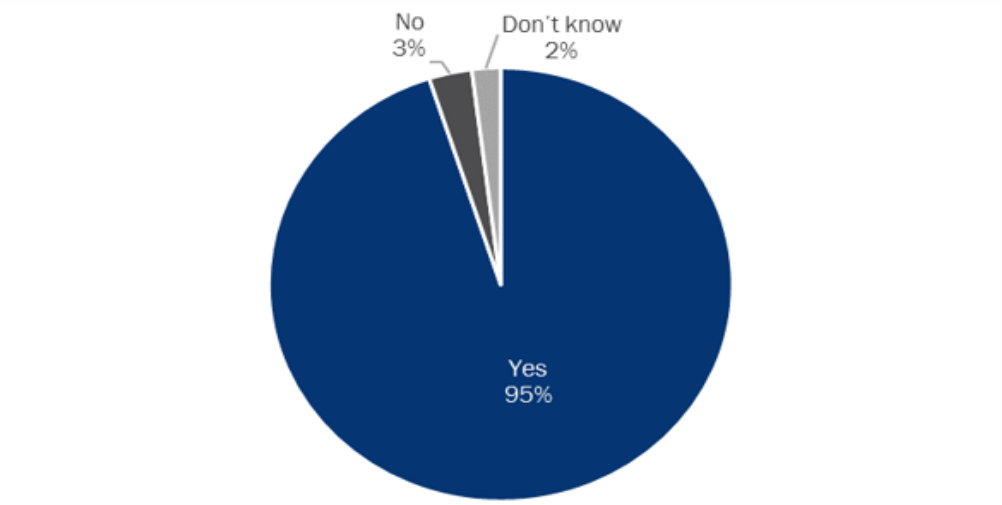
Value of Internet, TV and Phone Services

On a scale of 1 to 5, where 1 means a *poor value*, and 5 means an *excellent value*, how would you rate each of the following services:



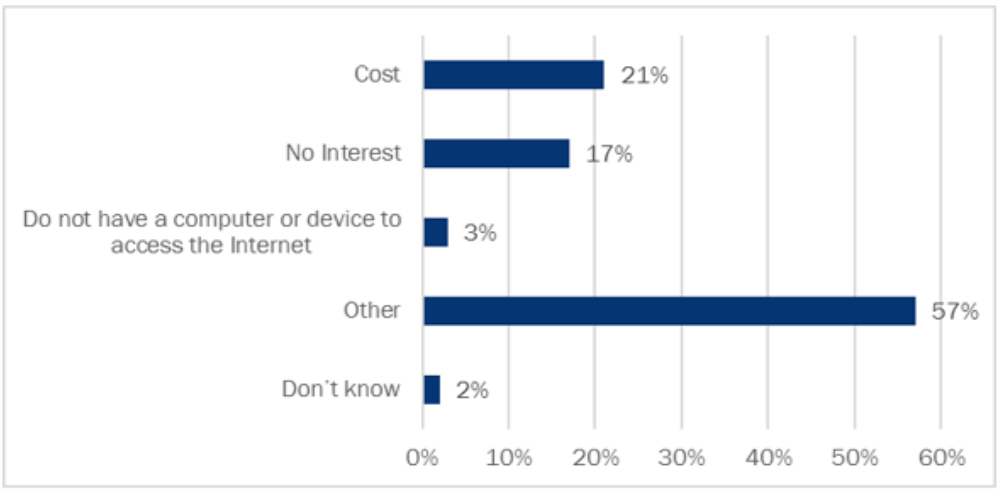
Internet Access At Home

Do you have access to the Internet at home—excluding access through a mobile cellular device? (n = 403)



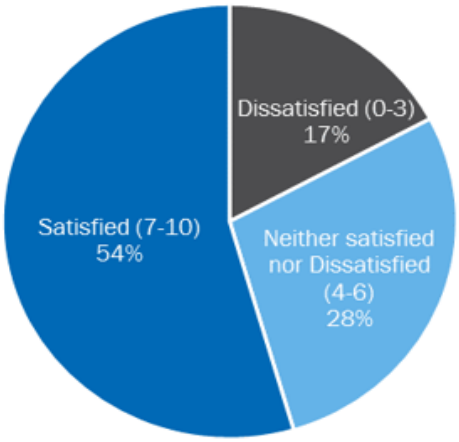
Reasons Participant Does Not Have Internet Access

What is the primary reason you don't have Internet access at **home—excluding access through a mobile cellular device?** (n=11)



Satisfaction with Quality of Internet Service

On a scale of 0 to 10, where 0 means totally dissatisfied, 5 means neither satisfied nor dissatisfied and 10 means totally satisfied, how would you rate your level of **satisfaction** with **the overall quality of your Internet service at home?** (n=382)

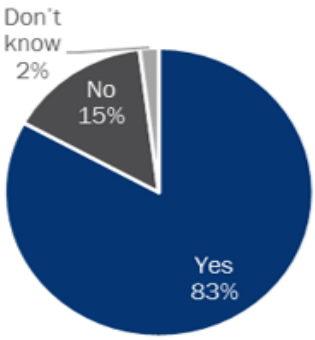


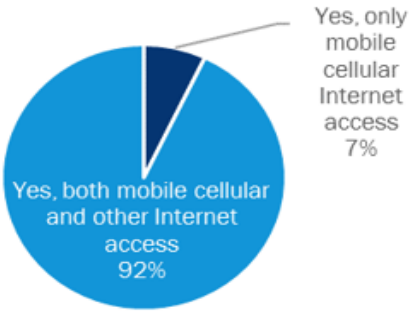
Mean = 5.9

Internet Access Through a Mobile Cellular Device

Do you, or any member of your household, have access to the Internet through a mobile cellular device? (n=390)

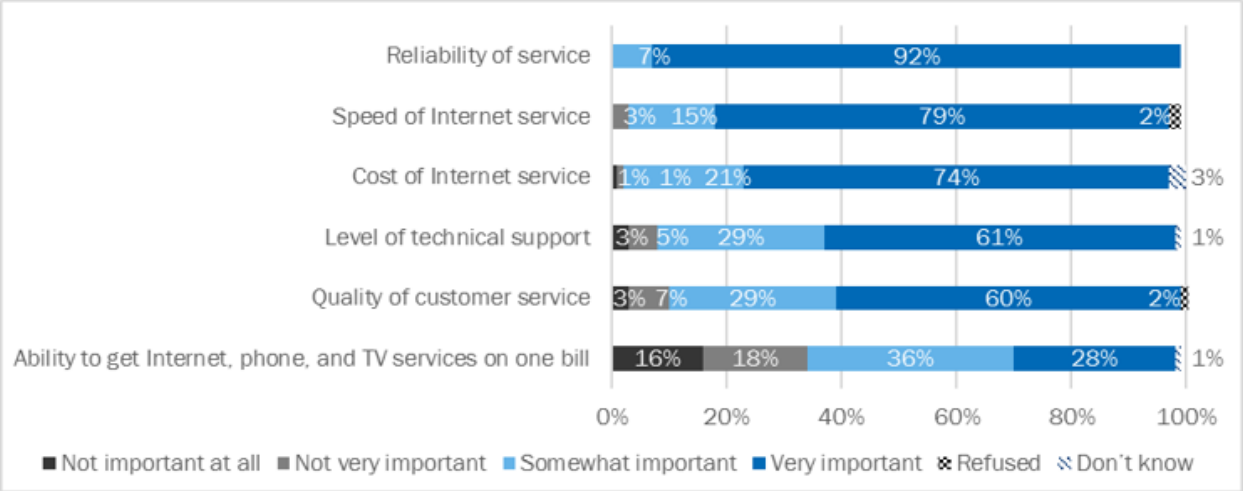
[Of 323 "Yes" responses] Do you or a household member have only mobile cellular access to the Internet, or are there also ***other*** ways to access the Internet at home?





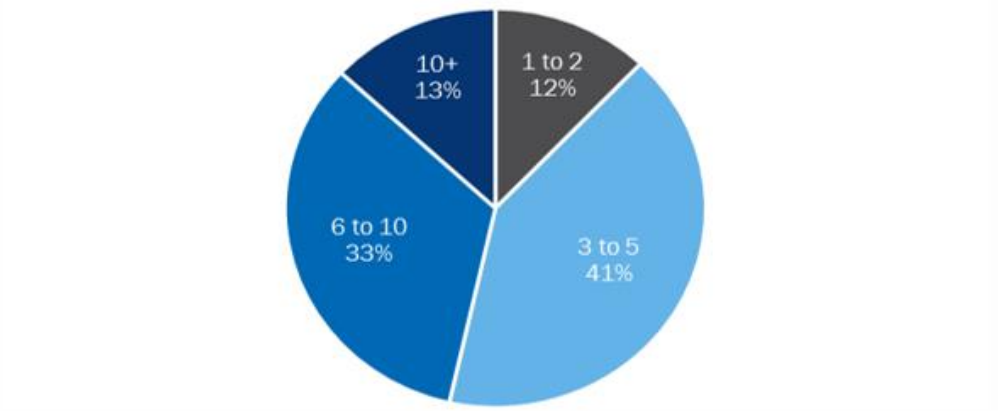
Important Attributes of Internet Service

Tell me whether you consider an attribute to be very important, somewhat important, not very important or not important at all in your evaluation of Internet service. (n=403)



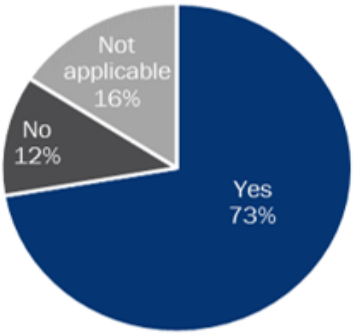
Number of Devices on Home Internet Network

All together, about how many devices do you use in your home that can connect to your home's Internet network? (n=382)

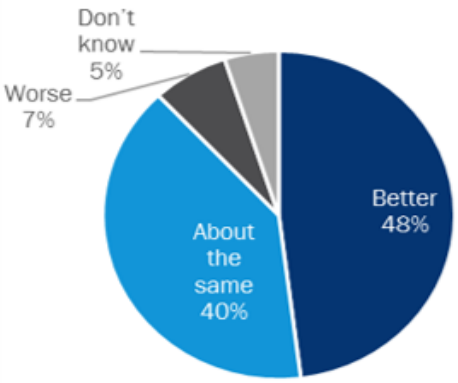


Internet Access at Work

Do you also have access to the Internet at work? (n=382)

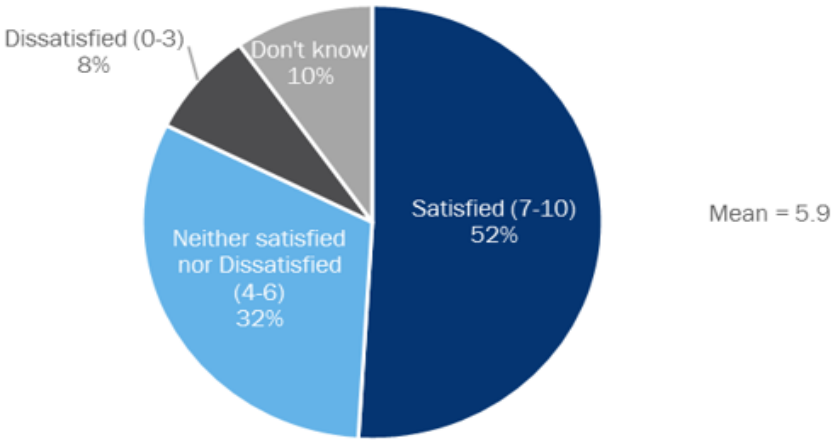


[Of 277 "Yes" responses] In general, would you say the quality of your Internet service at work is better, worse or about the same as your home Internet service?



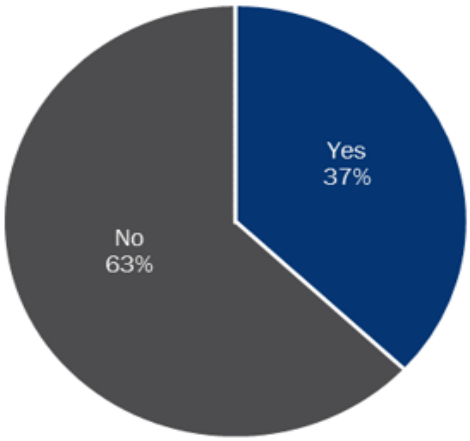
Satisfaction with City of Cambridge Public Wi-Fi

On a scale of 0 to 10, where 0 means totally dissatisfied, 5 means neither satisfied nor dissatisfied and 10 means totally satisfied, how would you rate your level of satisfaction with the overall quality of the City's public Wi-Fi system? (n=174)



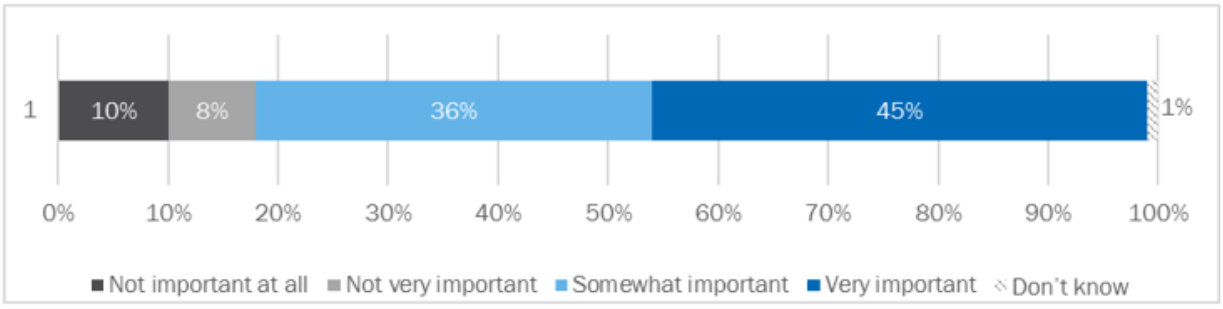
Public Internet Service Use

Have you ever used public Internet services—like computers at the Cambridge Public Library? (n=403)



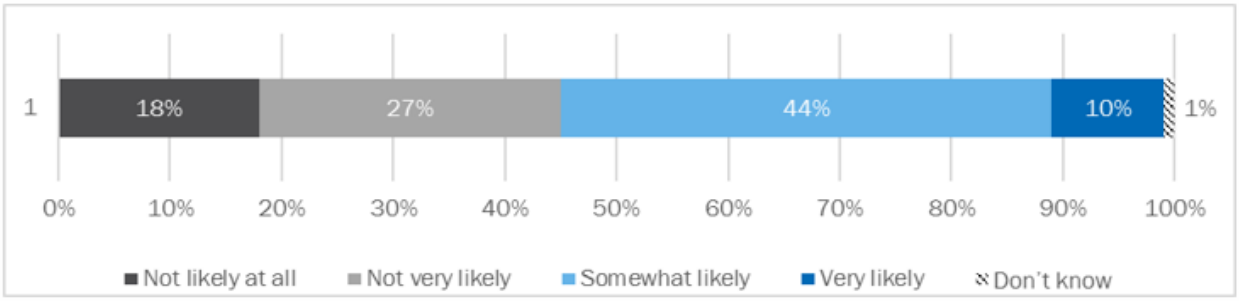
Importance of Quality Home Internet When Moving

If you were moving, how important would the quality of home Internet service be in your decision of which house, apartment or condominium to live in—very important, somewhat important, not very important or not important at all? (n=403)



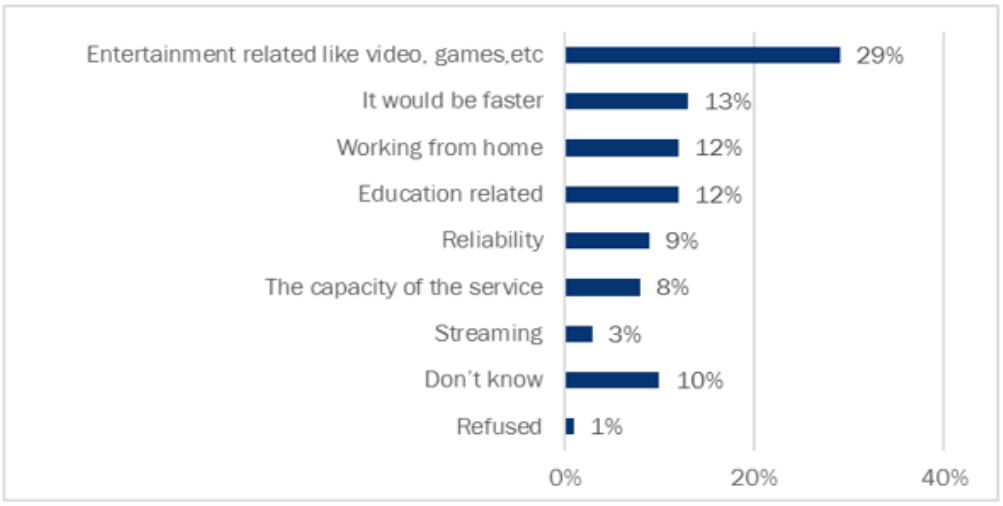
Likelihood to Pay More for Faster Internet

How likely would you be to pay more to get much faster Internet service than is currently available to Cambridge homes: very likely, somewhat likely, not very likely, or not likely at all? (n=403)



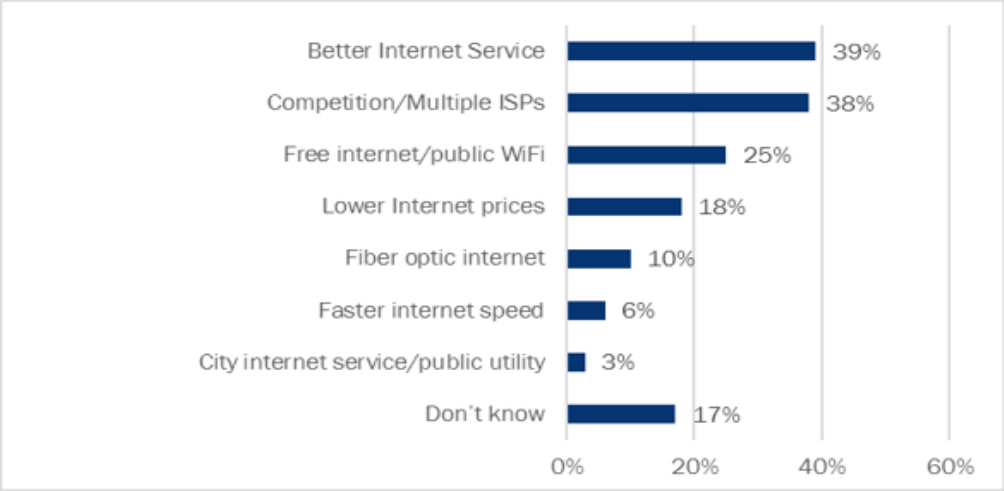
Biggest Benefit for Faster Internet Service

Assuming you had access to much faster Internet service in your home, what do you think would be the single biggest benefit of that faster service? (n=403)



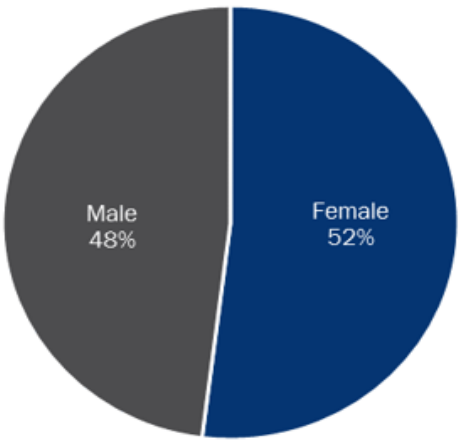
Most Important Improvements to Cambridge Internet Services

If you were speaking directly to the leaders of city government here in Cambridge, what are the two or three issues you would recommend to improve overall Internet services in the city? (n=403)



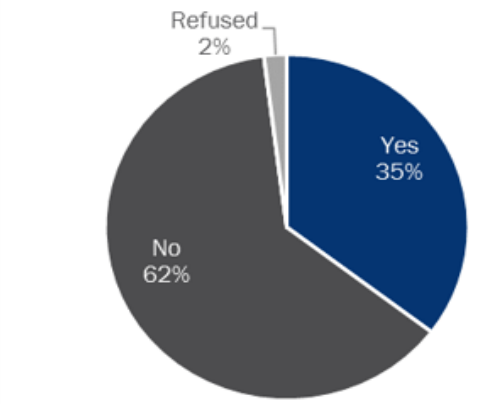
Gender of Survey Participants

(n=403)



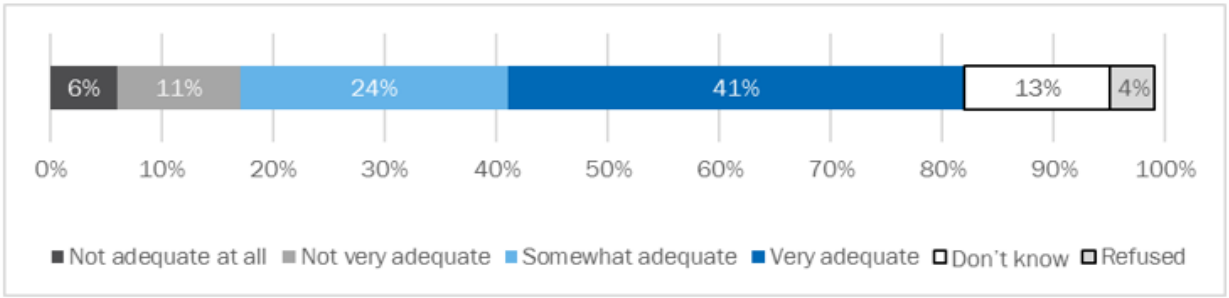
Children Under the Age of 18

Are there any children under the age of 18 living in your household? (n=403)



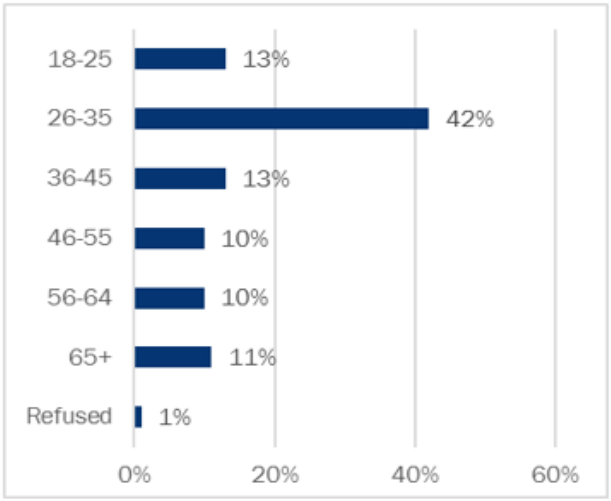
Adequacy of Home-Based Internet for Children's Homework

How adequate is your home-based Internet service in meeting your children's homework requirements: very adequate, somewhat adequate, not very adequate or not adequate at all? (n=142)



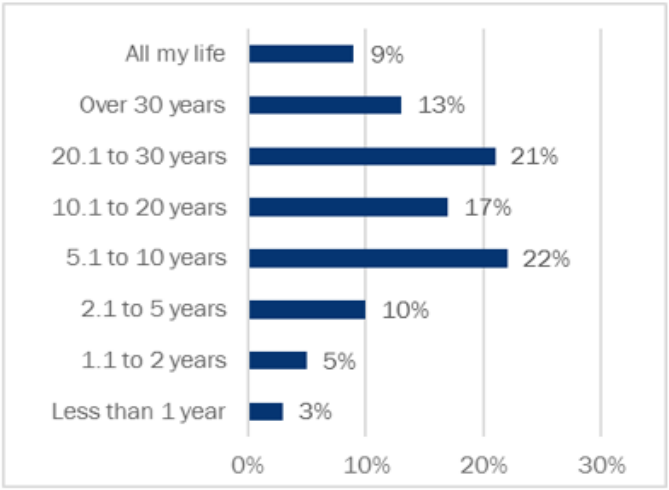
Age of Survey Participant

In which of the following categories is your age? (n=403)



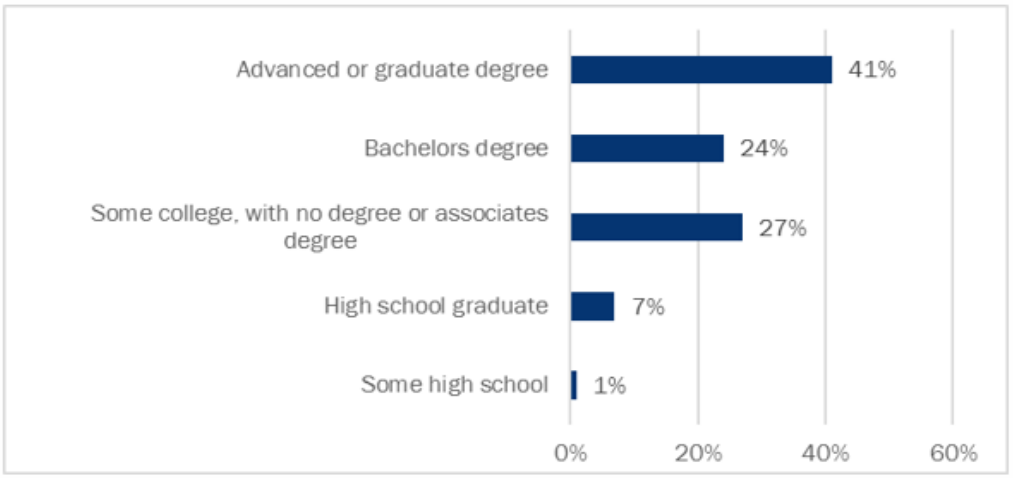
Years Living in Cambridge

How many years have you lived in Cambridge? (n=403)



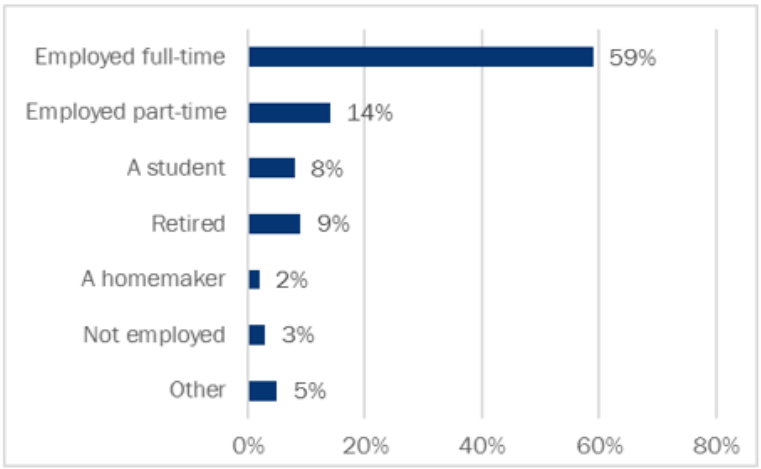
Educational Attainment

Please tell me which best describes the level of education you have completed. (n=403)



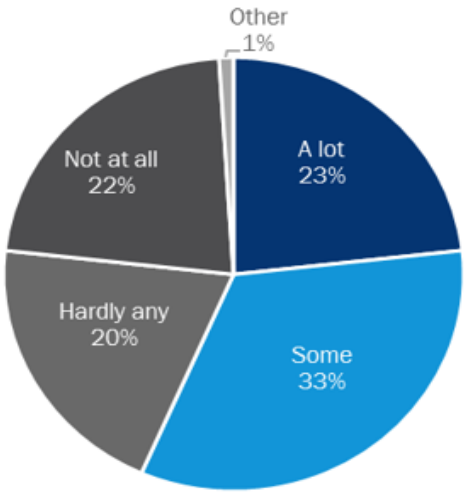
Employment Status

Please tell me which of the following best describes your current employment status. (n=403)



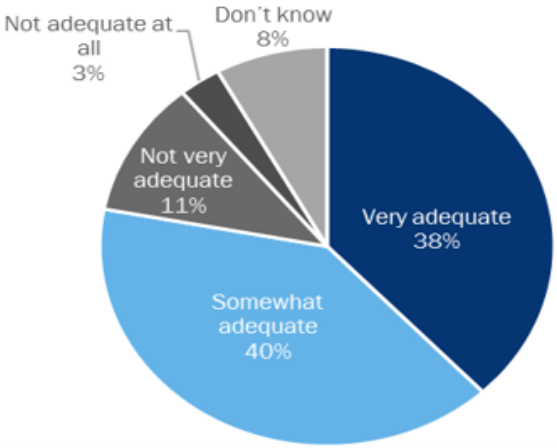
Frequency of Working from Home

How frequently would you say you work from home: A lot, some, hardly any, not at all? (n=292)



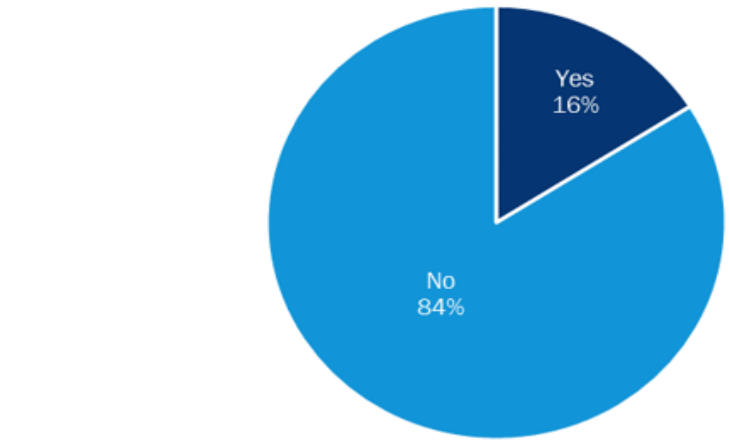
Adequacy of Home-Based Internet for Working from Home

How adequate is your home-based Internet service to meet the needs of the work you do at home: very adequate, somewhat adequate, not very adequate or not adequate at all? (n=292)



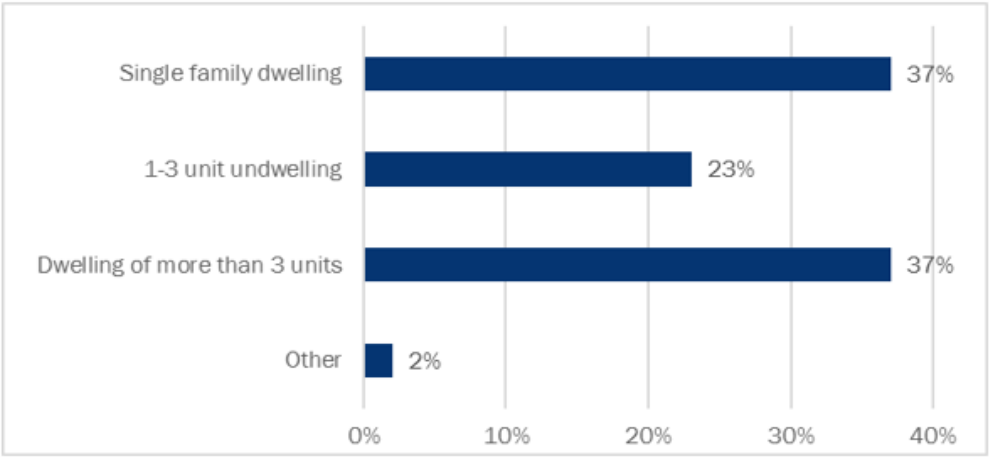
Operate a Business from Home

Do you operate a business from your home? (n=292)



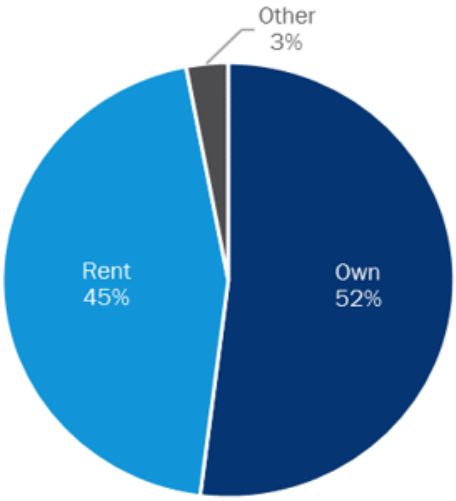
Home Type

Which of the following best describes your home? (n=403)



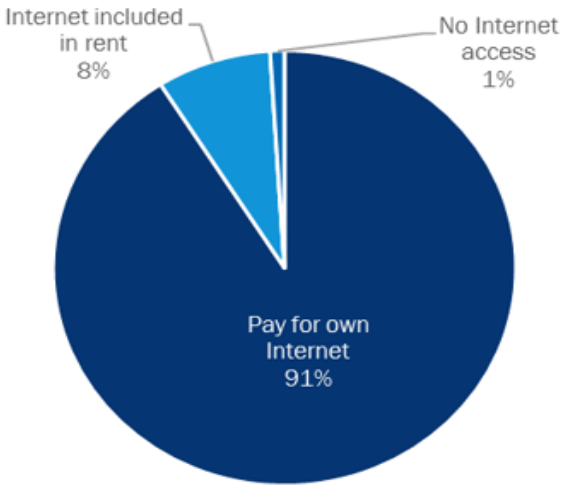
Rent or Own

Do you own or rent your home? (n=403)



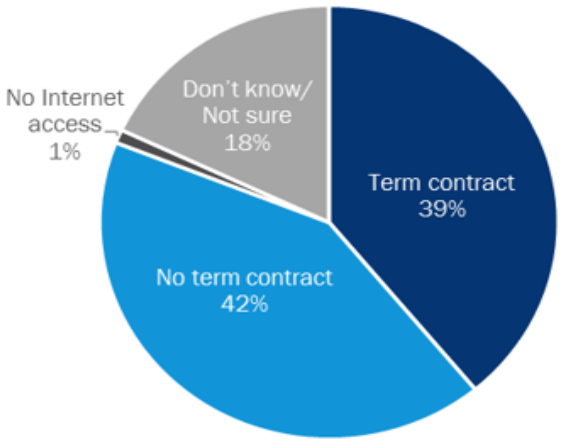
Internet Services Included In Rent

Do you pay for your own Internet services, or are they included in your rent? (n=180)



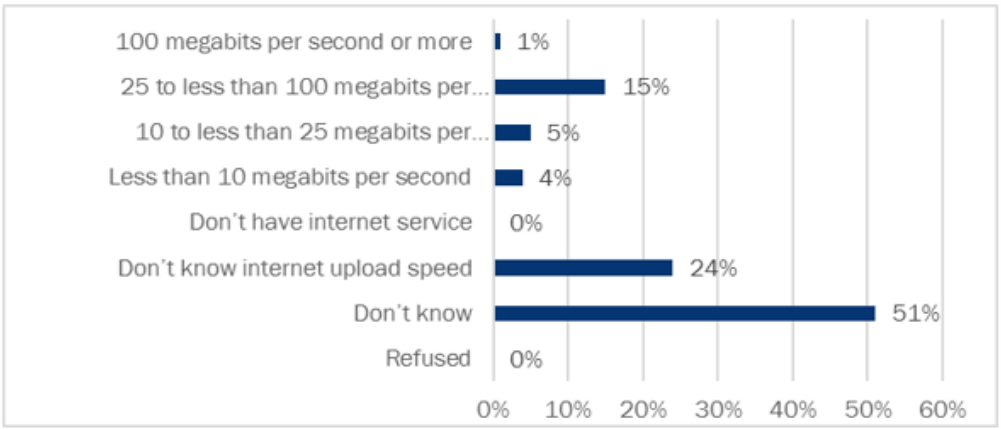
Term Contract With Service Provider

Are you currently in a term contract with your Internet service provider? (n=403)



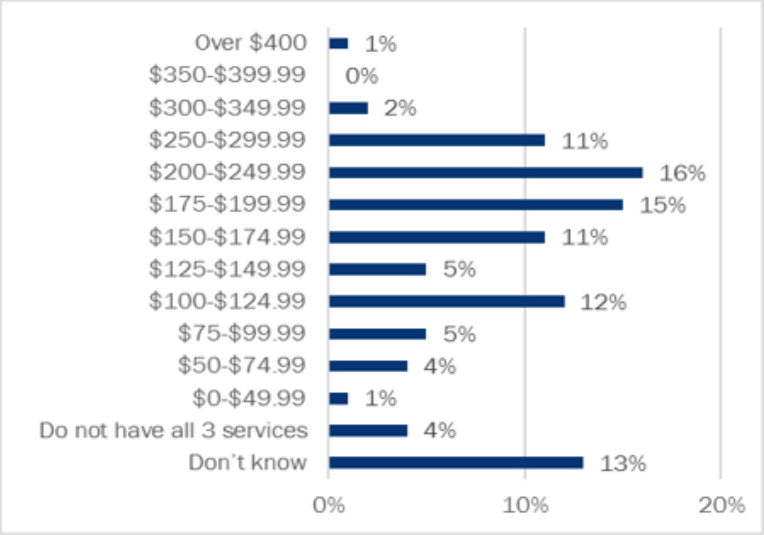
Speed of Home-based Internet

If you know, please estimate for me the download speed of your home-based Internet? (n=400)



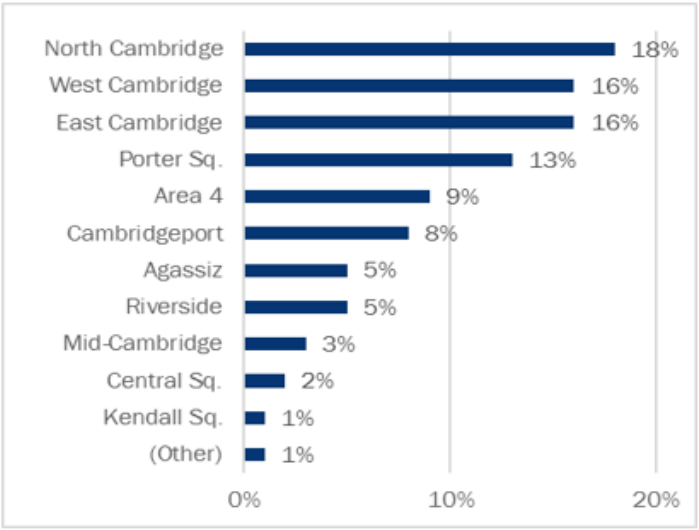
Monthly Payment for Internet, TV and Home Phone

If you know, please estimate about how much you pay each month on TV, Internet and primary home phone service combined. (n=327)



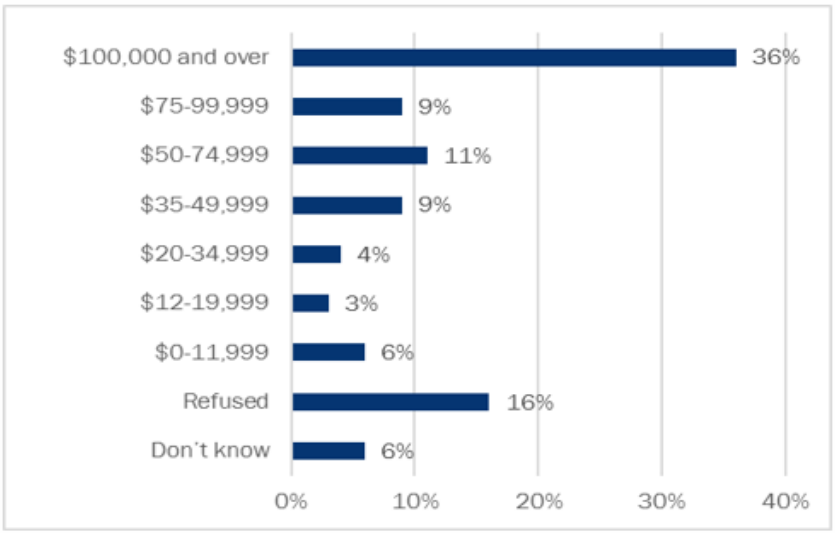
Neighborhood of Residence

Which one of the following best describes the neighborhood of Cambridge you live in? (n=403)



Household Income

Would you please tell me in which of the following categories I read is your total household income—that is, of everyone living in your household? (n=403)



26. Appendix K: Fiber Infrastructure Maps

All maps sourced from FiberLocator.

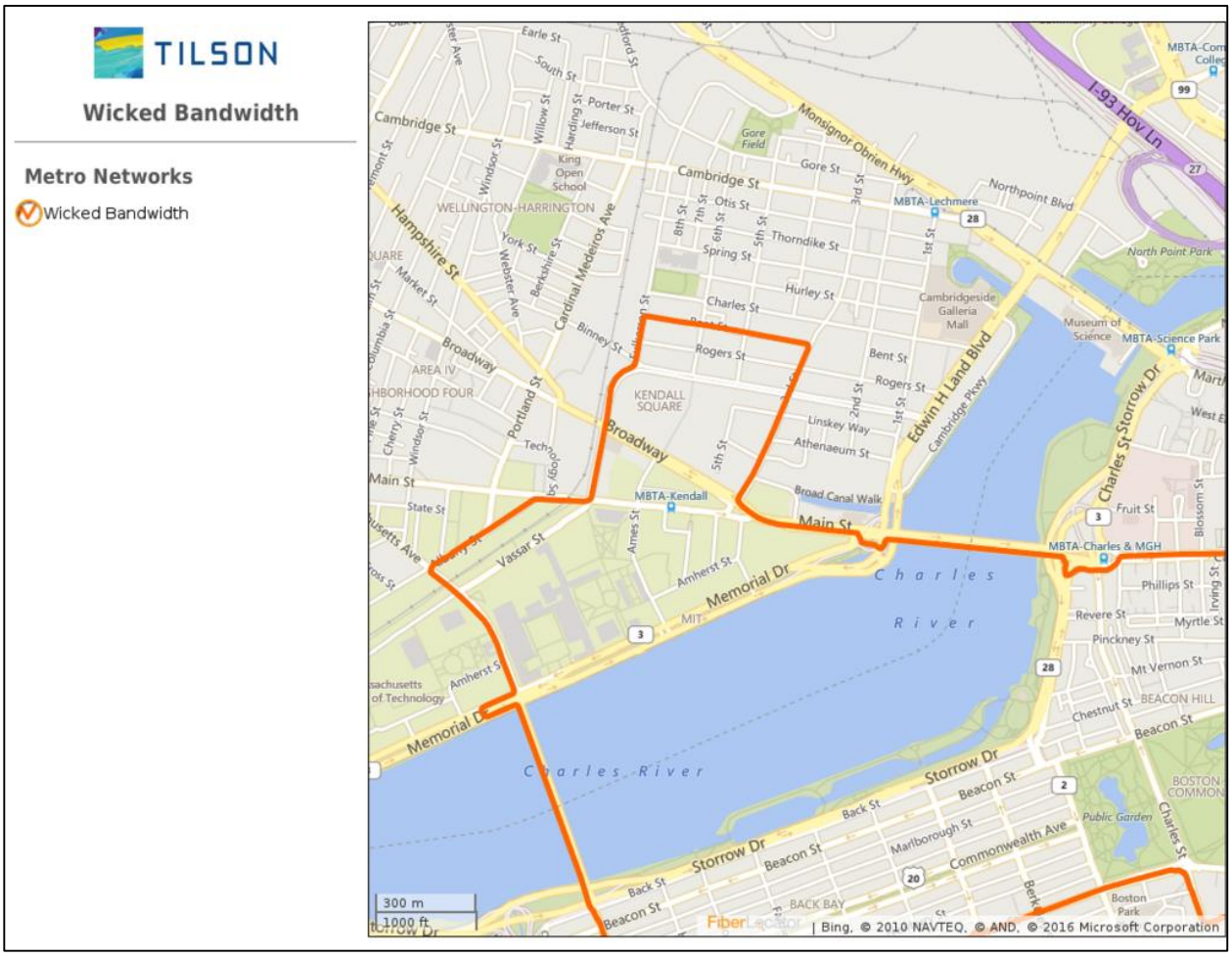


Figure 25: Map of Wicked Bandwidth's Backbone Fiber Network

Maps of these companies' self-reported fiber routes are in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**. These are split into three separate maps for readability's sake, since many of their routes overlap. As can be seen from these maps, existing dark fiber infrastructure, and therefore service availability, is concentrated in the southeast portions of Cambridge. Unlike other business connectivity services, dark fiber services are highly customized to the individual customer and locations. Typical parameters include exact services required, bandwidth needs, location of the fiber entrance to each building, and network scale. Prices are highly variable and also depend on costs to build new infrastructure if needed. Dark fiber prices are generally negotiated for each individual solution.

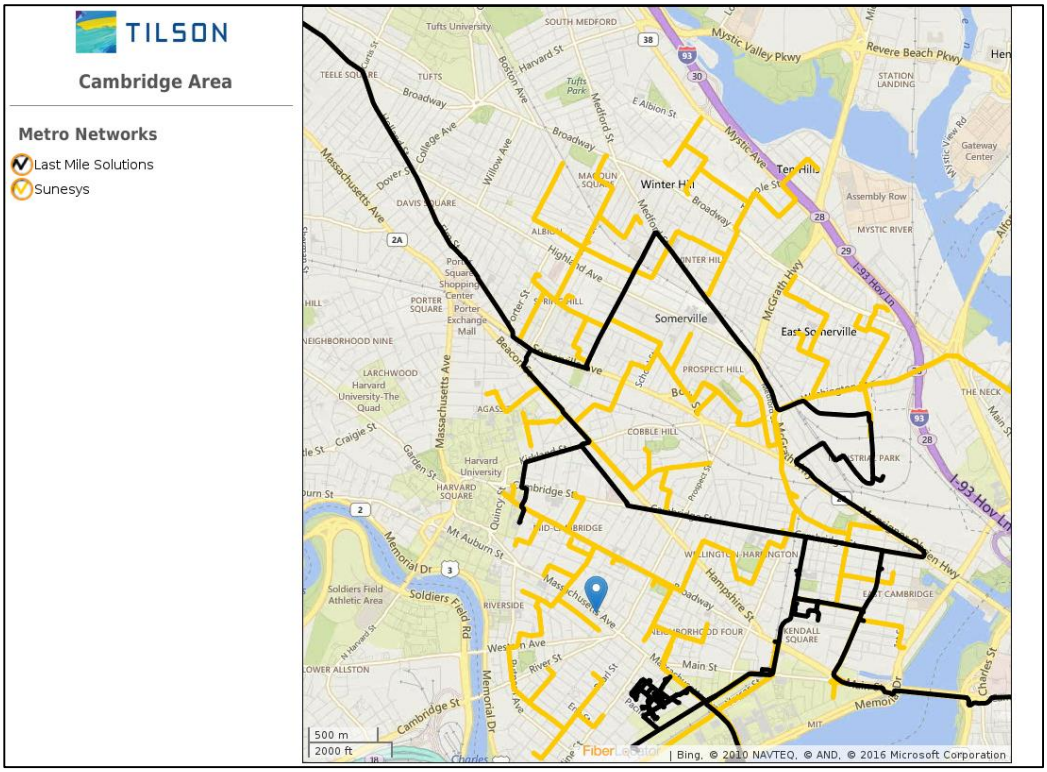


Figure 26: Map of Last Mile Solutions and Sunesys Dark Fiber

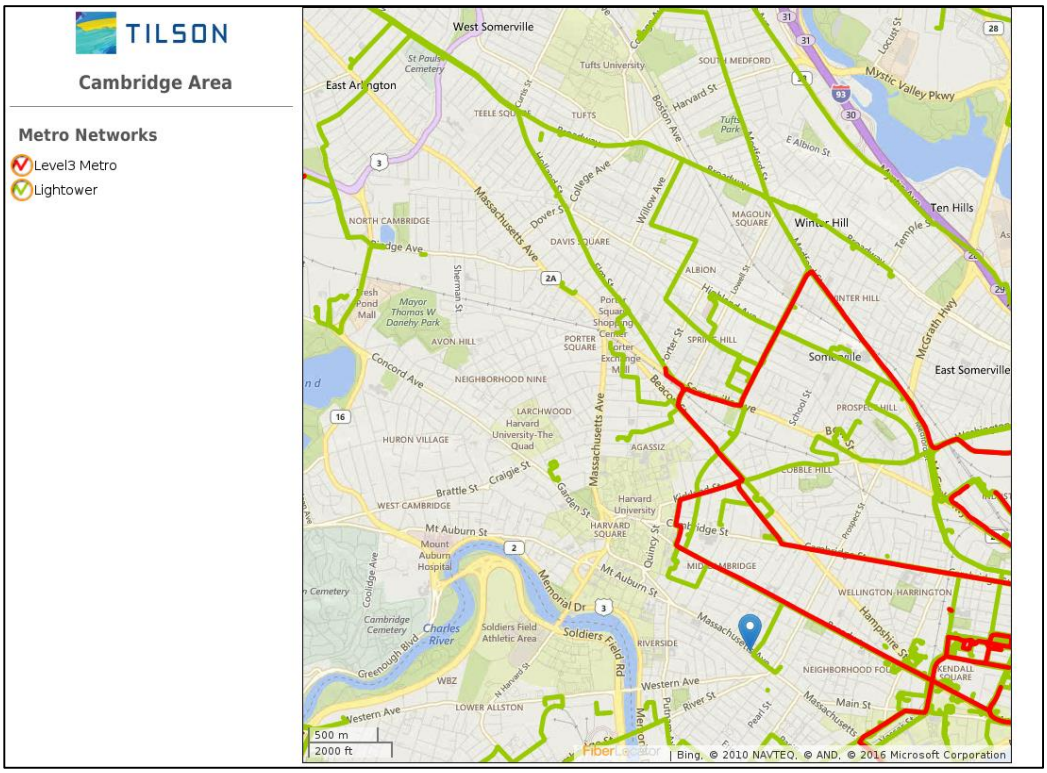


Figure 27: Map of Level 3 and Lightower Dark Fiber

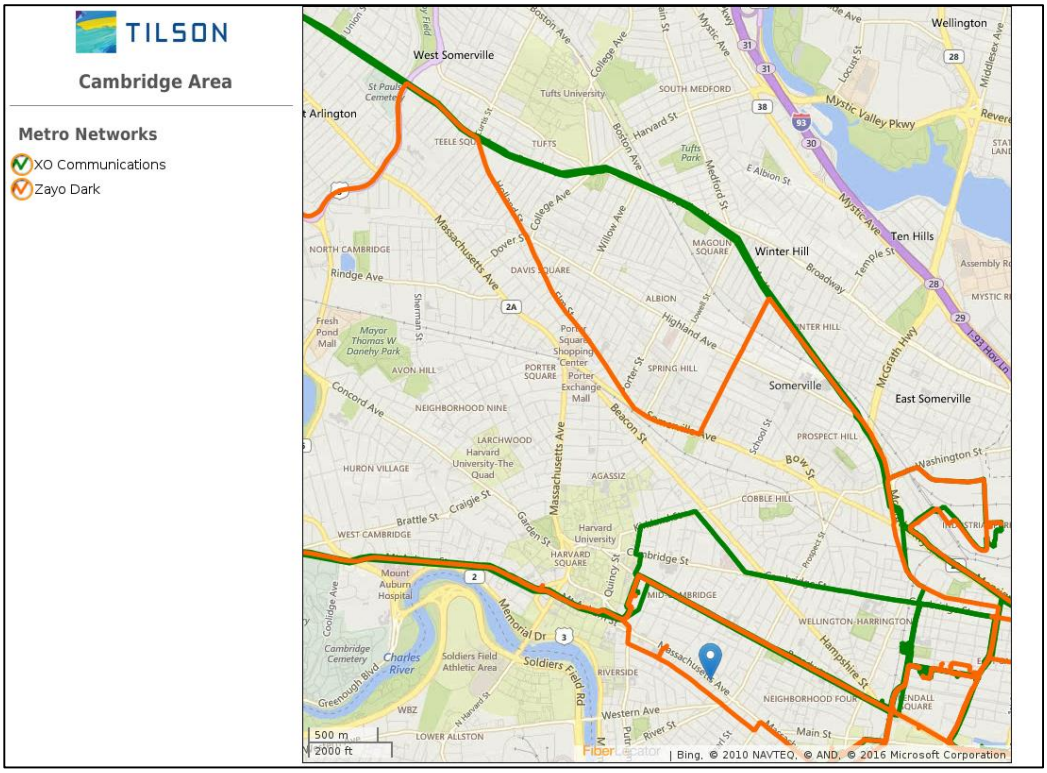


Figure 28: Map of XO Communications and Zayo Dark Fiber

27. Appendix L: Capital Expense Calculations

Small Build

Small Build			Project Miles		Poles
		4.44		75	
			Aerial feet	272	Premises
		9,010			

Make Ready	Description	Units	Unit Cost	Cost	
App Fee - Telco	Application Fee (200) Poles)	1	$2,556.00	$2,556.00	
App Fee - Elco	Application Fee (up to 200 Poles)	1	$2,100.00	$2,100.00	
Make Ready	Make Ready (per pole)	160.00	$720.00	$115,200.00	
Sub Total					$119,856.00

Materials	Description	Units	Unit Cost	Cost	
	12 Fiber	9010	$0.18	$1,636.22	
	Messenger Strand	9280	$0.23	$2,109.41	
	Strand and Lash Materials (per ft)	9010	$0.61	$5,496.10	
	Snow-shoes	12	$18.32	$220.08	
	8 Port MST	22	$250.00	$5,500.00	
	MST In-line Closure	7	$270.00	$1,890.00	
	96 Fiber--UG	14434	$0.60	$8,660.40	
	Fiber Drop	272	$52.00	$14,144.00	
	1x16 Splitter	17	$90.00	$1,530.00	
Sub Total					$41,186.21

Labor	Description	Units	Unit Cost	Cost	
	Place Strand	9,280	$1.58	$14,662.87	
	Lash Fiber	9,280	$1.10	$10,208.00	
	Install Anchor/ Guy (includes materials)	7	$325.00	$2,218.37	
	Prep Splice Case	29	$268.00	$7,772.00	
	Splice	520	$28.00	$14,560.00	
	MST Install	29	$250.00	$7,250.00	
	Lateral Trench from MH material and labor	8,700	$80.00	$696,000.00	
	Trenching Material and Labor	14,434	$80.00	$1,154,720.00	
	Install Fiber in conduit	14,434	$1.60	$23,094.40	
	Rod and Rope Conduit	14,434	$1.35	$19,485.90	
	Manholes materials and labor	29	$5,000.00	$145,000.00	
	Install Fiber Drop UG	155	$200.00	$31,000.00	
	Install Fiber Drop Aerial	95	$200.00	$19,000.00	
	Splice Fiber Drop - ONT Side	272	$75.00	$20,400.00	
	Contaminated Soil Removal (tons)	9,254	$40.00	$370,144.00	
	Police Detail - % of Baseline Cost	10%	$2,696,557.76	$269,655.78	
Sub Total					$2,805,171.32

Network Equipment	Description	Units	Unit Cost	Cost	

	E7-2 empty chassis, 2 slots, fan module	1	$900.00	$900.00	
	8-port GPON card	2	$11,200.00	$22,400.00	
	10Gbps ethernet, multimode SFP+	2	$900.00	$1,800.00	
	GPON OIM, 1:32 20KM	9	$1,200.00	$10,800.00	
	711GE outdoor ONT w/ 2GE ports and 2 POTS	272	$230.00	$62,560.00	
	Corning ONT clam shell OSP enclosure	272	$28.00	$7,616.00	
	Alpha or Cyber Power 8 HR UPS	272	$46.00	$12,512.00	
	Estimated install cost for all Node Equipment	1	$6,000.00	$6,000.00	
Sub Total					$124,588.00
	Baseline Cost				$3,090,801.53
	Engineering / Drafting			$0.10	$309,080.15
	Contractor's Margin			$0.20	$618,160.31
	Contingency			$0.30	$1,205,412.60
Total Cost					**$5,223,454.59**
		6.25%	Massachusetts Sales & Use Tax		$251,127.62
				TOTAL EST	**$5,474,582.22**

Medium Build

Medium Build		17.02	Project Miles	659	Poles
Dark Fiber Only		79,071	Aerial feet	0	Premises

Make Ready	Description	Units	Unit Cost	Cost	
	Application Fee (200) Poles)	3	$2,556.00	$8,421.02	
	Application Fee (additional poles)	59	$10.00	$590.00	
	Application Fee (up to 200 Poles)	4	$2,100.00	$8,400.00	
	Make Ready (per pole)	659	$720.00	$474,480.00	
Sub Total					$491,891.02

Materials	Description	Units	Unit Cost	Cost	
	144 Fiber	29,883	$0.91	$27,053.33	
	288 Fiber	29,883	$1.60	$47,813.24	
	432 Fiber	29,883	$2.29	$68,432.70	
	Messanger Strand	81,443	$0.23	$18,511.94	
	Strand and Lash Materials (per ft)	79,071	$0.61	$48,233.09	
	Snow-shoes	120	$18.32	$2,194.81	
	Butt Splice Case	10	$321.95	$3,290.13	
	Fiber Tray	60	$24.52	$1,471.20	
	MST In-line Closure	329	$270.00	$88,954.47	
	144 Fiber--UG	3,594	$0.91	$3,253.76	
	288 Fiber--UG	3,594	$1.60	$5,750.59	
	432 Fiber--UG	3,594	$2.29	$8,230.53	
	POP	1	$225,000.00	$225,000.00	
Sub Total					$548,189.79

Labor	Description	Units	Unit Cost	Cost	
	Place Strand	81,443	$1.58	$128,679.56	
	Lash Fiber	89,650	$1.10	$98,614.81	
	Install Anchor/ Guy (includes materials)	60	$325.00	$19,468.15	
	Prep Splice Case	340	$268.00	$91,034.34	
	Splice	520	$28.00	$14,560.00	
	Splice 144 -287	3	$1,200.00	$3,600.00	
	Splice 288+	7	$2,500.00	$17,500.00	
	Inline MST install	329	$250.00	$82,365.25	
	Trenching material and labor	12,544	$80.00	$1,003,520.00	
	Lateral Trench from MH material and labor	7,500	$80.00	$600,000.00	
	Install Fiber in conduit	12,544	$1.60	$20,070.40	
	Rod and Rope Conduit	12,544	$1.35	$16,934.40	
	Manholes materials and labor	25	$5,000.00	$125,000.00	
	Contaminated Soil Removal (tons)	8,018	$40.00	$320,704.00	
	Police Detail (% of baseline cost)	10%	$3,357,131.72	$335,713.17	
	POP Installation	1	$25,000.00	$25,000.00	
Sub Total					$2,902,764.08

	Baseline Cost	$3,942,844.90

	Engineering / Drafting		$0.10	$394,284.49
	Contractor's Margin		$0.20	$788,568.98
	Contingency		$0.30	$1,537,709.51
Total Cost				**$6,663,407.87**
		6.25%	Massachusetts Sales & Use Tax	$320,356.15
			TOTAL EST	**$6,983,764.02**

Large Build

Large Build	-	148.00	Project Miles	4,620	Poles
	-	554,409	Aerial feet	58,229	Premises
				100%	Take Rate

Make Ready	Description	Units	Unit Cost	Cost	
	Application Fee (200) Poles)	45	$2,556	$115,020	
	Application Fee (up to 200 Poles)	45	$2,100	$94,500	
	Make Ready (per pole)	4620	$720	$3,326,400	
Sub Total					$3,535,920

Materials	Description	Units	Unit Cost	Cost	
	96 Fiber	481009	$1	$288,605	
	144 Fiber	145216	$1	$131,464	
	288 Fiber	23507	$2	$37,611	
	Messenger Strand	571041	$0	$129,798	
	Snow-Shoes	739	$18	$13,542	
	Strand and Lash Materials (per ft)	1541441	$1	$940,279	
	Butt Splice Case	125	$322	$40,244	
	Fiber Tray	206	$25	$5,051	
	12 Port MST	4852	$250	$1,213,000	
	In-line MST Closure	970	$270	$261,900	
	96 Fiber--UG	193270	$1	$115,962	
	144 Fiber--UG	75983	$1	$68,787	
	288 Fiber--UG	33477	$2	$53,563	
	Mule Tape	227031	$0	$34,055	
	Fiber Drop	58229	$52	$3,027,908	
	FDP in Business/MDU	1165	$90	$104,812	
	1x16 PLC Splitter x 2	1250	$90	$112,500	
	1x32 PLC Splitter	600	$150	$90,000	
Sub Total					$6,669,082

Labor	Description	Units	Unit Cost	Cost	
	Place Strand	571041	$2	$902,245	
	Lash Fiber	1541441	$1	$1,695,585	
	Install Anchor/ Guy (includes materials)	420	$325	$136,502	
	Prep Splice Case	970	$268	$259,960	
	Splice 288+	202	$2,500	$505,000	
	Inline MST install	4852	$250	$1,213,000	
	Trenching material and Labor	231175	$80	$18,494,000	
	Lateral Trench from MH material and labor	138600	$80	$11,088,000	
	Install Fiber in conduit	231175	$2	$369,880	
	Rod and Rope	231175	$1	$312,086	
	Manholes materials and labor	462	$5,000	$2,310,000	
	Install Fiber Drop UG	615	$200	$123,000	
	Install Fiber Drop Aerial	57614	$200	$11,522,800	

	UG-MH Business/MDU Pull-ins	1070	$5,000	$5,350,000	
	Splice Fiber Drop - ONT Side - DMARC side of Building	58229	$75	$4,367,175	
	Contaminated Soil Removal (tons)	147910	$40	$5,916,400	
	Police Detail (% of Baseline Cost)	0	$74,770,636	$7,477,064	
Sub Total					$72,042,697
Carrier Facilities					
	POP Install East and West	3	$250,000	$750,000	
	East and West Juniper Transport Gear	6	$130,000	$780,000	
Sub Total					$1,530,000
Network Equipment	Description	Units	Unit Cost	Cost	
	E7-20 Chassis, two SCP cards	12	$13,500	$162,000	
	GPON 8x-line card	240	$7,200	$1,728,000	
	10Gbps ethernet, multimode SFP+	24	$900	$21,600	
	GPON OIM, 1:32, 20KM	1920	$1,200	$2,304,000	
	711GE ONT	58229	$230	$13,392,670	
	Corning ONT clam shell OSP enclosure	58229	$28	$1,630,412	
	Alpha or Cyber Power 8 HR UPS	58229	$46	$2,678,534	
	Estimated install cost for all Node Equipment	1	$40,000	$40,000	
Sub Total					$21,957,216
	Baseline Cost				$105,734,915
	Engineering / Drafting			$0	$10,573,492
	Contractor's Margin			$0	$21,146,983
	Contingency			$0	$41,236,617
Total Cost					**$178,692,007**
			Massachusetts Sales & Use Tax		$8,590,962
				TOTAL EST	**$187,282,969**

28. Appendix M: Bridging the Digital Divide at Newtowne Court – Pilot Program Evaluation

The following report, while not prepared by Tilson, is appended here at the request of the City to provide additional historical context on prior City efforts to address the Digital Divide.

BRIDGING THE DIGITAL DIVIDE AT NEWTOWNE COURT

PILOT PROGRAM EVALUATION

Prepared by:
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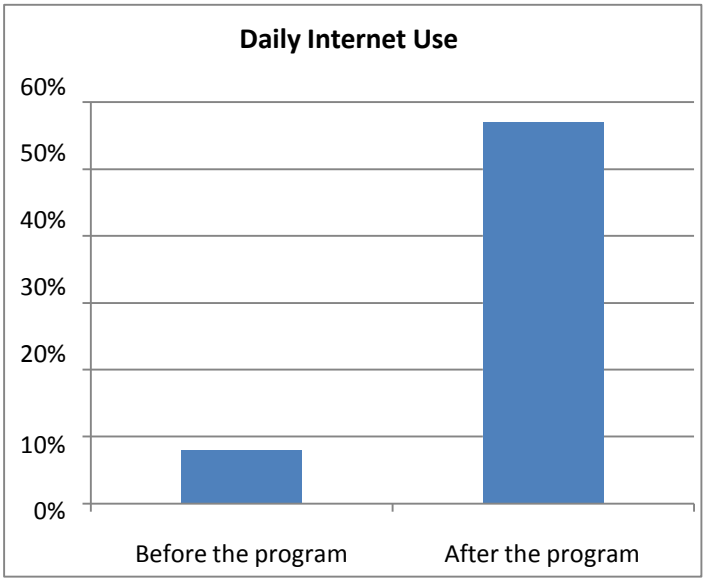
Employment Planning & Development Director
Office of Workforce Development – Department of Human Service Programs
City of Cambridge, MA

EXECUTIVE SUMMARY

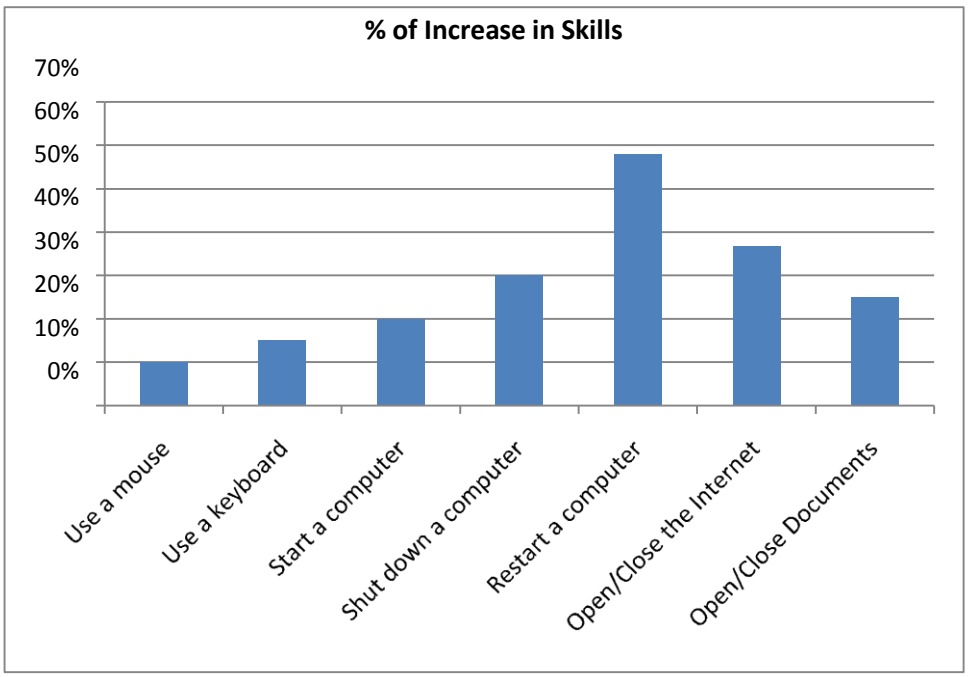
In November 2006, in response to a Council Order requesting that the City help bridge the digital divide, the City Manager appointed a committee charged with finding ways to address barriers to Internet access. This committee was to include members of the City Council, School Committee, and other agency representatives. The City Manager appointed the committee and designated Assistant City Manager Ellen Semonoff as its chair.

The pilot program developed by the committee served 35 families providing them with computers to access the free wi fi network supplied by the City of Cambridge, along with training and technical support for 6 months in hopes of increasing participants‟ access and use of the Internet.

Before the start of the program, approximately 8% of program participants used the Internet daily. After completing the program, 57% were using the Internet daily with an additional 10% using it at least a few times a week.



Participants were satisfied with the program; almost 90% reported they were happy they completed the program *and* that they would recommend the program to a friend.



Many participants had very basic skills, (i.e. they knew how to use a mouse or keyboard). The program was successful in developing higher level skills (although still basic) in some participants.

All respondents remarked that additional training was needed.

Many of the advisory committee members surveyed believed the highlight of the program was the amount of community-building occurring through collaborations. The process of creating the program was exciting, challenging, and progressive due to the support of strong leaders.

Issues that are likely to arise in replication include:
Connectivity – access to a reliable and consistent network is key to any program's success.
Hardware – refurbish or partner to receive new?
Program support – strong collaboration is a must, with a leader who can hold partners accountable.
Outreach – How can program enrollment be maximized?
Training – How extensive should it be? To what extent, if any, should the program provide participants with referrals to other programs to develop further computer skills?
Technical support – how long should it be offered and how personal should it be?

Background & Introduction

In response to a Council Order requesting that the City help bridge the digital divide, the City Manager appointed a committee charged with finding ways to address barriers to Internet access. This committee was to include members of the City Council, School Committee, and other agency representatives. The City Manager appointed the committee, and designated Assistant City Manager Ellen Semonoff as its chair. The first meeting of the committee was held in March, 2007.

The Digital Divide Committee surveyed many projects that provide computers, training, technical support and Internet access to students and households. After reviewing the several different models and the pros and cons of those models, the group reached consensus on several critical issues: First, the decision was made to provide desktop computers and not laptops. Second the decision was made to use refurbished computers rather than purchase new computers. Third, the decision was made to incorporate workforce development opportunities into the program by having the computers refurbished by RSTA students who would also provide the majority of the call center tech support. Finally, the decision was made to do the pilot at Newtowne Court in conjunction with the City's existing wi fi pilot and to target residents of any age and family structure who do not currently have access to the Internet. Through smaller working groups, the pilot proposal was developed with the purpose of examining how various departments of the City of Cambridge and local non-profit organizations could work together to help bridge the digital divide in low-income households.

Pilot Program Description

Pilot program research showed that technical support and user education are the most important issues to solve in a network deployment. Since users – particularly in low-income housing developments – have a wide variety and age of equipment, it is difficult to provide a universal set of guidelines that will work for every user. Therefore, a technical support call center providing users with assistance for their specific problems is important in a full-scale deployment.

In order to get the most out of a community network, education is also a critical issue. Education can include a wide variety of topics from email usage to network management to website development and everything in between. By providing such education opportunities – both on and offline – a community can derive the greatest benefit possible from its wireless network.

The goals of the proposed pilot program were:

1. To develop a model to provide low-income residents with tools to access the Internet
2. To provide the tools, training, and technical support for 50 Newtowne Court households to successfully utilize the free wi fi Internet access that the City has made available
3. To serve as a workforce development tool for RSTA students.

The first step in the pilot program was to ensure reliable wi fi coverage. Prior to the establishment of the Digital Divide pilot, the City's **IT Department** (ITD) had been working diligently to make wireless access available to the residents of Newtowne Court. ITD upgraded the network hardware in Newtowne Court so that units throughout the development would be able to receive a consistent, strong signal. ITD established mechanisms for monitoring the network and procedures for responding to user reports of outages and connectivity issues.

Refurbished computers were available to the pilot program at no cost. These computers were decommissioned 833MhZ Pentium II computers from the City of Cambridge and were refurbished by students at the Rindge School of Technical Arts. **Cambridge Community Television** (CCTV) donated (in-kind) 9 Macintosh computers of comparable specifications in order to determine which platform was most cost effective in the short and long term. See Specifications Addendum A.

Pilot program participants were recruited through the Cambridge Housing Authority using household mailings in multiple languages.

35 pilot program participants were selected according to the following criteria:

1. Live in Newtowne Court
2. Do not currently have broadband access to the Internet either because there is no computer in the household or because the existing computer is not capable of accessing the wireless signal
3. Be willing to help the City evaluate the effectiveness of the pilot by answering questions about household use of a computer and the Internet prior to, during and at the end of the pilot
4. Be willing either to demonstrate computer proficiency or to complete training successfully
5. Have at least one adult member of the household who agrees to participate in the pilot

Selected households met with technical support staff to establish specific needs, existing level of skill and usage, and assurances that participants were willing to engage in assessment and evaluation. A clear explanation of what the pilot would and would not deliver and limitations of liability were explained. Applicants completed a pre-test to collect data on their previous experience and skill with computers and the Internet and to ascertain the level of training they would require.

Most pilot program participants attended three two-hour sessions of training offered at various times and with assistance in the language in which they are fluent. See Lesson Plans in Addendum B. The first two sessions were designed and required for those with limited computer/Internet experience, while participants with demonstrable skills were able to bypass sessions. The last session, on Internet safety and computer maintenance, was required of everyone. Participants received their computers at the end of the third session.

Tech support for the pilot program was available for 6 months after participants received their computers. Tech support included a call center, staffed by RSTA students for 2 hours each day during the school year and 2 hours a day, twice weekly during the summer. The call center included a voice mailbox and was staffed 5 days per week for 2 hours each day. Additional support in the form of an in-home specialist was also provided to program participants.

The City of Cambridge budgeted $50,000 for this project. Please see Addendum C for the full monetary and in-kind budget breakdown.

Purpose of the Evaluation

The evaluation is designed to examine *the process* of creating this pilot in an attempt to lay the groundwork for future replication by community organizations seeking to "Bridge the Digital Divide". It also seeks to answer the following questions:

1. Costs of implementation for a larger population, including equipment, tech support and training
2. Changes in participants" access to and use of Internet
3. Participant satisfaction
4. Process issues: what would we do differently next time?
5. What are the tech support needs at the end of the project?
6. In households with school-aged children, has there been increased interaction by parents with the school department? Have students shown increased involvement with or success in their school work?

Methodology

This evaluation utilizes both qualitative and quantitative tools. These methods were intended to provide participants with an environment in which their ideas, suggestions, and criticisms could be clearly conveyed. Program staff and advisory board members were surveyed via email and, in some cases, phone interviews. Program participant feedback was collected during focus groups and pre-program interviews. Each qualitative tool consisted of less than ten open-ended questions asking about the process and experience of creating the pilot program. The only quantitative tool used was Pre/Post test issued to program participants to measure growth in both computer skills and Internet use.

In order to ensure quality, scripts were developed for all interviews and are attached in Addendum D.

The sample size and population for each tool is listed below:

Population	Tool	Number of Respondents
Participant	Pre Test	35
Participant	Post Test	23
Participant	Intake assessment	35
Participant	Focus Group	7
Staff	Phone Survey/Email	7
Advisory Committee	Email Survey/Phone	6

Focus Groups

Two focus groups took place over two consecutive Saturday afternoons. Late Saturday afternoons worked well for the group of participants. Each focus group was scheduled for one hour and took place at CCTV less than half a mile from where participants reside. A short telephone script was created and used to recruit participants. Telephone calls were made by program staff who offered participants the choice of two dates, both at the same time of day over the span of two Saturdays. As each focus group drew closer, follow-up calls were made to program participants in an effort to ensure adequate attendance.

Each focus group was recorded by an assistant with a laptop; participants signed a consent form at the start. At the end of each session the focus group minutes were reviewed for accuracy. After completion of the editing process, the transcripts were then analyzed for common themes.

Program Staff Phone Interviews

Program staff phone interviews consisted of seven open-ended questions designed to assess how the program progressed. A phone script was developed and used to introduce the survey. There were approximately thirteen program staff and they were initially contacted by phone.

Phone interviews were easier for some respondents. In most cases, the survey administrator left messages asking program staff to call back with their availabilities. The survey administrator recorded as the respondent spoke. This method provided rich data; some respondents were very talkative and had many ideas that they wanted to share. Other respondents preferred to respond to the survey in email, as they were not available to talk during the day. This additional contact (via email) produced a slight increase in the response rate. Two additional program staff surveys were submitted as a result.

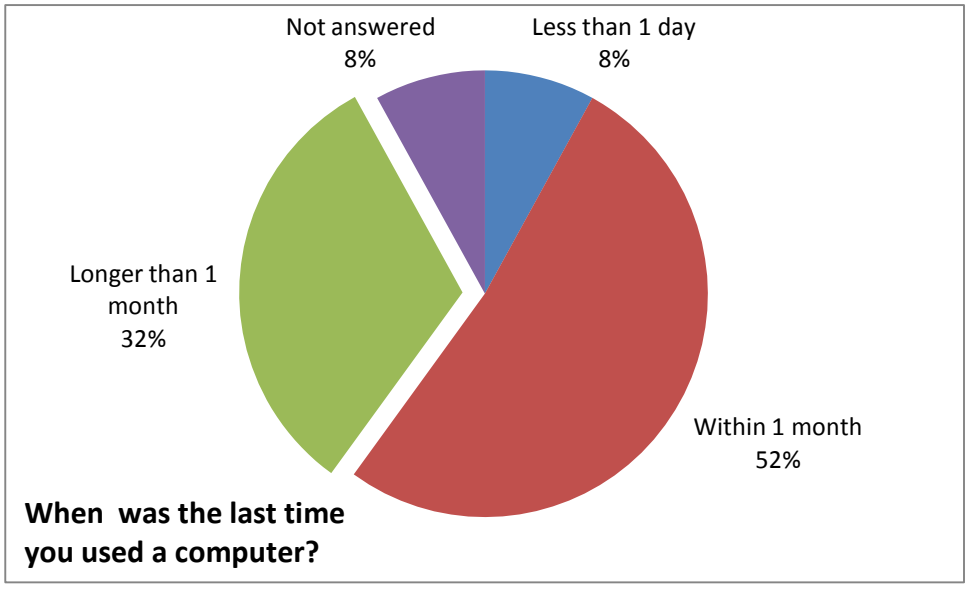
Advisory Committee Email Survey

An email survey was administered to the Advisory Committee. As with the program staff survey, there was a brief script prepared to introduce the survey followed by seven open-ended questions. The questions were very similar to those used in the program staff survey.

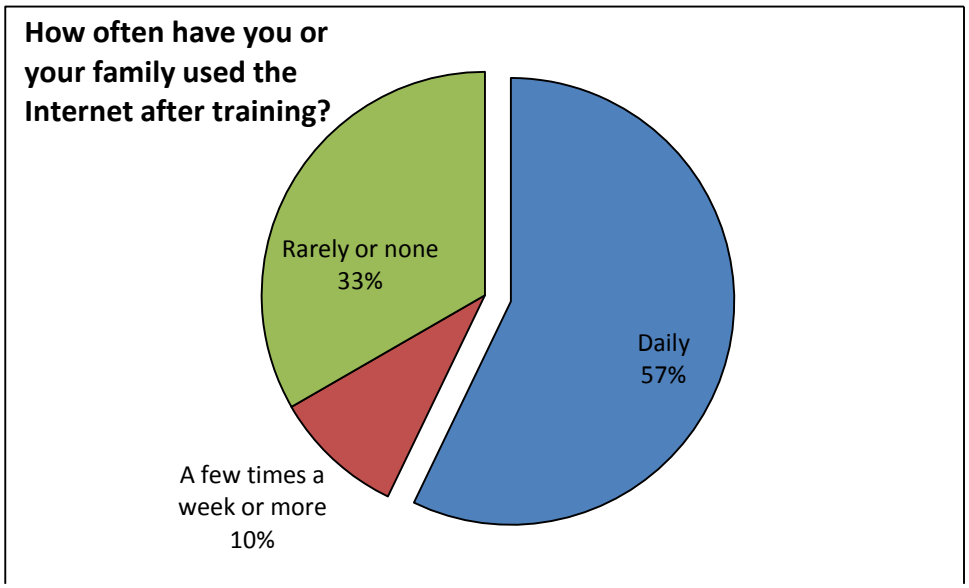
In an effort to make completing the survey as convenient as possible, the email survey was sent in the body of the email, along with an attached Word document of the survey. This provided the advisory committee with the option or replying using the text in the email, or by using the attached Word document. The use of email to distribute our surveys proved to be a much more effective way to disseminate materials to a large population in a shorter period of time. On average, it took 7 fewer days to receive the email survey than to complete them by phone.

Analysis

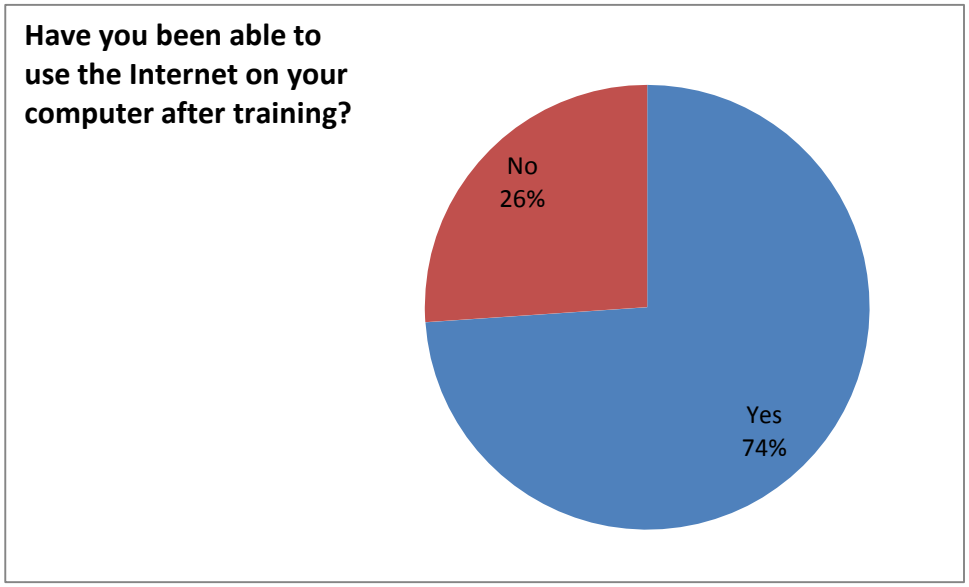
The chart below shows the last time the program participants used a computer ***before*** participating in the program:



This chart shows that the amount of daily users greatly increased ***after*** participating in the program.



Despite reporting a large increase in daily Internet usage by participants, the following chart reflects that more than a quarter of program participants did not have Internet access after completing training.



Connectivity was a chronic issue for some program participants. Others received a consistent signal when they logged onto the Internet, but they report the Internet "bounced on and off" and was "unpredictable" and "random". Participants remarked that it was "impossible" to access the Internet on the weekends. One factor was the location of a resident's unit in relation to the city's fiber optic network and the wireless mesh network.

This program provided the first opportunity to deeply monitor the network at Newtowne Court, and the program uncovered dead spots where no signal could be received. There two aspects to the network inconsistency: 1) hardware failure and 2) human error. Hardware failure relates to the discovery that the equipment was not placed appropriately to optimize Internet connectivity. Human error explains that the network fails when a user unplugs, moves, or removes a networking unit.

Because of the challenges of the network, the City's ITD agreed to provide additional funding to upgrade the network. January 2009, the pilot program contracted with Anaptyx (http://www.anaptyx.com/) to install an upgrade to the network at Newtowne Court. Anaptyx installed additional units to draw the signal into the building to improve the network's overall stability and performance.

After the completion of the upgrade, 13 of the 35 pilot program families were surveyed; 10 confirmed with CCTV that the network is better than before the upgrade. Respondents told CCTV that they've noticed that the network is faster, more reliable and they are not getting "bumped off" the network as they were before. In addition, CCTV is collecting information from residents and program participants to collect unused mesh units to redistribute them in areas where residents are still having difficulty connecting.

Participant Satisfaction

What worked well?

Overall, satisfaction was high. Many of the program participants were very pleased to have received computers at no cost. In addition, the technical training and support they received enhanced their experience in a positive way. Despite the difficulties of obtaining consistent Internet connectivity, participants felt they were able to better their personal circumstances by being able to prepare a resume, or seek employment online. Participants also reported using the Internet to look up city-wide events, communicate with family overseas, build business and for mental health support.

Approximately **87%** of program participants reported they are ***happy they completed the program*** and that they ***would recommend the program to a friend***.

*the other 13% did not respond to that question.

A question was posed during the creation of the program: "Would families be able to connect to their child's school online after training?" There were 2 program participants who didn't anticipate using the Internet to connect to their child's school, *but in fact did so*. However, quite a few participants who had hoped to use the Internet for that purpose did not. This finding could mean that additional support is needed in order to help families connect better with the schools online. Simply providing the Internet access is not enough to help these families engage online with the school system. It is not known if the *students* in the programs" families were able to use the Internet and other computer programs to complete schoolwork. Some of the families who had hoped to use the Internet to help with their child's schoolwork reported using the Internet for that purpose after training.

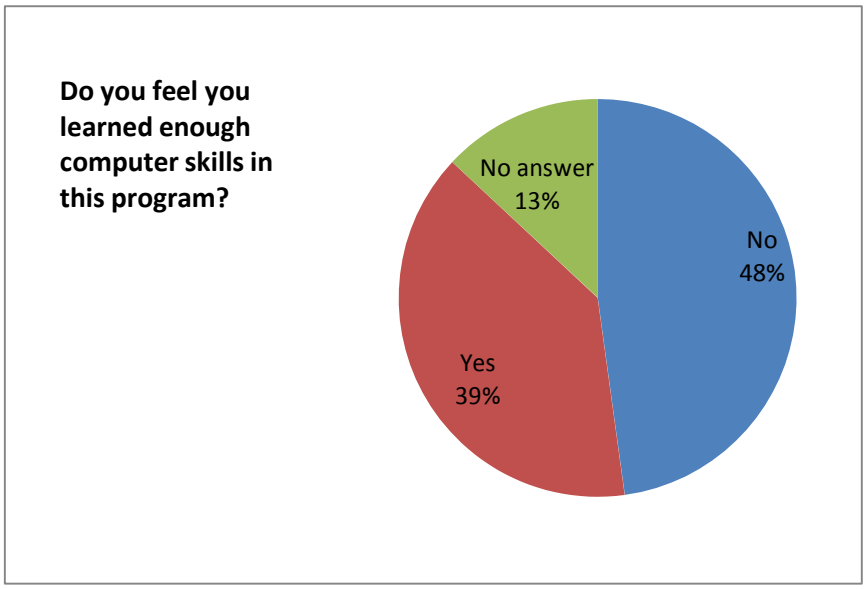
What skills did participants gain?

Almost 2/3 of the participants who said they would use the Internet for email in fact used the Internet for that purpose. Approximately 75% of the participants *who had not expected* to use the Internet for email, *did in fact use it for email after completing training*.

The list below shows how many of the 20 respondents obtained the skills described *before* and *after* completing training.

# Before	Skill	# After
18	Use a mouse	20
17	Use a Keyboard	20
16	Start a Computer	20
14	Shutdown a Computer	20
8	***Restart a computer***	***19***
12	***Open & Close the Internet***	***19***
9	Open & Close Documents	12
9	Create & Save Documents	11
7	Copy & Paste	9
5	Use Folder to Organize	8

The program was designed to give its participants basic skills necessary to conduct Internet searches and to use Open Office and other open source software. This level of training proved to be adequate as evidenced in the chart above that shows growth in daily Internet use, however, many program participants indicated that they need additional training. A major theme was that the training was not long enough.



Upon completion of the program, program staff at CCTV contacted program participants to gauge computer interests and offer additional classes.

Program participants‟ interests included: learning to type, utilizing the graphic capabilities available on their computers, conducting comprehensive Internet searches, burning CD‟s, downloading from the Internet, writing and formatting documents, emailing, and creating web pages. Other participants believe training should have spent more time explaining how to compute safely by providing more information on computer maintenance and Internet safety. There was a consensus among program participants that the training provided a rudimentary understanding of how to navigate the Internet and Open Office and other open source software, but that more training is required in order for them to maximize their computer and online experience.

Process

In response to a Council Order requesting that the City help bridge the digital divide, the City Manager appointed a committee charged with finding ways to address barriers to Internet access and designated Assistant City manager Ellen Semonoff as its chair. This group was comprised of City & Cambridge Public Schools staff, City Councilor - Henrietta Davis, local nonprofits and other community organizations, as well as interested residents. Overall, the advisory committee members felt their experience creating this pilot program was positive. Some committee members believed the group moved forward with the help of key leaders. Others felt the group contained the right mix of interested parties and believed the group was most productive when broken into small work groups. It was important however, to have a point person be the „thread" throughout all the work groups. A person in this role keeps the communication open and flowing to promote sharing in a project with as many moving parts as this pilot. In this pilot, a City staff member was appointed to carry the thread of communication because the Project Manager was brought on late (in the opinion of some respondents) into the process. In replication, ideally the Project Manager would play this role.

This project proceeded with the support and resources of the City of Cambridge. It is unlikely that the City has the infrastructure to continue to do this work. Therefore, any community groups hoping to replicate the program should find equally strong partners and community leaders in local agencies, universities, and businesses to support this work. All committee members surveyed spoke of the importance of community-building and appreciating all the committee members that took on responsibility and were active participants. Suggestions for improvement and replication are continued below.

<u>Youth Refurbishing & Technical Support</u>

Almost every staff and advisory committee respondent highlighted the partnership with RSTA as an integral part of the program, since the project received recently decommissioned computers from the City's IT Department. RSTA students rebuilt each computer to uniform specifications (See Addendum C) including parts installation and troubleshooting. The committee's Cambridge Public School representative reports that the refurbishing project provided a live work experience for the students while also providing the opportunity to participate in community development. Student engagement was high and the students were eager to learn and happy to help others obtain their goal of computer proficiency.

Led by committee member Ellen McLaughlin at Tutoring Plus, RSTA high school students were able to create a help desk to track calls for service and monitor the network. The pilot program was designed with 6 months of technical support and supervised RSTA students filled this role through the school year and summer, responding to emails and phone calls in addition to voicemail messages.

Having RSTA students refurbish the computers fulfilled the committee's goal to use this project to foster civic engagement; however, some committee members questioned the ease of replicating such a program. The question is: Under what circumstances is it cheaper to secure new computers rather than refurbish decommissioned computers? Two of the 35 computers had to be replaced due to hardware complications. As evidenced in other programs researched before creating this pilot, using new computers means fewer technical support calls. A community group seeking to create a program to Bridge the Digital Divide will have to weigh the bounty of collaborating with RSTA students or another technology vocational program against the capacity for managing technical support calls. Committee members suggested that organizations looking to create a similar program investigate a corporate sponsorship program, where a company would use their bulk rate to buy extra computers to donate to the project.

Lastly, some committee members feel laptops should replace the desktops provided in this program.

In-Home Technical Support

In additional to live technical support, the pilot program also offered in-home technical support provided by a community member residing in Newtowne Court, hired as contract staff for the pilot. Program participants indicated that the level of in-home support they received was necessary and very accommodating. They noted that the technical team was responsive and thorough. When problems occurred that could not be readily reconciled, technical support personnel followed up with participants regarding possible solutions and other trouble-shooting techniques. The program initially decided to offer both in-home technical support and a Saturday drop-in clinic. Since the in-home support was preferred by participants who needed help beyond what the help desk could provide, Saturday drop-in hours were never utilized.

Accessibility – Outreach & Training

Communications to solicit program participants were written in English, Spanish and French. This project was created to support 50 families, yet only enrolled 35. It is unclear why the program was unable to recruit more participants. Participants were shocked to find out that the program was unable to serve as many families as planned, and in fact, 5 participants at the focus group enrolled in the program as a result of personal referrals from other program participants and partner programs. It is possible that the advertised refurbished computer dissuaded potential participants; it certainly caused 1 potential candidate to withdraw from the application process. It also possible that times and/or commitment were prohibitive to potential participants, although the program designed a very short curriculum consisting of 2 three-hour classes for some participants. A major theme among the suggestions for improvement was a more direct form of communication, i.e. door-to-door, partner with local churches, civic organizations.

Bilingual trainers were available at each training session for participants needing translation, however very few participants utilized the translator services. Trainers came from both CCTV and the Community Learning Center (CLC). Those agencies are only two of many possible partners with bilingual trainers.

Training occurred at CCTV, CLC and the CHA computer lab directly across the street from Newtowne Court. All locations were chosen with regard to their proximity to Newtowne Court.

According to most staff reports, participants were engaged and asked numerous questions. One trainer remarked that teaching these participants was more rewarding than teaching other computer classes, due to their eagerness to learn and motivation. Staff reported little attrition of participants, mostly among those frustrated with the lack of connectivity to the Internet.

Additionally, because the knowledge base of the participants varied, different levels of training were suggested. For example, some suggested that novice students would be placed in the same training class while, all intermediate students could be placed in a different class. In the model for this program, proficient participants would „test out" of the required classes. This would allow everyone to get the desired level of training, and provide space for those who already possess some skills to enhance their proficiency. Due to the inclusive nature of training, families were able to bring other family members including small children, since child care was provided. Some participants remarked that training was loud and too crowded to focus on the lesson. Suggestions for replication include scheduling one-on-one training appointments or limiting training sessions to smaller groups of families and offering more training times.

Information & Referrals

Program participants, program staff, and members of the advisory committee agreed that participants could have benefitted from a more systematic method of providing referrals to other computer training programs. Program staff called participants to identify further training needs. In a testament to the community-building aspect of the program, some program participants reported running into program trainers in the community and making connections to other programs in that way.

Conclusion

Almost everyone surveyed stated that this pilot program was "a steppingstone" or just the beginning of necessary efforts to truly bridge the digital divide. There is consensus that more works needs to be done. Many felt that this program helped generate a lot of learning about what it takes to run and support a program designed to get low-income residents connected to the Internet. Initially, spotty Internet access hindered the program's efforts to get participants online. Consistent, reliable, and *monitored* Internet access is the basis for a successful program. Now that the network has been upgraded, it was suggested that the program look into expanding, with the help of new partners, to reach more residents at Newtowne Court. One response wished for the whole City to be "hooked up".

Most respondents agreed that the goal of serving as a workforce development tool for RSTA students was a shining achievement of the program. Also highlighted by respondents was the promotion of civic engagement and community-building by the many community agencies and individuals (including residents) working toward the goal of making this program successful. At least 3 residents of Newtowne Court participated in the program *and* were hired as program staff to do either training or technical support. These community leaders remain even though the program has concluded.

Generally, responses reflected participants‟ high satisfaction and engagement with the program. Participants felt rewarded and staff felt enriched by their work in the program. Students were motivated and excited to learn more and therefore remain engaged with CCTV for further learning and support.

ADDENDUM A
Computer Specifications

	Windows	**Mac**
Processor	1GHz Pentium 3/4	933 MHz G4
Monitor	15” flat screen	15” flat screen
Memory	256 MB	512 MB
Hard drive	40 GB	40 GB
Optical drive	CD-RW/DVD	CD-RW/DVD
Networking	Wireless Network Card, IEEE 802.11g capable	Wireless Network Card, IEEE 802.11g capable
Video Ram	64 MB	128 MB
Operating System	Windows XP	Mac OSX
Software	**Productivity:** Open Office Acrobat Reader 7-Zip **Browser – E-Mail:** Firefox Gmail **Security:** Spybot Ad-Aware Avast Anti-Virus **Graphics:** The Gimp Picasa Tux Paint **Multimedia:** iTunes WinAmp VLC Flash Player **Entertainment:** Google Earth Jardinains	**Productivity:** Open Office Acrobat Reader 7-Zip **Browser – E-Mail:** Firefox Gmail **Security:** Spybot Ad-Aware Avast Anti-Virus **Graphics:** The Gimp Picasa Tux Paint **Multimedia:** iTunes WinAmp VLC Flash Player **Entertainment:** Google Earth Jardinains

ADDENDUM B
Lesson Plans

Lesson Plans

*adapted from GCLearnFree.org
Customized with screen prints for both Apple computers and PCs

Lesson 1
Part I – 30 min – What is a computer?
Part II – 30 min – Input Devices & Output Devices
Part III – 30 min – Types of Software
Part IV – 30 min – File Maintenance

Lesson 2
Part I – 30 min – The Internet and the Web
Part II – 30 min – Connecting to and Using the Web
Part III – 30 min – All about email
Part IV – 30 min – Making the most of your experience

Lesson 3
Part I – 45 min – Setting up your Computer and Keeping it Clean
Part II – 45 min – Connecting and Staying Safe on the Internet
Part III - 30 min – Backing up, Troubleshooting and Diagnostics
Part IV – 30 min – Support

Digital Divide Pilot Project Budget		
	Actual	**Proposed**
Income		
City of Cambridge	**$57, 194**	$47, 550
CCTV	**$ 6, 764**	$ 2, 000
Cambridge Housing Authority	**$ 5, 000**	$ 3, 000
Total Cash Income	**$68, 958**	$52, 550
Expenses		
Project Manager	**$18, 000**	$18, 000
Computer Refurbishing	**$ 8, 308**	$ 7, 900
Mac Computers	**$ 2, 000**	$ 2, 000
Windsor Lab Computer Upgrade	**$ 9, 500**	$ 9, 500
Intake Workers	**$ 624**	$ 1, 300
Call Center Staffing/Tech Support	**$ 3, 133**	$ 7, 850
Training	**$ 2, 084**	$ 4, 000
Network Upgrades	**$25, 309**	$ 2, 000
Total Expense	**$68, 958**	$50, 550

ADDENDUM D -1
Consent Form

Oral Consent Script for the Newtowne Court Housing Development Digital Divide Project
Hello, I'm calling from UMass Boston. My name is _____. We are conducting a evaluation

of The Newtowne Court Housing Development Digital Divide Project to lay the groundwork for the program's replication in the event that any other organization in the City wish to create a similar program. The formative evaluation includes researching the effectiveness of the program's delivery via secondary data from surveys with participants and focus groups and interviews with program staff and members of the advisory committee. Your participation is voluntary.

May we proceed?

What We Should Learn from Pilot:

1. Costs of implementation for a larger population, including equipment, tech support and training
2. Changes in participants‟ access to and use of Internet
3. Participant satisfaction
4. Process issues: what would we do differently next time?
5. What are the tech support needs at the end of the project?
6. In households with school-aged children, has there been increased interaction by parents with the school department? Have students shown increased involvement with or success in their school work?

If you would like a copy of our final report you may request one by emailing Allyson Allen (aallen@cambridgema.gov) at the City of Cambridge.

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ADDENDUM D - 2
Advisory Committee Email Survey

"Good day,

My name is Carlotta Hampton and I am writing to you on behalf of Allyson Allen and the University of Massachusetts. We are sending you this email in an attempt to assess the Digital Divide project at Newtowne Court administered this year by Cambridge Community Television.

The goal of this survey is to capture your thoughts regarding the project in effort to determine what was most successful in implementing this project and what the areas for improvement in replication are. The email survey is voluntary and will take about 25 minutes.

Please take a moment to answer this short survey, as it will help lay the groundwork for other community groups to create similar programs. Upon completion, please forward your comments to Carlotta.hampton001@umb.edu on or before October 27, 2008.

Thank you for taking the time to participate in this important survey."

1. Do you think the project achieved its intended goal of bridging the digital divide at Newtowne Court? Was the vision to foster civic engagement and encourage community-building upheld?
2. The target population for this project was anyone without Wi-Fi Internet access. In replication, should the scope of the target population be narrowed or expanded? If so, why?
3. What type funding is feasible for future replication of the program? What suggestions do you have to secure computers? Is using refurbished computers an option in replicating the program. Why or why not?
4. Describe your experience as an advisory board member. What suggestions would you offer regarding the structure of future advisory committees or community organizations?
5. What suggestions would you offer for future program design?
6. Additional comments:

UMB does not share this information or keep it permanently, as it is for the sole purpose of sending this one time e-mail.

ADDENDUM D - 3
Program Staff Phone/ Email Survey

Oral Consent Script for Telephone Interviews with Staff: Newtowne Court Digital Divide Project

Hello, my name is Carlotta Hampton and I am calling on behalf of the City of Cambridge and the University of Massachusetts Boston. I am conducting a phone survey to gather feedback regarding the Digital Divide project at Newtowne Court.

I am calling program staff that participated in the facilitating this project. This survey is voluntary and will take about 20 minutes. Your opinions are very important to us and all responses are confidential. May I proceed?

Program Staff questions:

1. Do you think the project achieved its intended goal of bridging the digital divide at Newtowne Court? Was the vision to foster civic engagement and encourage community-building upheld?
2. Describe your experience as a staff member on this project. What suggestions would you offer to future advisory committees or community organizations wishing to replicate this project?
3. What changes would you suggest to further engage project participants from recruitment through project participation and post project?
4. What obstacles did you encounter in administering the project?
5. What suggestions would you offer for future program design?
6. Additional Comments:

We have completed the interview. I would like to thank you for participating in this important survey. Your feedback has been invaluable.

If you would like a copy of our final report you may request one by emailing Allyson Allen (aallen@cambridgema.gov) at the City of Cambridge.

ADDENDUM D - 4
Program Participant Focus Group Survey

Welcome – how's everyone doing today.

My name is Allyson Allen and I am Director of Planning & Development in the Office of Workforce Development with the City of Cambridge. Alongside me is Carlotta Hampton, a graduate student from the University of Massachusetts. She will be assisting me with today's focus group. We'd like to thank you all for coming in today.

We are here today to discuss the Digital Divide Project at Newtowne Court that you participated in earlier this year. Basically, we are looking for your feedback on the program. We'd like to talk a bit about your experiences so that we can work to improve future programs of this kind.

I would ask that you all take a moment to introduce yourselves – starting on this side, please tell us your name and how you heard about the program.

Okay, let's begin. I will be asking you some questions about the Digital Divide program and would like you to respond freely and honestly. If you feel uncomfortable about any of the questions you can decline to answer.

The first thing we'd like to know is:

1. Why did you choose to get involved in the program?
2. What was your experience in the program?
3. Did the program meet your needs?
4. Has your internet use changed since participating in this program? If so, how?
5. In households with school-aged children, have you been able to interact with the school department by using the internet? Have your children shown any increase in using the computer to do schoolwork?
6. What are your thoughts on the training you received in the program? Have you learned any more about computers and the internet since the project has ended? If so, how did you learn these new skills?
7. Do you have any thoughts on how we can improve this program in the future?
8. What suggestions would you offer to other community groups looking to create this project?

Well, that just about wraps it up. But before we finish, do you have anything you'd like to say that we haven't already covered?

Okay. To thank you for coming in today, we have some gift cards for you – they are from Target and are worth $10. We are so pleased that you took the time to help us out, and we hope you enjoy spending your money. Christmas is right around the corner, so we hope this will help.

Take care everyone and thanks again.