Feasibility Report for a Community Network

Falmouth, Massachusetts

November 16, 2020

Falmouth
EDIC | Economic Development & Industrial Corporation

Falmouth
EDIC | Economic Development & Industrial Corporation

ACKNOWLEDGEMENTS

This report was commissioned by the Falmouth Economic Development and Industrial Corporation, a 501 c 3 non-profit corporation established in 1981 by Falmouth Town Meeting in accordance with C. 121 C of the Mass General Laws. The mission of the Falmouth EDIC is to increase business and job opportunities in the Town of Falmouth.

The Board of Directors and staff of the Falmouth EDIC are as follows:

Christopher Land, Chair
Christopher Simmler, Vice Chair
Paul Burke, Treasurer
Thomas Feronti, Clerk
Michael Galasso
Patti Haney
Samuel Patterson
F. Michael DiGiano, Executive Director
Lynne Broderick, Administrator

The Falmouth Economic Development and Industrial Corporation wishes to acknowledge the following individuals, organizations, institutions, and businesses in Falmouth who gave freely of their time, expertise, and insights to help complete this first ever study of Falmouth's broadband infrastructure.

Members of the Falmouth Community Network Committee:
Courtney Bird, Art Gaylord, David Isenberg, Peter Cook, Marilois Snowman and **Sam Houghton**.

Julian Suso, Town Manager
Peter Johnson Staub, Assistant Town Manager
Jennifer Mullen, Finance Director
Michael Palmer, Town Clerk
Greg Banwarth, Director of Information Technology
Rod Palmer, Building Inspector
Peter McConarty, Director of Public Works
Jim McLoughlin, Town Engineer
Scott Schluter, Staff Engineer
Tom Bott, Town Planner
Bob Shea, GIS Coordinator
Patricia O'Connell, Town Collector
Trisha Favulli, Town Assessor
Linda Collins, Director, Falmouth Public Library
Patrick Murphy, Director of Finance and Operations, Falmouth Public Schools
Carol Chittenden, Falmouth League of Women Voters
Michael Kasparian, Falmouth Chamber of Commerce
Ryan Castle, CEO, Cape and Islands Realtors Association
Clark Guinn, Delaware North / Seacrest Beach Hotel
Todd Bidwell, President, Island Commuter Corporation
Aileen Landry, Manager, Hematology and Oncology Specialists of Cape Cod
Bill Hough, Editor and Publisher, The Falmouth Enterprise
Sean Greenwood, Manager, Windfall Market
Bill Zammer, President, Cape Cod Restaurants
Frank Geishecker, The Black Dog
Paul Speer, COO, Marine Biological Laboratory
Scott Koerner, IT Director, Marine Biological Laboratory
Nick Lowell, President, Lowell Instruments
Max Egan, Accurate Plastics
Keith Glavin, Senior Director Information Services, Woods Hole Oceanographic Institution
John Park, Manager, Networking and Telecommunications, Woods Hole Oceanographic Institution

Table of Contents

Page

Summary of Findings

The Falmouth Economic Development and Industrial Corporation (EDIC) is the primary agency responsible for developing increased economic opportunities for the Town of Falmouth, Massachusetts. The Falmouth Community Network Committee (Network Committee) is a citizens group in Falmouth focused on providing the people in Falmouth with locally controlled internet service. Both the EDIC and the Network Committee believe that a robust broadband infrastructure is critical to the Town of Falmouth's economic growth. In 2019, the Network Committee approached the EDIC with the idea of doing a first ever study of Falmouth's broadband infrastructure. The EDIC agreed and retained CCG to analyze Falmouth's broadband infrastructure and make recommendations regarding the viability of a new, alternative, broadband network that would address gaps in the current system and provide capacity for future growth

CCG found that broadband customers in Falmouth experience inconsistent speeds and frequent outages and that as many as 61% of residents and many businesses would consider moving to a new broadband network. With that level of potential demand, CCG determined that it would be financially feasible to build and operate a new high-speed fiber optic network that would bring gigabit broadband capability to every home and business in Falmouth.

This new fiber network would eliminate the slowdowns and interruptions in internet service that many homes experienced during the pandemic. It will also have the capacity to accommodate future growth for broadband services as more people work from home on the Cape; as business demand for uploading data continues; and as health care providers, schools, and community institutions continue to provide more internet-based services in a post-pandemic world.

This Summary of Findings references the more detailed study that follows and that discusses the various topics and key findings in more detail.

Broadband is Not as Good as it Should Be

Broadband in Falmouth is not as good as it should be. Consider the following:

Comcast Download Speeds. The Comcast network is not delivering the speeds that customers are paying for. As part of the study, we asked the public to take a speed test and the results surprised us. 43% of Comcast customers showed download speeds under 100 Mbps (megabits per second), with 23% of customers getting download speeds under 50 Mbps. This surprised us because we've studied other Comcast markets where the large majority of customers are receiving speeds equal or greater than the subscribed speeds. When asked, Comcast advertises the basic speed in Falmouth as 'up to 150 Mbps". We also heard in the broadband survey that the biggest complaint about Comcast was inconsistent speeds that vary throughout the day with intermittent outages (Page 38).

There are a few possible explanations for the slow speeds. We know that the Comcast network has been updated to the newest DOCSIS 3.1 standard since we found some customers able to buy Comcast's gigabit product. The most likely reason for the slow speeds is that the Comcast network configuration has not been modernized. Comcast purchased this network from Adelphia and much of the original network design from Adelphia is likely still in place. This means that there might still be large neighborhood nodes where too many homes are sharing broadband. A more likely explanation is a

configuration described as cascading. In the ideal network configuration Comcast would bring fiber to small nodes of a hundred or so homes. In a network with cascading, fiber is brought one neighborhood node, but then additional neighborhoods are added off this one fiber. The customers in the first node get the best download speeds, with subsequent nodes seeing slower speeds. We can't think of any other reason why homes would be getting download speeds under 50 Mbps and even 25 Mbps.

There are always some homes that get slow speeds due to having outdated WiFi routers – but we generally don't see this impacting more than 5% of customers in a market, so this can't explain the universally slow speeds in Falmouth.

Verizon DSL. The download speeds on Verizon DSL were mostly under 10 Mbps, which demonstrates that Verizon is still operating older versions of DSL technology in the town that were first installed in the early 2000s. Verizon no longer upgrades DSL technology, so these speeds will never improve. We expect within the next decade, and likely sooner, that Verizon will stop offering DSL (Page 40).

Fiber in Falmouth. Fiber broadband is provided by OpenCape to larger business, to government locations, and to the downtown business district, including a small number of residential customers. Comcast also is bringing fiber to some businesses. In total, only a tiny percentage of customers in Falmouth can buy broadband on fiber.

Upload Speed Gap. Much of the study was done after the start of the pandemic in March 2020. The pandemic uncovered a new broadband gap where residences began caring about upload speeds. Upload speed measures how fast data can be sent from a user's computer to the internet. Good upload speeds are needed for connecting to a school server, for working at home and connecting to a work server, and for connecting to online video meetings like Zoom. Additionally, just before the pandemic, many of the big gaming platforms moved their games online, creating a new demand for low-latency uploading. Many residents who thought they had adequate broadband suddenly found that they were unable to conduct multiple simultaneous upload connections at the same time. This phenomenon appeared all over the country as residences cared about upload broadband speeds for the first time.

The upload speeds in Falmouth are particularly sluggish. On Verizon DSL the upload speeds are all under 1 Mbps. On Comcast, 78% of upload speeds are under 15 Mbps, 55% are under 10 Mbps, and 14% are under 5 Mbps. Comcast reports to the Federal Communications Commission (FCC) that all of its customers in Falmouth can achieve upload speeds of 25 Mbps when only 15% are doing so. There is a discussion of upload bandwidth speeds starting on page 43.

The Broadband Gap is Growing. To add to the broadband gap problem, the demand for broadband is growing at an extraordinary rate. Perhaps the easiest way to understand this is through the average amount of bandwidth homes use each month. The following statistics are gathered and reported by OpenVault, a company that provides software for the large companies that operate the Internet backbone. In early 2018, the average home used 215 gigabytes per month of broadband (combined download and upload usage). By early 2019 this had grown to 274 gigabytes. By December 2019 the average home used 344 gigabytes. After the onset of the pandemic, by March 2020 the average home was using 403 gigabytes. This slowed a bit by June 2020, but the average home in the country was still using 380 gigabytes – a 74% increase since 2018 (Page 57).

According to Cisco, the amount of bandwidth used by homes has been growing at a steady rate of 21% annually since the early 1980s. Network engineers that operate broadband networks are terrified by the numbers cited in the preceding paragraph. Even if networks can handle the customer demand for bandwidth today, broadband networks will be severely distressed as broadband demand keeps growing at a torrid pace.

Other Broadband Gaps. The study examines other broadband gaps in Falmouth.

- The Affordability Gap. Like in all communities, there are residents of Falmouth that can't afford the cost of broadband. This was verified by the residential survey that showed that 9% of residents don't have a home broadband connection. This was further verified by discussions with the libraries that report that there are many residents of the community that rely on the broadband and computers available at the libraries. The libraries have recently been experimenting with lending WiFi hotspots to residents (Page 50).
- The Homework Gap. Falmouth, like other communities has students that don't have home computers or home broadband connections. The school system has addressed this issue during the pandemic by providing WiFi hotspots and Chromebook computers to students that needed help in order to connect to school classwork from home. These are temporary solutions and is something the community will have to continue to solve (Page 52).
- The Digital Literacy Gap. We had no easy way to measure this, but every community has residents who aren't comfortable working with computers or navigating the web. Communities are tackling this issue by ongoing basic computer training for residents (Page 56).

The Consequence of Slow Broadband Speeds. Slow broadband speeds put Falmouth at a competitive disadvantage. A recent national survey showed that one of the major consequences of the pandemic is that people are fleeing major metropolitan areas. As many as 23 million people plan to move in the coming year. Over 50% of the people who say they want to move are able to work from home and they are looking for communities that offer less costly housing and a better lifestyle than the cities they are fleeing. We talked to real estate agents in Falmouth who say there is a current real estate boom of people from New York City and Boston looking to relocate fulltime to Falmouth. One of the biggest hurdles the town faces is that the broadband is far better in these other markets than in Falmouth. Many urban customers in the Northeast are currently served by Verizon FiOS, which delivers symmetrical fast broadband on fiber. Comcast and other cable companies in the cities have upgraded networks to deliver the speeds they advertise. The broadband in Falmouth is not nearly as good as the broadband in nearby urban centers and the surrounding suburbs.

There is Market Demand for Better Broadband

As part of the study we looked at market demand. We first conducted a statistically valid random residential survey that asked about the current state of broadband with a target accuracy of 95% plus or minus 5%. The key findings of the survey are as follows: (Page 24)

- 91% of residents have a wired home broadband connection today, which is reasonably close to the national average.
- 88% said they are still buying a traditional cable TV package which is this is higher than the nationwide average, which was just under 70% at the time of the survey.
- One-third of respondents say they are unhappy with their current home broadband provider.
- Most residents in Falmouth are buying a bundle of multiple telecommunications services and the survey showed an average bundled monthly bill of $183 per month. That's one of the highest

numbers we've ever seen but is likely due to the large number of homes that still buy traditional cable TV.

- 53% of survey respondents said they are unhappy with the value they receive for the price they pay for telecommunication services.
- 70% of survey respondents support the idea of the town bringing a new fiber network, with an additional 16% saying they might support the idea but need more information. The primary reasons cited for wanting a fiber network are the hopes for more competition, the hope for lower prices, and the hope for more reliable broadband. .
- The key finding of the survey is that 36% said they would definitely buy from a new network; another 30% said they would probably buy service; 16% said they would consider buying service. Only 18% said they were unlikely to consider buying service from a new network. We interpret the survey to mean that as many as 61% of residents in Falmouth would consider moving broadband service to a new fiber network.

It's worth noting that the survey was done before the COVID-19 pandemic. Nationwide trends would suggest that the demand for broadband has increased during the pandemic as workers and students have been forced to function out of the home. The nationwide trends would also suggest that a lot of homes are starting to ditch the traditional cable TV products.

Business Questionnaires and Interviews. We communicated with businesses through a business questionnaire and through direct interviews. Here is what we learned from businesses: (Page 31)

- Every business that uses Verizon or Comcast told us their broadband speeds are "adequate," but that they would like faster speeds. The biggest complaint of the businesses that are not connected by fiber is the inconsistency of the broadband connection and the recurrence of outages.
- Almost every business told us that they didn't feel like they had any choice of Internet providers. Even businesses that use OpenCape fiber said they wanted a second competitive alternative.
- We reached out to businesses after the onset of the pandemic and heard that employees were having trouble working from home.
- We reached out to realtors that represent rental properties. They told us that 80% of potential renters now inquire about the availability of broadband. The number one complaint from seasonal renters is the inconsistency of the broadband connection – the same complaint we heard from residents.

Building a Fiber Network Would be Expensive

Our study considered wireless technology as well as several different fiber technologies. We found the most efficient and cost-effective new network would use Passive Optic Network (PON) technology using fiber to bring gigabit broadband to every home and business in the town. Our network design would also allow any large customers to be served using Active Ethernet technology that can deliver dedicated bandwidth speeds up to 100 gigabits per second (Page 69).

The fiber network is designed to go primarily on poles where other utilities are on poles but would be buried underground where other utilities are currently buried. The network design is robust and is designed to provide fiber for every home and business in the study areas today as well as the capacity for future expansion and growth. The extra capacity could be used for numerous reasons such as supporting electric smart-grid, supporting smart-city applications, or for providing for new housing and

business growth. Our engineers determined that a new fiber network would require 390 miles of new fiber construction on existing utility poles and 70 miles of new buried fiber construction

Following is a summary of the cost of building the network. This cost estimate considers a customer penetration rate of 50% at the end of year 5. The investment would vary with greater or fewer customers (Page 132).

Fiber	$41,260,625
Fiber Drops	$ 3,722,685
Electronics	$ 7,735,306
Operational Assets	$ 1,877,055
Total	$54,595,670
Cost per Passing	$ 2,272
Cost per Customer	$ 4,544

It's Financially Feasible to Build a Fiber Network

We considered a number of different potential business models. The report looks at the pros and the cons of the various operating models (Page 111). The study considers the following operating models:

- The town government or some other local entity like the EDIC would build and operate a fiber business.
- The town would attract a private ISP Internet Service Provider) to invest in building and operating a broadband business.
- The town would partner with an ISP to build an operate a broadband business. We discuss many variations on ways such partnerships might work.
- The town would build an open access fiber network and invite multiple ISPs to compete on the network.

Our Approach to the Financial Analysis**.** We created detailed financial models to quantify the potential for building and operating a successful ISP for each operating model. We used the following approach in estimating the revenues and costs for operating a new fiber network for each operating model (Page 125):

- A base model was created for each operating model. We arbitrarily chose a starting market penetration of 50% (the percentage of customers using the network). The residential survey had predicted a penetration rate of 61%, and we wanted the base study to be more conservative. We can't know how many customers a new fiber business might, but this penetration rate is typical for other similar fiber markets.
- All financial models cover a 20-year period.
- All projections include projected financing costs for borrowing the money needed to build and launch the network.
- We believe the engineering cost estimates are conservatively high.
- All studies include an estimate of future asset costs that are needed to connect future customers and to maintain and upgrade the network over time. We've assumed that electronics wear out and need to be replaced periodically during the studied time frame.

- Products were priced at a modest discount to Comcast rates since Comcast has the majority of existing broadband customers in town. The expectation is that the internet speeds on fiber will be significantly faster than the speeds available today.
- The estimates of operating expenses represent our best estimate of the actual cost of operating the fiber business and are not conservative. Most operating expenses are adjusted for inflation at 2.5% per year.

Key Financial Study Results**.** The assumptions used in creating the various financial plans for each scenario are included in Section III.C of the report. The results of the financial analysis are included in Section III.D of the report (Page 137). A summary of the financial results is included in Exhibit II (Page 210). Following are the key financial findings of our analysis.

It's Feasible to Operate a Fiber ISP in the Town. Most scenarios with a 50% market penetration are cash positive over 20 years, although there are scenarios where an ISP might struggle with that level of customers. Perhaps the key finding associated with profitability is the breakeven penetration rate. This represents the number of customers needed to create a business that should always remain cash positive. With revenue bond funding the breakeven penetration was calculated at a 48%. With bank financing the breakeven drops to a 42% penetration rate.

A Public-Private Partnership Could Succeed. There is enough potential profitability in the business models to contemplate public-private partnerships where the town builds a fiber network with an ISP partner.

Open Access Does Not Look Feasible. With open access the town would build a network and invite multiple ISPs to compete on the network. We could not find an open access scenario that is profitable for the town. This scenario does look to be profitable for ISPs that would operate on the network.

The Needed Debt to Financing is Significant. If the town financed the business with bonds the needed bond financing would be in the range of $70 million. Traditional commercial bank financing would require almost $8 million in equity and loans of approximately $55 million. Unfortunately, there are few private ISPs that would be able to raise the cash needed to build a fiber network in the town.

A Fiber Business is Sensitive to a Few Key Variables. All of the scenarios are sensitive to changes in a few key variables (Page 140):

- Penetration Rate: The most important variable is customer penetration rate. Our starting analysis was at a 50% penetration rate to be conservative. Our analysis shows that changing the penetration rate by just 1% will change cash over 20 years by $1.8 million. While that means a sizable boost in earnings for getting more customers than expected, it also uncovers the penalty associated with underperforming.
- Broadband Prices: The financial results are also highly sensitive to broadband prices. The studies all used an assumed starting price of $60 for the basic broadband product. Changing broadband prices higher or lower by $1 changes long-term cash flow over 20 years by $1.5 million.
- Rate Increases. The base models assume no rate increases to be conservative. It's possible in a competitive market that rate increases could be slim or even not happen. Raising rates by less

than 1% per year increases cash flow over 20 years by $8.9 million. Rate increases at some level will be needed to cover the cost of inflation.

- Interest Rate: The business plan scenarios are sensitive to changes in interest rates. A change of 50 basis points (changing interest rate from 3.5% to 4%) will change the cash flow in a bond-financed project by $6.1 million over 20 years. The impact on a bank-financed project is smaller, but still significant at $2.26 million over 20 years. While we've had a long period of over a decade where interest rates have remained steady, in a time of economic uncertainty it will be vital to keep an eye on interest rates.
- Loan Term. Increasing the length of loans by five years would provide a major benefit to financing fiber. With bond financing, changing from 25-year bonds to 30-year bonds would improve cash flow over 20 years by $10.9 million. With bank financing, changing from 20 years to 25 years improves cash flow by $10.4 million over 20 years.
- Changing Capital Costs. The impact of changing the amount of capital needed for a project has a much smaller impact than other variables. With bond financing, changing capital costs by $1 million changes cash flow over 20 years by $1.4 million. With bank financing the impact of changing capital costs by $1 million is a little less than $1 million.

Other Findings

There are other findings that are important for the community to consider when contemplating if you should try to build a new fiber network:

Existing Providers. The incumbent telephone company is Verizon, which provides broadband using DSL technology using copper. The incumbent cable company is Comcast. Some businesses and government entities in town get broadband from OpenCape, a local ISP that owns a fiber network that reaches across the town. There are residents who rely on cellphones for broadband. We looked at the key products and prices currently offered by the existing broadband providers (Page 15).

Passings. The telecom industry uses the term passing to mean any home or business that is near enough to a network to be considered as a potential customer. We used the town's robust GIS system to identify structures and potential customers. Our engineers settled on the following as the count of potential passings for the study.

Full Time Residences	14,232
Seasonal Residences	7,800
Business Passings	2,000
Total	24,032

Funding Options. The report discusses a wide array of funding options.

- Unfortunately, there are no grant programs we know of that could be used to build significant amounts of fiber in the town. The current federal and state broadband grant programs are aimed at rural markets. It's always possible to attract grant money for small incremental fiber builds like the grant used to serve the downtown business corridor.
- If the town finances the fiber network, all or most of the funding would likely have to come from municipal bonds.

- However, there are some interesting funding option worth considering such as direct tax funding, raising local start-up capital, partnering with an incumbent, and opportunity zone financing (Page 149).

Finding a Partner. The report describes the process of finding an ISP partner to help bring better broadband. The report doesn't suggest specific potential partners but describes the process used by other communities that have found and worked with ISP partners (Page 166).

Other Findings. The report also explores a number of other specific questions asked by the RFP.

- Future Technologies. The report explores if there are future technologies other than fiber that might present a competitive threat to any entity building a fiber network today, including 5G. We conclude that none of these technologies will be a strong competitor to a fiber network (Page 104).
- Summer Population. This report considers how better broadband fiber would impact the summer population in Falmouth (Page 61).
- Falmouth Community Television. The report explores the impact of a fiber network on Falmouth Community Television (Page 186).
- Fiber and Other Utilities. The report looks at how a fiber network might benefit the existing electric, water, and gas utilities (Page 191).
- Regional Fiber Solution? The report discusses the issues involved with collaborating with neighboring communities to create a larger and regional fiber business (Page 195).
- Other Cities that Have Built Fiber Networks. The report discusses some cities that have already built fiber networks like the one considered in the study. This includes cities that have been profitable, cities that have been unprofitable, and cities without electric utilities that have tackled fiber (Page 198).
- No Municipal Electric Utility. The RFP recognized that most cities that have built fiber already have an existing municipal electric utility. The report looks at what that means for Falmouth (Page 168).

Recommended Next Steps

1. **Decide if You Want to Proceed Further**. This study shows that it can be financially viable to build a fiber network and a fiber ISP in Falmouth. The study also demonstrates that there is enough likely customer demand in the community to support a fiber-based ISP.

   It's likely that this report will kick-off a more detailed discussion in Falmouth about the possibility of getting a fiber network. The decision to move forward with a fiber network is not an easy one. The three following recommendations address the need to figure out funding, local control of a new fiber business, and communicating with the public about a complex technical subject. Moving forward probably also means opening a dialogue with potential ISP partners if the town is not comfortable with the concept of operating a municipal broadband business.

   We think the first step after getting this report is to digest the findings of the report and then develop a specific plan and process for taking the next steps. Such a plan needs to be structured with time goals for reaching conclusions on the major elements of being able to make decision. Without a structured plan, the town could end up talking about fiber for years with no action.

2. **Educate the Public**. The report discusses a number of ways that other communities have educated the public on the broadband issue. The first step is to circulate this report. This written report was created for the purpose of explaining the wide range of issues associated with fiber to elected officials and the public. Our goal was to explain highly technical issues in plain English for the benefit of the nontechnical layperson.

   But there are many additional steps needed to bring the general public into the discussion of broadband. For example, many communities follow up a report like this one with neighborhood meetings intended to answer basic questions the public has about broadband. Most communities also begin the process of gathering public support and a method to further communicate with the public through such tools as a broadband website, a broadband newsletter, or some other kind of tool that can be circulated to discuss the progress of the investigation into fiber (Page 183).

3. **Figure out Funding.** Perhaps the hardest hurdle to overcome in getting a fiber network in any community is figuring out how to fund the network. That conversation can't be done in a vacuum and would include local government, the EDIC, and any potential ISP partner.

   We rarely see new community fiber networks funded from only one source. It wouldn't be surprising to see the funding for a network in Falmouth that derives funding from bond funding from the local government and/or the EDIC, from local equity or loans from community members, and from an ISP partner. There are also additional funding sources such as bringing in funding from a fund that utilizes Qualified Opportunity Zone funding.

   It's always complicated using funding from different sources because that requires figuring out such things as how each provider of funds is protected in the case the project doesn't succeed. This process of negotiating priorities of claims by lenders is one of the hardest challenges for this kind of funding.

But there is also the more mundane issue of getting funding commitments from different parties. Every party involved is going to hope that most of the funding comes from somebody else, and so there is always a process needed to take the money needed as identified from the business plan and turning that into specific commitments of exact amounts from the various funding sources.

4. **Figure out the Local Angle**. One message I heard from talking to various segments of the Falmouth community is that it is going to be important to have some level of local control and/or influence over any network and ISP that builds and operates a fiber network. This issue can probably best be described using the term governance, which asks about who decides policies for the new fiber business.

   Understanding governance is going to require two steps. First is to determine the structure of the new fiber business. There are numerous ways that the community could structure the business, and these are discussed in the report. This would include options like creating a municipal utility, creating a broadband cooperative owned by customers of the business, creating a non-profit business to operate the network, or creating a for-profit corporation. There are pros and cons for each of these business structures. The business structure can't be decided in a vacuum and the decision on how to fund the business might eliminate some of these options (Page 118).

   The second step is then deciding within the chosen business structure how to define governance. Generally, anybody that provides a large share of funding is going to want to have some say into how the business is operated. Some lenders might have strong opinions on the topic that must be followed in order to get the funding. There is also going to be interest in somehow including the local government, the EDIC, or other local voices into the governance structure. Finally, any operating ISP is going to have a strong opinion – commercial ISPs are almost automatically leery of local control by government.

   Governance can get complicated and will eventually include specific details about how various parties vote on issues, and what happens when a consensus can't be reached. But that is the last step in the process. The specific recommendation is that the community tackle the governance issues such as business structure as part of considering moving forward.

5. **Talk to Potential ISP Partners**. This report provides a list of steps that other communities have undertaken in finding and opening a dialogue with potential ISP partners. The process most favored by ISPs in an informal process where discussions can be had that are not in writing or on the public record. Some communities insist on a more formal process, and that can drive away some potential ISP partners.

   The early stages of talking to ISPs are first to find out the level of interest in providing the local ISP function in Falmouth. There are numerous other aspects of working with an ISP that can't be fully explored until the decision has been made about important steps like the business structure and the way the business will be governed. ISPs are obviously going to be highly interested in understanding how they will be compensated for their effort.

There are numerous parameters for judging ISPs and each community must decide your specific priorities. For example, if there is an expectation that an ISP brings some funding, then that eliminates ISPs that can't bring funding.

While any discussions held with ISPs are preliminary, we think it's a step worth taking early in the process, because the ISP partner chosen is likely to influence some of the other questions such as business structure, governance, and funding (Page 166).

6. **Find a Local Champion**. It's been CCG's experience that a project of this magnitude is not going to progress unless there is some kind of local champion. A local champion is some person or group that is tasked with tackling the various recommendations made in this report. A local champion clearly has to be pro-broadband, but open to all possibilities of how this might work in the community.

   Communities have staffed the ongoing effort in a number of ways. There are communities for which broadband is such an important issue that the dedicate government or economic development staff to the issue. It would be unusual for this to effort to immediately be a full-tie task, but eventually it could become so.

   But typically, government staffing is not going to be efficient to move the broadband issue forward. That's not hard to understand by looking at these recommendations and seeing a list of issues must be tackled like public education and outreach, funding, governance, finding an ISP partner, etc.

   Most communities that have successfully tackled getting broadband network also bring in volunteers from the community. Falmouth already has a volunteer broadband committee, but the ongoing volunteer effort is likely to be different than that. To be effective, volunteers need to be organized and giving specific tasks to achieve and a schedule to meet. It would be somewhat normal to have several different volunteer committees that tackle different issues. Such volunteer efforts need some level of funding to achieve their goals. It's also important that any volunteer efforts have oversight to make sure they are headed in the right direction.

   The recommendation is to identify and activate both government and volunteer resources and to develop a plan to use these staffing resources to tackle the various issues associated with broadband. The most successful efforts require that staffing be directed to solve specific tasks, given specific timelines to meet, and are properly funded to achieve the goals.

7. **Tackle the Steps that Can Reduce Construction Costs**. The study identified a few steps that can be taken that could reduce the cost of the network that has been estimated by CCG engineers. One issue is the cost of make-ready, which is getting poles in the town ready to accept fiber. One of the issues we've identified is that there are many residential streets where trees are going to need to be trimmed before fiber construction can take place. This is normally the responsibility and at the cost of the existing companies that have wires on the poles. The community needs to take steps to see that tree trimming is up to date before tackling fiber construction.

   We also think there are possibilities for sharing fiber with OpenCape. In many cases a second fiber is going to have to be built along the same routes where OpenCape already has fiber. But

there may some neighborhoods where OpenCape already has enough fiber to serve all of the local potential customers. There are likely some existing OpenCape fiber routes where leasing a few fibers from OpenCape might be all that is needed to avoid new construction, particularly on some of the roads that reach between the neighborhoods in town. Finally, there might be a savings if there are places where a new fiber could share the same space on the pole as the OpenCape fiber.

Determining these savings will likely require more detailed engineering, and the specific details of these savings might require a block-by-block determination.

8. **Reach out to Verizon**. Verizon has begun to deploy a fixed wireless technology being marketed as FWA (Fixed Wireless Access). The product is described in more detail in Section II.C. of the report. This technology involves building fiber on residential streets and then beaming broadband into the home using millimeter wave spectrum. In terms of technology we call this fiber-to-the-curb. Verizon currently claims to be achieving speeds close to a gigabit with the new technology, which is currently being introduced in neighborhoods in Detroit and a few other cities. Verizon says they plan to deploy the new technology to pass 30 million homes, so they company will be making significant investments in fiber in neighborhoods.

   Verizon never brought its fiber FiOS product to the Cape and we have no idea if the company is thinking about bringing this technology to Falmouth or other towns on the Cape. The town should reach out to Verizon to see if they will share their intentions.

   There are a few things we understand about Verizon that need to be considered with this technology. The company is unlikely to bring the technology to all of Falmouth even if they are coming to Falmouth. Verizon is a highly disciplined overbuilder in that they only build where costs meet certain parameters. When Verizon built FiOS fiber, it didn't build to the "best" neighborhoods, but rather to neighborhoods where the construction costs fell within the company's cost goals.

   It's not an easy decision to invite Verizon and the technology to town since they will only bring it to some parts of the town. That would result in a town where some neighborhoods have choice while other would be stuck with only the Comcast monopoly. If Verizon is coming to town it might be possible to partner with them to complete the build somehow. We're not aware of Verizon ever entering in this kind of partnership, but we're seeing other large telcos like CenturyLink and Consolidated partnering with communities to bring gigabit broadband.

9. **Be Persistent.** The path to go from this report has a lot of moving parts and is likely to move forward by fits and starts. We caution the town to be persistent if you really want fiber – if not, you might bet stopped by roadblocks that pop up along the path to get fiber.

I. MARKET ANALYSIS

A. Providers, Products and Price Research

The two major incumbent residential service providers are Comcast and Verizon. According to the survey, Comcast has won the majority of customers in town. Both incumbents also serve the business market. OpenCape has built fiber to the larger businesses and anchor institutions in the town. There are also residents in the town who use their cellular phones as the only source of home broadband.

Incumbent Telephone Company

Verizon. Verizon is the incumbent telephone company in Falmouth. Verizon was formed under the name of Bell Atlantic as a spin-off from AT&T in 1984. Verizon is the second largest cellular company in the country after AT&T. As of the end of the first quarter of 2020 Verizon was the fourth largest ISP in the U.S. with just under 7 million broadband customers along with 4.1 million video customers. Verizon purchased AOL in 2015 and in 2017 purchased Yahoo. In recent years, the company sold a significant number of customers to Frontier Communications, mostly properties outside of the northeast corridor.

Stand-Alone Internet

Verizon delivers broadband using two technologies. In cities where it's built fiber, the company sells under the FiOS brand name. FiOS currently offers three Internet products with speeds of 200 Mbps, 400 Mbps or 940 Mbps. FiOS is not available in Falmouth.

In Falmouth, the company still offers broadband using telephone copper wires using DSL technology. The company pushes customers to buy a bundle of telephone and Internet, but it will sell standalone DSL.

Verizon only has one DSL product in Falmouth that offers speeds up to 15 Mbps. The list price for standalone DSL is $49.99 per month. As this report was being written the company was offering a web special for $40 per month that would be good for a year.

Verizon has been aggressive with price increases on DSL. There are customers that were paying less than $20 per month a decade ago that have been increased over time to the current $49.99 price.

Verizon allows customers to provide their own DSL modem and WiFi router. Verizon is currently selling a combined DSL/WiFi box for $50, and these are also available from electronics vendors. Customers report a range of different rental fees if a customer chooses to lease the box from Verizon, with the most commonly cities prices being $5 and $7 per month.

Telephone Service.

Verizon currently is only offering Verizon Freedom Essentials to new customers on the web. This is a telephone line that includes unlimited long distance and up to five common features. Verizon is currently advertising this as an add-on to a DSL connection for $25. But there are customers who have gotten the product in a bundle for as little as $15 – the amount charged for bundling varies according to how and when a customer subscribed. There are grandfathered customers who are buying other Verizon telephone products with DSL.

Verizon also provides some customers an additional bundling discount for those that are using the company for cellular service.

Customer Support. Verizon supports technical questions about broadband for a limited time after installation. Customers that want a guarantee to task to tech support are asked to subscribe to Tech Support Pro at a cost of $10 per month.

Verizon also offers a premium support product called Verizon Protect Home. This product costs $25 per month. It provides 24/7 access to tech support. It also covers two in-house visits by technicians per year. Verizon will replace any non-working Verizon devices for free for subscribers of the plan. The product also comes with a suite of security and WiFi protection software.

Incumbent Cable Company

Comcast Xfinity. Comcast is the incumbent cable TV provider in Falmouth. Comcast markets and bills using the "Xfinity" brand name. The company offers the traditional triple play of cable TV, internet, and voice services. Comcast is the largest cable TV company in the US with 2019 revenues of nearly $109 billion, and the second largest cable company in the world. They are headquartered in Philadelphia. At the end of the first quarter of 2020 the company had 29.1 million broadband customers and 20.8 million cable customers.

In addition to providing triple-play services the company owns a number of media assets like NBC, Telemundo, MSNBC, CNBC, USA Network, The Golf Channel, Syfy, numerous regional sports networks, Universal Pictures (and theme parks), DreamWorks, and the Philadelphia Flyers hockey team and arena. The company now sells cellular phone service. They are also probably the largest seller of smart home services in the country.

Stand-Alone Internet[1]

Comcast offers significant discounts to some new customers. Promotional products eventually revert back to list price, generally within one or two years. Following are the most recent list prices for standalone Internet.

Performance Starter	15/2 Mbps	$ 53.00

[1] The Comcast rate sheet as of December 2019 is at: https://comcaststore.s3.amazonaws.com/prod/wk/urc/585bc4be5bcd10375b2cf1d8/high_res/UC0000002_sik_high_res.pdf

Performance Plus	60/5 Mbps	$ 73.00
Blast! Pro	150/5 Mbps	$ 83.00
Extreme	250/10 Mbps	$ 93.00
Gigabit	1,000/35 Mbps	$113.00
Gigabit Pro	2,000/2,000 Mbps	$299.95
WiFi Modem (for all products)		$ 14.00

We don't believe that new customers can buy the 15/2 Performance Starter product, so the minimal Comcast product is now priced at $73 after the end of any promotional discounts.

Comcast raised broadband rates by $3 and the cost of the modem by $1 in December 2019. Industry analysts expect prices to increase annually.

Comcast has data caps. Most broadband products are capped at 1 terabyte of download per month (1,000 gigabytes). There are lower caps that apply to grandfathered legacy products. When customers exceed that cap for a given month (the usage adds together both download and upload data usage), Comcast bills $10 for each additional 50 gigabytes of data used, with a maximum of $50 extra.

Telephone

Comcast sells standalone residential telephone service. The prices are as follows.

Basic	$30.00
Additional Line	$ 9.95

The basic line is a telephone line with the standard features but no long-distance option. Comcast used to offer a telephone line with unlimited long distance, but that's no longer in their price list. My guess is that they will direct customers to the Comcast cellular service for those wanting unlimited calling.

Cable TV

The following prices are for standalone cable TV. These packages follow the tiers of service required by the FCC. The Limited Basic tier includes the network broadcast channels like ABC, CBS, FOX, NBC and PBS. The tier also has a number of other channels such as shopping channels and a few others – varies by market. The Extra tier includes most of the popular channels that people expect from a cable subscription. Finally, the Preferred tier adds on a number of additional channels and includes every non-premium channel offered by Comcast.

Limited Basic	$32.95
Extra	$70.00
Preferred	$90.00
Set-top box	$10.45
DVR Service	$10.00

Comcast adds the following fees to every cable subscriber.

Broadcast TV Fee	$14.95
Regional Sports Fee	$ 8.25

These fees are controversial. There is currently a lawsuit filed by the State of Minnesota that is challenging these fees. Lori Swanson, the Attorney General of Minnesota sued Comcast in 2018 seeking refunds to all customers who were harmed by the company's alleged violation of the state's Prevention of Consumer Fraud Act and Uniform Deceptive Trade Practices Act.

These two fees are a part of every cable package and are not optional to customers. Comcast doesn't mention the fees when advertising the cable products. Further, Comcast customer service has repeatedly told the public that the fees are mandated by the government and are a tax that is not set by Comcast.

Comcast only started charging separately for these two fees in 2014, but the size of the fees has skyrocketed. In recent years the company has put a lot of the annual rate increases into these fees, allowing the company to continue to advertise low prices. The Regional Sports fee passes along the cost of regional sports networks. The Broadcast TV fee includes the amounts that Comcast pays local affiliate stations for ABC, CBS, FOX, and NBC.

Comcast argues that breaking out these fees makes it easier for customers to know what they are paying for – but there are numerous examples cited in customer complaints where new customers were surprised at the size of the first bill they receive from the company.

The Comcast Bundle

It is important for anybody that wants to compete against Comcast to understand the power of its bundles. The most obvious reason for giving bundles is to entice customers to buy more than one service from the company, and Comcast provides increasing discounts for customers that buy multiple products. Because the company has so many products, it offers a dizzying array of bundles, with prices that change often as inducements to get customers to buy additional products. Comcast has learned that customers that buy multiple products - particularly products in addition to the triple play – rarely churn and become loyal customers.

One of the most important aspects of the bundles are that they punish customers for dropping a bundled service. Consider the following simplified example of how this works. Suppose that a customer purchased the $73 broadband product and the $70 cable product and is given a $20 bundling discount and charged is $123 for the bundle. If a customer drops either product, the customer loses the entire $20 discount and remaining product reverts list price.

Customers never know what they pay for any given product within the bundle. For example, there are bundles that make it look like a customer is getting telephone service for free. But if the customer breaks the bundle and wants to keep only telephone with Comcast it reverts to the prices above.

This is one of the primary reasons that most competitors to Comcast offer cable TV. Otherwise, if a customer tries to change just their broadband to the new provider but leaves cable TV with

Comcast, they are charged a "penalty" for breaking the bundle. Once customers understand the financial consequences of breaking the bundle, many won't change to a competitor since they might not get any net savings.

Comcast has expanded the bundle in the last few years. Their newest offering is cellular service which is only available for customers buying Comcast broadband. The pricing is simple, and inexpensive. Customers pay by the amount of data used, at $12 per gigabyte. A customer using less than 1 GB of data pays only $12 per month for the connection. For $45 per month customers get unlimited data. Comcast uses the Verizon network to carry the traffic, but the company recently purchased spectrum and is planning on providing the service directly to customers in some markets.

Comcast also provides smart home products under the brand name of Xfinity Home. The company is now supporting the home automation devices of nine major manufacturers: August (smart locks), Automatic (automobile), Cuff (fitness tracking), Lutron (smart lighting), Leeo (alarms), Nest (thermostat), Rachio (sprinkler system), Skybell (doorbell), and Whistle (pet tracking). It's an impressive suite of products and is all integrated through the Comcast portal.

Comcast also offers traditional home security with hardware developed at Comcast Labs. This includes the traditional suite of burglar, fire, and other alarms that are monitored and reported to authorities when there is a problem.

Other Incumbent Provider

OpenCape Corporation is a 501(c)(3) non-profit corporation that owns an extensive fiber network throughout Cape Code and southeastern Massachusetts including connectivity back to Boston. The company is headquartered in Barnstable Village.

OpenCape acts as an Internet Service Provider (ISP) for more than one hundred institutions including libraries, government buildings, schools, colleges, hospitals, public safety agencies and research institutions. They also serve large business customers. The company operates an active Ethernet network that can provide speeds as fast as 100 Gbps.

In Falmouth, OpenCape provides connectivity between nineteen buildings operated by the town. OpenCape provides connectivity to provide the survivability of public safety networks during bad weather conditions. OpenCape also connects to the schools in Falmouth as well as places like the business park, research facilities, and other key employers in the community.

Main Street Initiative. In 2019, The Falmouth EDIC and OpenCape received state funding to provide fiber connectivity to businesses located along Main Street in Falmouth, as well as businesses in Woods Hole. Merchants reported significant problems with existing broadband such as being unable to process credit cards and in having periodic network outages during the tourist season.

The project will bring a shared gigabit of bandwidth to the business districts. Merchants have three options for connecting. They can pay the $400- $600 connection charge up front, with the options to spread the connection fee over a year. Businesses and non-profits that qualify can get the installation fee covered by a grant through the joint EDIC / Open Cape program. Open Cape is selling a gigabit

broadband connection to downtown businesses for a rate of $117, guaranteed for 2 years and is also offering broadband to residents who live in the immediate neighborhood of the fiber.

Other Providers

Dish Network is a large satellite provider and has customers in the county. The company had around 9.5 million cable customers nationwide at the end of the third quarter of 2019. Dish Network now also offers an Internet-based cable product branded as Sling TV. This service offers an abbreviated channel line-up and costs less than traditional cable products.

Dish Network has the same pricing nationwide. The standalone price with no discounts is as follows:

190 Channels	$ 79.95
190 Channels +	$ 84.99
240 Channels +	$ 94.99
290 Channels +	$104.99

It's worth noting that Dish now plans to become the fourth major cellular carrier in the country. This expansion was activated from negotiations involved in the merger between T-Mobile and Sprint.

DirecTV is one of the largest cable providers in the US. The company is now owned by AT&T. The company had 16.8 million cable customers at the end of 2019, down almost 2.4 million customers during 2019. AT&T has decided to end all discount packages, resulting in significant rate increases for many customers who were getting various promotional discounts. DirecTV now offers an online version of its programming that was called DirecTV Now, but which was recently renamed as AT&T TV.

Current prices after any promotional discounts are:

155 Channels - Select	$ 85.00
160 Channels - Entertainment	$ 97.00
185 Channels - Choice	$115.00
235 Channels – Xtra	$131.00
250 Channels - Ultimate	$142.00
330 Channels - Premier	$197.00

The above includes rate increases effective January 2020 that range from $4 to $8 per month.

Satellite Broadband.

There are two satellite broadband providers available to homes and businesses. Both Viasat and HughesNet utilize satellites that are parked at a stationary orbit over 20,000 miles above the earth.

There are a few problems that customers consistently report with satellite broadband. Customers complain that satellite costs too much (Viasat claimed in their most recent financial report for June 2019 that the average residential broadband bill is $84.26). Customers also hate the high latency, which can

be 10 to 15 times higher than terrestrial broadband. The latency is due to the time required for the signals to go to and from the satellites parked at over 22,000 miles above earth – that adds time to every round trip connection to the web. Most real-time web connections, such as using voice-over-IP, or connecting to a school or corporate WAN prefer latency of less than 100 ms (milliseconds). Satellite broadband has reported latency between 400 ms and 900 ms.

The other customer complaint is about the tiny data caps. As can be seen by the pricing below, monthly data caps range from 10 gigabytes to 150 gigabytes. To put those data caps into perspective, OpenVault announced recently that the average US home used 344 gigabytes of data per month in the fourth quarter of 2019, up from 275 gigabytes in 2018 and 218 gigabytes in 2017. They also reported that the average cord-cutting home used 520 gigabytes per month in 2019. The small data caps on satellite broadband make it impractical to use for a household with school students or for a household that wants to use broadband to work from home.

Viasat (was formerly marketed as Exede or WildBlue) offers broadband from one older and also a newer satellite. Following are the products from Viasat:

	Price	Speed	Data Cap
Liberty 12	$30	12 Mbps	12 GB
Liberty 25	$50	12 Mbps	25 GB
Liberty 50	$75	12 Mbps	75 GB
Unlimited Bronze 12	$50	12 Mbps	35 GB
Unlimited Silver 12	$100	12 Mbps	45 GB
Unlimited Gold 12	$150	12 Mbps	60 GB
Unlimited Silver 25	$70	25 Mbps	60 GB
Unlimited Gold 50	$100	50 Mbps	100 GB
Unlimited Platinum 100	$150	100 Mbps	150 GB

Online reviews say that speeds can be throttled as slow as 1 Mbps once a customer reaches the monthly data cap.

HughesNet is the oldest satellite provider. They have recently upgraded their satellites and now offer speeds advertised as 25 Mbps download and 3 Mbps upload for all customers. Prices vary according to the size of the monthly data cap. Their packages are as follows:

10 GB Plan	$ 59.99
20 GB Plan	$ 69.99
30 GB Plan	$ 99.99
50 GB Plan	$149.99

These packages are severely throttled after meeting the data caps.

Cellular Data

There are four primary cellular companies in the country—AT&T, Verizon, T-Mobile, and Sprint. As this paper was being written, the courts approved the final challenge to a merger between T-Mobile and Sprint. Part of the merger conditions was that Sprint would provide spectrum that would allow Dish

Networks to become the fourth cellular nationwide carrier.

The residential surveys showed that 5% of households use their cellphone data plans for household broadband. There are a few issues that are experienced with cellular data. First, customer speeds decrease with distance from a cellphone tower, so cellular data speeds are not the same everywhere in town. Data speeds also weaken when passing through walls into building, so indoor speeds are not as fast as outdoor speeds.

Following are the nationwide average 4G data speeds for the four carriers, shown for 2017 and 2019. Speeds are improving over time. However, these are nationwide averages and rural customers likely get slower speeds than these averages.

	2017	2019
AT&T	12.9 Mbps	17.8 Mbps
Sprint	9.8 Mbps	13.9 Mbps
T-Mobile	17.5 Mbps	21.1 Mbps
Verizon	14.9 Mbps	20.9 Mbps

All four carriers now offer "unlimited" data plans. The plans for AT&T, Sprint, and Verizon are not actually unlimited and have monthly data caps in the range of 20 - 25 gigabytes per month of downloaded data. These plans might provide some relief to homes that rely on cellular broadband, although there have been reports of Verizon disconnecting rural customers who use too much data on these plans. These plans allow have limits on how much data can be used when tethering from a cell phone for use in other devices, so the plans are not much more useful for home broadband than normal cellular plans. T-Mobile claims to offer unlimited data but begins throttling customers after 50 GB of data usage in a month.

There are two different cellular data standards in use: 3G and 4G. 3G data speeds are capped by the technology at 3.1 Mbps download and 0.5 Mbps upload. There are likely to still be some 3G cellular towers in rural parts of the county. The amount of usage on 3G networks is still significant. GSMA reported that at the end of 2018 that as many as 17% of all US cellular customers still made 3G connections, which accounted for as much as 19% of all cellular connections. Opensignal measures actual speed performance for millions of cellular connections and reported the following statistics for the average 3G and 4G download speeds as of July 2019:

	4G 2019	3G 2019
AT&T	22.5 Mbps	3.3 Mbps
Sprint	19.2 Mbps	1.3 Mbps
T-Mobile	23.6 Mbps	4.2 Mbps
Verizon	22.9 Mbps	0.9 Mbps

B. Residential Survey

The first phase of the Broadband Feasibility Study was to conduct a residential survey to understand residential interest and demand for a new fiber network in the town.

Survey Methodology

The survey covers the town boundary of Falmouth.

The survey was conducted by telephone. The Falmouth EDIC wanted this survey to represent households across the socioeconomic and age range, and the easiest way to get that broader mix is to include cell phones in the survey. Some of the largest survey companies that undertake nationwide surveys have reported that households with landlines tend to be older and more conservative than the average household in a community. It's become obvious that giving surveys only to landline households will skew the results.

The town provided CCG with a list of telephone numbers that it gathered from voter registration records that included both landline and cellular telephone numbers. One of the interesting aspects of using telephone numbers from voting records is that everybody on the list considers themselves to be a resident of Falmouth, other than perhaps folks who have moved since the Town gathered their phone numbers.

A survey must be conducted randomly, meaning that the calling shouldn't be clustered around any one particular portion of the study universe. For example, the survey would not be considered to be valid if all of the calls were placed only to one portion of the town.

Since Falmouth is a community with distinctly different neighborhoods, we thought it was important to try our best to reach all parts of the community. The telephone records we obtained were sortable by voting precinct, so we purposefully collected a set number of surveys from each voting precinct to give us the desired geographic diversity. When doing surveys, this method is called directed calling, and the method is still a valid sampling technique as long as we were completely random in choosing numbers inside each voting precinct. Our method of using the list of numbers for each precinct was to call every tenth phone number on the list after each completed call. We cycled through the calling list for each precinct until we got the desired number of completed surveys.

Most business and political surveys strive to achieve an accuracy of about 95% with results that are plus or minus 5%. In layman's terms, this means that the results of such a survey are reliably accurate (the 95% number) and you would expect to get the same results (within 5%) if you could ask the same questions to everybody in the Town.

CCG uses an online survey tool to determine the number of surveys needed to achieve the desired accuracy. The tool is provided by Creative Research Systems and is found online at https://www.surveysystem.com/sscalc.htm. We've used this tool for many years and have manually done the mathematical calculations that demonstrate that the tool is accurate. This tool told us that we needed 378 completed surveys in Falmouth to achieve the desired accuracy of 95%, plus or minus 5%.

In the US we know that many people distrust the results of surveys, mostly due to results obtained for political surveys. This speaks to the issue of bias. When callers are asked about sensitive topics like politics, religion or anything personal or controversial it's well-known that many respondents don't answer questions honestly to a stranger like a survey taker. The best example of this is when surveyors ask people for their household income. Survey companies have often said that as many as half of residential homeowners will not give an accurate response to the salary question.

However, experience shows that there is high reliability with surveys that look at non-emotional topics, such as this survey talking about a routine product purchased by most households. We have anecdotal evidence that they broadband surveys are good market predictors because CCG has been giving these surveys for 20 years and we've had many opportunities to see the broadband penetration rates in communities to compare to the predictions made by our surveys. Surveys are never 100% accurate because sometimes an ISP does something to change the public perception. For example, an ISP that has problems during a network launch might underperform a survey. In general, we've learned to have faith in the predictions made by these broadband surveys.

Survey Results

The survey produced some interesting results. A full copy of the survey questions and the responses are included in Exhibit I of this report. Here are highlights of the survey results:

The Survey Respondents

Since the telephone numbers we used came from voter rolls, it was expected that most people we called would be residents. That held true to expectations and 95% of respondents were fulltime residents of Falmouth. 2% of respondents live in Falmouth and rent their homes to others full time. 3% of respondents rent their homes for part of the year, between 6 and 9 months.

Broadband Customers

91% of survey respondents have some form of landline broadband. 83% of respondents use Comcast and 8% use Verizon. We normally see a larger percentage of homes still using the incumbent telco, so it's apparent that Comcast has done better than normal in capturing the Falmouth market. Nationwide the big cable companies have twice as many broadband customers as the big telephone companies.[2] The survey didn't ask about this difference, so we don't know why such a large percentage of residents use Comcast. We can speculate that the DSL network in the town might be in bad condition – but that is purely speculation and there might be other reasons why Comcast has done so well.

CCG Consulting has been tracking the nationwide telecom markets for years and we know that customers nationwide are abandoning telco DSL in favor of the faster cable modem broadband. In 2018 we saw the big cable companies collectively gain over 2.9 million new customers for the year while the largest telcos collectively lost almost half a million customers.

The FCC reports that almost 86% of homes nationwide now have a broadband connection. However, the FCC nationwide numbers are skewed because the numbers don't account for the roughly 14 million rural homes in the country that have no option to buy broadband. If the FCC statistics are adjusted for those homes, then the nationwide average broadband penetration everywhere except those rural areas is 93% - right in line with the results of this survey. (This is a good reason to always be careful when using a nationwide statistic – unless you know how it's calculated.)

The mix of customers between Comcast and Verizon is not the same everywhere. For some reason all of the Verizon customers we surveyed live in voting precincts 3, 4, and 6.

[2] At the end of the first quarter of 2019 the big cable companies had 64.3 million broadband customers while the big telcos had 33.4 million customers.

Another 4% of the respondents said their only source of broadband is cellular. Nobody claimed to be using satellite broadband. Only 5% of the respondents have no broadband access.

Cable TV Penetration

In another interesting result, 88% of survey respondents report the purchase of traditional cable TV. That is significantly higher than the nationwide average, which dipped below 70% early in 2019. In Falmouth 79% use Comcast, 5% use Verizon, and 4% use satellite.

One of the puzzling aspects of the results is the Verizon cable TV product. To the best of our knowledge, Verizon only offers cable TV over fiber. We've been told that the town has good knowledge that Verizon doesn't provide their fiber-based FiOS products anywhere on the Cape – the most typical way that Verizon provides cable TV. Verizon does sometimes sell broadband and other products on fiber to apartments, condominiums, townhouses, and similar properties and it's possible that there are a few places in the community with this kind of wholesale fiber connection.

We also note that the number of households using satellite TV is smaller than what we normally see. In most towns, the satellite penetration of cable TV is often between 10% and 15% of homes. The survey didn't ask customers why they chose their current provider, so we don't know why there are a smaller than expected number of homes using satellite TV.

Only 4.5% of survey respondents claim to be cord-cutters that watch all content online. There are not yet any reliable count of the market share of cord-cutters, but most estimates put it somewhere between 15% and 20% of households. The percentage of cord-cutters is growing rapidly, so it is expected for the homes with traditional cable in the town to drop over time.

Telephone Penetration

60% of homes still claim to have a landline telephone. The nationwide landline penetration has dropped below 40%.

This is the one statistic from the survey that we can't fully trust. This statistic could be driven by the percentage of landlines that are included in the list of telephone numbers. We have no way of understanding the mix of cellular and landline telephone numbers in the numbers provided to us since numbers can be transferred to and from landlines and cellphones today. It's also possible that this is an accurate statistic and that the town has a significant percentage that still uses landlines.

Customer Bills

The survey asked customers what they pay each month for the triple-play services (Internet access, cable TV, and telephone). We've found that this question always has to be taken with a grain of salt because what people say they pay is often quite different than what they actually pay. For example, a household

might cite a $100 special price they are paying without realizing that they actually pay more due to hidden fees and additives. It's especially easy these days for customers that pay automatically with credit cards or bank debits and not know how much they pay.

With that said, here is what customers say they are spending:

Customers buying a bundle of service	$183
Customers buying standalone broadband	$ 92
Customers buying standalone cable TV	$ 59
Customers buying standalone telephone	$ 72

We note that the $183 average for bundles is one of the highest amounts we've ever seen on a survey. Most communities average less than $150. One of the factors that might be driving this high number is the small percentage of homes that claim to be cord-cutters. Cable TV is the most expensive portion of the Comcast bundle, so having a higher percentage of cable users would drive up this average price.

Uses of Broadband

26.5% of respondents say that somebody in their homes uses the Internet to work from home. That is made up of those that work at home fulltime (4.5%), those that work several days per week (8.5%), and those that work from home occasionally (13.5%).

22% of respondents report having school-age children at home.

Satisfaction with Existing Broadband

27% of respondents say they are unhappy with their Internet download speeds at home, while 33% are satisfied.

33% of respondents are not happy with the customer service from their ISP, while 31% are satisfied with customer service.

36% of homes are not satisfied with the reliability of their broadband connection, while 28% are satisfied.

53% of respondents say that they are unhappy with the value they get from their ISP compared to the price they pay. 26% of homes are satisfied with the value they are getting.

We asked about Internet outages in the last year. 51% of respondents said they have had an outage (where there is no Internet access). 15% of those with outages only experienced outages for a short time. 45% reported outages of one day, and 45% said that had had an outage that lasted multiple days. 53% said the outages were very inconvenient and only 2% weren't bothered by the outages.

We also asked about Internet slowdowns, where the broadband speeds sometimes are slower than normal. 63% of respondents said they had noticed Internet slowdowns in the last year. Just over half said the slowdowns seemed to happen at random while the rest said that they noticed them daily. 64% of

respondents said they found the slowdowns to be annoying or bothersome. Only 1% of respondents weren't bothered by the slowdowns.

Support for a Fiber Network

One of the key questions asked in the survey is if respondents support the idea of Falmouth trying to get better Internet access. 70% of households support the concept. Another 16% said they might support the idea but need more information. Only 14% of households said they do not support Falmouth pursuing a better broadband solution.

We asked the reasons why respondents support bringing a new network to the town. An overwhelming 92% said they hope for more competition. 79% of households hope for lower prices. 55% of respondents hope for more reliable service. 41% of respondents hope a new broadband solution would mean better customer service.

We then asked all respondents which factors would lead a household to move their service to a new network. 82% said that lower prices would make them consider changing. 59% of respondents would be interested in better network reliability. A smaller 45% liked the idea of having faster Internet speeds for the same price they pay today. 24% said they might change to keep profits in the community. Only 20% of respondents thought that better customer service from a new network provider would be a lure.

We asked the reasoning for respondents who don't support a new fiber network - recall from above that this is 14% of all respondents. 81% of these respondents are happy with their current provider and see no reason to switch. 17% of respondents don't use broadband.

Switching Service to a New Network

In probably the most important question of the survey, we asked households if they would buy Internet service from a new fiber network. 36% said they would definitely buy. Another 30% said they would probably buy service and 16% said they would consider buying service. Only 18% said they were unlikely to consider buying service.

We next asked if respondents would buy cable TV from a new network. 32% said definitely yes and another 29% said probably. Only 20% said they were unlikely to buy cable TV.

When asked if they would buy a landline telephone, only 14% of the respondents said yes with another 19% saying probably. 48% said they were unlikely to buy a landline.

Questions for Landlords

We had a few questions aimed at landlords that rent their property to others, either part-time or for the whole year. Only 3% of respondents say that they rent their home to others. There was hope that the survey would reach more people in this category. I guess that since the calling numbers come from the voting rolls that the universe of callers is heavily weighted towards those that consider themselves as Falmouth residents, which seems to be mostly full-time residents.

Since the universe of respondents is so small for these question it is not possible to put any statistical importance on the response – meaning that the way that this handful of respondents answered might not represent the larger universe of homeowners that rent their property for parts of the year.

With that said, those that rent their homes say that they can get seasonal billing from their ISP (meaning Comcast). Seasonal billing means that homeowners don't pay full prices during periods when the home stands empty. Every homeowner who rents said it is important or very important for the rental units to have good broadband. One-third of respondents said they've received complaints from renters about the broadband.

Interpreting the Results of the Survey

It's always a challenge to interpret survey results. It's easy to interpret a broadband survey in a rural community that has poor broadband, and we have done surveys where 80% to 90% of citizens support a new fiber network. It's much more of a challenge to understand what the responses are telling us in a town like Falmouth. Proponents of fiber will see plenty of support in the survey responses, but opponents of fiber can probably say the same thing. Following are my observations of what your survey tells us:

Dissatisfaction with the Incumbents. The surveys show that generally, residents aren't as unhappy with Comcast as the town might have imagined. 27% of respondents were unhappy to some extent with download speeds. 33% are unhappy with customer service. 36% are unhappy with reliability. Those percentages would not indicate enough support to launch a new broadband network. While it may be common to hear complaints about Comcast, overall the surveys don't show massive dissatisfaction.

Support for a New Network. This low dissatisfaction with Comcast is offset by 70% positive to the direct question asking residents if they support the idea of Falmouth getting better Internet access. That response further has 16% of the community that said they might support the idea but need more facts. Only 14% of respondents said they didn't support a new broadband network.

Perceived Value. We expect to see different responses throughout the survey for those who say they are getting a value compared to those that don't perceive value. I looked through the responses to see what else might support one of these two responses. One such response was that those they didn't think they were getting a value today were highly likely to hope that a new network will bring "lower prices than today."

Customer Service. Customer service is not a major concern for the community. Nationwide surveys often suggest that the big cable companies and telephone companies are dreadful at customer service. This survey shows customers don't particularly value better customer service. Only 20% of households would consider changing to a new network due to unhappiness with existing customer service.

More Competition. The driving force for the positive responses to a new network seems to be driven by a desire for more competition. An overwhelming 97% of respondents, including most

of those who oppose a new network said that they would consider changing to a new network if it brought more competition to the market. That's the highest response to that question we've ever seen.

High Cable Penetration. The town has a significantly higher percentage of traditional cable customers (84%) than the country as a whole (68% - 69%). Traditional cable is comprised of those getting cable through a wire to their home or from satellites. This is not unusual, and we've seen similar high responses in several other communities recently. However, a high current cable penetration rate doesn't necessarily translate into those that would buy cable TV from a new network. Only 32% of households said that they would definitely consider buying cable TV from a new provider. This tells us that there are probably a lot of people in the community paying for TV today who are contemplating cutting the cord and watching cable TV online.

Potential Customers on a New Network. The number one purpose for the survey was to provide a starting point for evaluating the feasibility of building a broadband network in the town. That boils down to using the survey to estimate how many customers a new network might attract. Following is how we interpret the responses about buying service from a new network:

- Our experience is that the surveys provide a decent prediction of how a new ISP will do within the first 3 - 5 years after market launch.
- Customers who say they will definitely buy probably will. Every community has some core of customers that don't like the incumbent providers. The customers who say they will definitely buy are dissatisfied with the current providers, really like the idea of having fiber. We typically see between 20% and 30% of customers saying they will definitely change to a new network. Your survey comes in higher than that range with 36% of the respondents ready to immediately change to a fiber network.
- We've always found that around 2/3rds of those that say they will "probably" change will also do so. Some won't overcome the ennui of taking the steps to make the change, and some will be lured with low-priced packages aimed to keep them on the current provider. But overall these respondents have indicated a decent interest in changing providers. In your case, 30% of respondents said they would probably change to a new fiber network.
- The "maybe" respondents are just that. We've always seen that a third of these customers can be gained as customers – but at a cost. This is the part of the market that requires the marketing budget. These customers can be won if you make the effort to explain the benefits of your network and if you have products and prices they find attractive.
- In summary, I think the survey indicates a 5-year target penetration of broadband of 61%. Of course, that prediction assumes that the network is launched on time and on budget and that the service provider does a good job of meeting expectations. There are plenty of opportunities for a new network to make mistakes and underperform.
- CCG has done hundreds of surveys for communities and the 61% result is near the top end of the range of results that we've seen for communities of your size. Surveys in cities of your size more typically predict penetration rates between 45% and 55%. The highest result I remember ever seeing was 65% of respondents who were likely to buy from a new network. In my opinion, this one survey result is highly promising and provide you with a good reason to take the next steps in looking at the feasibility of bringing fiber to the town.
- To summarize the opportunity that is predicted by the survey:
  - A realistic 5-year goal for broadband penetration is 61%.

        - The goal for cable TV is lower at 58%. While this number is true for now, I expect than within the next five years that a lot of the people who say they are interested in cable TV today will cut the cord and drop out of the market. It's an interestingly high prediction in light of the prevalence of cord cutting.
        - The 5-year market penetration for landline telephone is 33%. That's also higher than what I expect since homes continue to drop landlines year after year – but it's what your citizens say today.
    - It's also worth noting that a service provider could perform better than these predicted penetration rates with a concentrated marketing plan. A marketing plan is aimed at the "probably" and "maybe" customers, to convince such customers to buy service.

Variation by Precinct. One of the most intriguing aspects of the survey results is that we gathered results by the nine voting precincts. In your case, these precincts often represent unique and specific different demographics. After riding through the whole town my number one takeaway is that the various neighborhoods in the town are significantly different.

However, in pointing out some of the differences in responses by neighborhood, I must caution that the small size of the number of respondents in each precinct was only 42, and that is not a large enough sample to have a standalone statistical significant. In plain English that says I can't believe the results by precinct in the same manner that I can believe the overall results of the survey. The responses to any question for a precinct may not represent the way that everybody in that precinct might respond to the same question.

With that warning in mind, some of the differences by precinct are probably telling us something of interest. Consider the following topics where the response differed by precinct:

Verizon: We encountered customers that use Verizon for cable TV in precincts 3, 4, and 6. There were enough such responses that it doesn't seem like a case of respondents giving us the wrong answer. We always get a few respondents in every survey who swear they use a service provider that's not even in their market. This tells us that there must be a pocket of Verizon TV in the community. We have a lot of local evidence that Verizon has not built any FiOS in Falmouth. However, the company does serve apartment buildings, condominiums, townhouses and similar properties with large broadband products that are sold to landlords or managing associations and distributed to individual units. We have to guess that there are few such locations in the town located in these three precincts.

Uses of Broadband. Precincts 4 and 6 had a much larger number of households that work from home and that have school children at home. You might want to compare that finding with your knowledge of the community.

Value. Precincts 1, 8, and 9 had the largest percentage of households that had a negative response when asked if they were happy with the value they get for the price they pay for telecom services. We know by the response to other questions covered below that this is due to networks in these precincts that perform worse than the rest of the town. We have found that the coaxial networks used by cable TV companies is not always of uniform quality throughout a community. Perhaps the Comcast wires in these precincts are older or have suffered damage of some sort over time that makes the networks underperform compared to the rest of the town.

Network Outages and Slowdowns. The same three precincts mentioned in the last issue – 1, 8, and 9 - had a much higher percentage of people reporting both outages and slowdowns during the last year. There is something different about the Comcast networks in these portions in town. If the town requires trouble reporting as part of the cable TV franchise it would be interesting to see if problems are centered in these parts of the town.

Support for a New Network. The precincts with the highest level of support for a new network are 1, 3, 4, 8, and 9.

Lower Prices. The sectors where most people hope that a new network brings lower prices are 4, 6, 8, and 9.

Keeping Dollars in the Community. Precinct 1 is the only sector where more than half of the people cited this as a reason to support a new network.

Definitely Would Buy Broadband. Sectors 1 and 4 are the only two sectors where more than 50% of respondents said they would definitely buy broadband from a new network. These same two sectors also have the highest percentage who say they would definitely by cable TV from a new network.

Telephone Service. Sectors 4 and 7 had the largest percentage of those that said they would definitely buy landline telephone.

Trends Post COVID-19. The survey was conducted in the fall of 2019 and reflects pre-COVID opinions of residents. We can't precisely say how the results of the survey would be if taken today, but there are a few industry trends that would likely affect the results we obtained from the survey:

- Increased Demand for Broadband. As students and parents were sent home to work and for school, we saw an increased demand for home broadband. This likely would have resulted in a greater number of homes having broadband, and big ISPs are all reporting increased broadband subscription rates by the second quarter of 2020. The increased demand has also manifested in customers demanding faster speeds. Most ISPs report that a significant number of customers are upgrading to faster broadband packages. We also would expect this would mean more people migrating from Verizon to Comcast to get faster speeds. This would likely result in an even higher number of homes that are interested in fiber broadband.
- Cable TV Penetration. All of the big cable companies are reporting customer losses in 2020. Comcast lost 388,000 cable customers in the first quarter and 477,000 in the second quarter. Roku reported on a market survey conducted in June 2020 that says that most of the losses of cable customers are due to households trying to save money.

C. Other Market Research

Interviews and Business Questionnaires

CCG reached out to businesses in two ways. The EDIC posted a business questionnaire on their web site that asked businesses to tell us about their broadband. We also interviewed larger business and other

stakeholders in the town to learn about broadband issues in more detail. We gave the option to businesses to keep their responses anonymous and a number of them did so.

Here are a few of the things we learned from the questionnaires and interviews:

- In general, practically every business said that they didn't feel like they have any competitive alternatives. Even a few entities using OpenCape fiber say they would love to have a second option.
- The school district has 650 employees serving seven schools and an administration building. The school system serves 3,200 students. The schools report they have world-class broadband provided on fiber by OpenCape. The service is highly reliable and the only outages they can recall is when power goes out. The schools were worried in the spring when students were sent home due to the pandemic. The schools scrambled and provided Chromebooks to any student that needed a home computer. The district only needed about twenty cellular hotspots to provide home broadband for students that did not have home Internet access. The one issue that schools identified is that there are cellular dead spots in some schools where cellphones don't work.
- Falmouth Public Libraries operate three libraries in the town. Two are connected to OpenCape and one to Comcast. The download speeds are good at all three libraries, but the upload speeds are slow at times at all libraries, but particularly the one served by Comcast. The libraries have been closed to the public due to the pandemic and they've been beaming WiFi into the parking lots and they wish the signal were stronger. There are people working in cars and also using picnic tables provided by the library. The library has started a pilot program to let the public check out a few Chromebooks and cellular hotspots – they haven't yet concluded if this something that ought to be made permanent. The library's primary concern during the pandemic is digital literacy. When they are open to the public, they help people with things like applying for unemployment or in working with other government programs. They worry that people will struggle and get left behind.
- We talked to a doctor office with twenty employees that uses Comcast. They report that Comcast has improved significantly over the past few years, which likely is due to Comcast's upgrade to DOCSIS 3.1. The office shares 100 Mbps broadband connection and this is enough broadband most of the time, but there are times when they would like more speed. Like most physicians the office is now doing a lot of telemedicine during the pandemic. They are making telemedicine calls using their cellphones, connected through the Comcast broadband connection using WiFi. It's worth noting that the Cape has the highest percentage of seniors in the population in Massachusetts, which would suggest a higher than average need for telemedicine.
- There were several large employers like the Marine Biological Laboratory that are struggling with employees trying to work from home during the pandemic. They report that employees are having to resort to using cellphones or cellular hotspots when the home broadband connection is not adequate to connect the employees back to the work servers.
- We spoke with the Woods Hole Oceanographic Institution. They employ 1,200 people year-round. They have multiple broadband connections including OpenCape and Comcast and are satisfied overall with the broadband speeds they receive. The biggest concern of the Institution is that they are shut down during any electric outages and during bad weather. They wish they had more resiliency and an alternative during local Internet outages. Much of what they do is in the cloud and they are nearly shut down without Internet access. They still have a lot of employees working from home who are experiencing a wide array of connection problems.
- We spoke with Island Queen Ferry which runs the ferry between Falmouth and Martha's Vineyard. The company has several Internet connections. They use a local company FiberCape

which provides outdoor WiFi for use by visitors to the ferry service. The company also has a Comcast broadband connection which they generally report as working well. The company relies on good broadband because they need to post real-time information for customers about weather conditions or other delays in the ferry schedule. The company also maintains a few Verizon dial-up lines that are used to process credit cards if Comcast isn't working. The company's biggest wish is one provider that could offer a reliable connection and a bundle that includes everything they are buying.

- We talked to Bill Zammer who owns Cape Cod Restaurants and operates two restaurants chains in Falmouth and other nearby towns. He uses Comcast in all three communities and describes the broadband as "on the slower side." He says that Comcast is slow to respond to problems. Mr. Zammer was president of the Chamber of Commerce and thinks that Falmouth needs better broadband infrastructure if it wants to continue to be hot housing market.
- We talked to Bill Hough of the Falmouth Enterprise newspaper. He now has OpenCape and it works great for his needs. He used to use Comcast and had major problems. The service would go down regularly. On one occasion when Comcast was down the newspaper had to use a cellular hotspot to send the newspaper to print – which was incredibly expensive.
- We talked to a business that houses five employees in a shared work facility along with other businesses. All of the businesses share a 100 Mbps connection from Comcast, although tenants are allowed to bring in additional broadband. The biggest problem in the shared workspace is upload speeds. The shared WiFi is "glitchy" and large data files often have to be sent multiple times. None of the tenants can rely on the WiFi for making phone calls, and so they use cellular calling.
- One employer with over fifty local employees is unhappy with the quality of service from Comcast. The business routinely receives only a fraction of the speeds they are paying for. The company says that Comcast customer service is unresponsive. As an example, it took over a month to add an additional telephone line. The company says that poor broadband is negatively affecting the business. Almost all of the software used by the company is in the cloud, including software used to arrange for shipping products to customers. They routinely have cloud communications problems or broadband outages that stop them from shipping on time. The company would like faster Internet, but also redundancy, meaning they would like a backup connection using another ISP. However, they don't feel they have competitive alternatives.
- A local photographer works from his home and can only get Verizon DSL. Photographers routinely share large data files back and forth between clients. The broadband connection is so poor that he often has to go to a friend's home or the library to get his work done.
- We heard from half a dozen realtor offices that ranged in size from two to over forty employees. Realtors routinely exchange photograph albums which are large data files. The realtors all said that their download broadband connections were adequate for exchanging files. They often had problems sending large data files. Several of the larger realtors said that their broadband connection was not adequate at times when there were a lot of realtors in the office at the same time.
- We heard from two people in the medical field that often work from home. They both said that their Internet connection was not adequate to process medical data files. The privacy concerns associated with medical records require connecting through HIPAA-approved software connections on secure VPNs, and they say that routinely they have to redo work and send files multiple times due to the variance in their Comcast data connections.
- We talked to one business owner who has Comcast at home in Falmouth but has Verizon FiOS at a home off the Cape. He said the different between the two broadband services is startling.

We asked business in Falmouth how they used the Internet and got the following responses:

- To Communicate with Customers. Businesses routinely have portals that make it easy for customers to place and track orders and to communicate with the business. Inadequate broadband means lower sales. The old days of calling purchasing agents is gone and most commerce between companies has become automated – which improves accuracy and speeds up the ordering process. Businesses that operate busy ecommerce ordering sites need big amounts of bandwidth to make sure that all customers have a successful purchasing experience.
- To Communicate with Vendors. Businesses also routinely use the portals of their own vendors to buy whatever they need to operate.
- To Communicate with Other Branches of the Company. A number of businesses in Falmouth are part of larger corporations and maintain open data connections to communicate with other parts of the company and with headquarters.
- Working in the Cloud. It's now common for companies to work in the cloud using data that's stored somewhere offsite. This can be in one of the big public clouds like the ones offered by Amazon, Google, or Microsoft or it can be a private cloud available only to employees of the business. This is the change in the ways that companies operate that has probably created the most recent growth in bandwidth. Much of the routine software that companies use now works in the cloud, meaning that productivity comes to a halt when the Internet connection isn't working.
- Security Systems. Businesses often have their security monitored by offsite firms. Security today also means the use of numerous video cameras (and the ensuing video streams) used to monitor the inside and outside of a business.
- Sending and Receiving Large Data Files. Most businesses report that the size of data files they routinely transmit and receive have grown significantly larger over the last few years. Some of the businesses in Falmouth report routinely swapping terabit-sized files.
- VoIP. Many businesses now provide the voice communications between their various branches using Voice over IP. A reliable VoIP system needs to have dedicated bandwidth that is guaranteed and that won't vary according to other demands for bandwidth within the business.
- Communicating via Video. Communicating via video was building momentum during the last year but has exploded as the business world has migrated to Zoom and similar video platforms.
- Email and Advanced Communications. While many businesses still rely on email, many have gone to more advanced communications systems that let parties connect in a wide variety of ways. Businesses are using collaborative tools that let multiple employees from various locations work on documents or other materials in real time.
- Supporting Remote Employees. Supporting employees that work from home is a major new requirement for many businesses. Communicating with remote employees most generally is done by creating a virtual private network (VPN) connection with each employee. For the business that means establishing both a dedicated upload and download link to each remote employee. These connections can vary between 1 – 3 Mbps per second in both the upload and download directions. The big challenge for companies using Comcast is the limited size of the upload connection.
- Data Back-up. Companies are wary of hacking and ransomware and routinely maintain several remote copies of all critical data to allow them to restore data after a problem.

Impact of Poor Broadband for Businesses

There are numerous consequences of poor broadband for businesses. While some businesses have unique and specific requirements, there are a number of problems caused by poor broadband that affect most businesses. Some of the larger businesses in town are served with fiber from Open Cape. However, most businesses in the community have the same broadband choices as residents.

Impact on Day-to-day Operations. The list immediately above describes the many routine ways that businesses in Falmouth use broadband. Businesses without adequate bandwidth must forgo or compromise on how they communicate with the world and function day-to-day. Many of the businesses in Falmouth told us that they felt constrained from doing everything they could with broadband.

Entrepreneurship. Every community has success stories of companies that started in a home that are now significant employers in the community. Many communities have developed business incubator sites to support and promote start-up businesses. Good broadband is essential for a start-up ecosystem.

Smart Factories. The pandemic uncovered major problems in the US supply chain and both political parties are now talking about a big government push to bring manufacturing back to the US, particularly in vulnerable areas like medicines and electronics.

Over the past decade the US has created over 900,000 jobs in newly built "smart" factories. Smart factories need a lot of bandwidth for functions like the following:

- Programmable Robots. Automated factories are using robots that can perform a range of different tasks that can be directed by software to perform the need task at the right time.
- Collaborative Robots (Cobots). Collaborative robots work with human operators to take over time-consuming or high-precision work to enable the human operator to concentrate on the tasks that require judgement and experience.
- Precision Manufacturing. Robots can be used to perform high-precision tasks that were difficult and time-consuming with human operators.
- Making and Handling Customer Materials. Factories are manufacturing modern materials like carbon nanotubes on site as part of the manufacturing process.
- Performing Complex Chemical Processes. Automated machines are being used to handle the creation of complex chemicals that are either dangerous to handle or that require highly precise processes to create.
- Remote Instructions. Robots can be directed by remote engineers or technicians from a different location when that's needed for custom tasks.
- Equipment Monitoring. Sensors are used to monitor machinery and robots to predict machine failures and to dispatch repairs or order replacement parts before they are needed.

Economic Development and Jobs: Reliable and affordable broadband is still one of the key elements in traditional economic development to lure new companies to a community or to keep existing companies from leaving. As vital as broadband is to residents it's even more vital to businesses.

It's probably a minor point but building a fiber network in Falmouth brings roughly twenty new high-paying jobs to the community. It's been our experience that a new fiber network does not decrease the workforce for existing ISPs.

Businesses want more than just fast broadband. They often require multiple feeds of broadband from different ISPs, on diverse routes to guarantee that they don't lose connectivity. There are several businesses in Falmouth that require a diverse and redundant source of broadband.

Realtor / Rental Agent Survey

One of the most interesting challenges of understanding broadband demand in Falmouth is to get a feel for how the tourist rental market feels about broadband issues. The community grows from a population of 30,000 in the offseason to as much as 100,000 during the summer. The vast majority of tourists stay in rented houses and apartments.

We created an online survey for realtors / rental agents asking about broadband and cable TV. This was not a statistically valid sample and these results can't be easily applied to all renters in Falmouth, but the results are still interesting. The rental agent survey produced the following results:

Six rental agents took the online survey. They handled rentals in all parts of Falmouth including Falmouth proper, East Falmouth / Waquoit, West and North Falmouth, and Woods Hole.

The rentals varied by type as follows:

One Week or Less	44%
One Month	3%
All Summer	16%
Nine Months	16%
All Year	23%

Realtors reported that 80% of renters ask about broadband when considering a rental. 57% ask about cable TV.

Realtors report that 62% of the rental properties include Internet as part of the rent. The remainder, mostly the longer-term rentals, expect renters to buy their own Internet. 57% of rentals include cable TV.

The realtors report that 20% of renters have made a complaint about the Internet. The most common complaint is consistency.

All of the realtors said it would be easier to rent properties if they included high-speed fiber broadband. Several realtors noted that Internet access was of more importance to "higher end" renters.

Speed Tests

CCG created an online speed test that was published on the EDIC website. The primary purpose of the speed test was to see if residents and businesses were getting the broadband speeds they subscribed to.

The overall purpose of the speed tests is to judge the overall quality of broadband in the market. For example, CCG has conducted similar speed tests in markets where Comcast is the incumbent cable company, and we've seen markets where the speeds delivered are faster than advertised and other

markets where the speeds are slower. This is largely a qualitative test that tells about the quality of the overall network within Falmouth.

Speed tests are not a perfect measurement tool for several reasons:

- A speed test only measures the speed of a ping and a short-term connection under a minute between a user and the test site router used by the speed test. That doesn't necessarily indicate the speed of every activity on the web such as downloading files, making a VoIP phone call, or streaming Netflix.
- Every speed test on the market uses a different algorithm to measure speed. In Falmouth we used the speed test from Ookla, which is one of the most popular speed tests. Ookla's algorithm discards the fastest 10% and the slowest 30% of the results obtained. In doing so they might be masking exactly what drove someone to take the speed test, such as not being able to hold a connection to a VoIP call. Ookla also multithreads, meaning that they open multiple paths between a user and the test site and then average the results together.
- A speed test has no way to know if a customer has network issues within the home such as problems with a home WiFi router or faulty wires inside a home. A slow speed test doesn't always mean that the ISP has a slow connection.
- Speed change throughout the day, and anybody that takes multiple speed tests in the same day will see this. Most broadband connections today use shared bandwidth, meaning that multiple customers in a neighborhood share the bandwidth in some manner. When a neighborhood node is busy, the speed tests will be slower.
- Some ISPs use something called "burst" technology. This provides a fast Internet connection for one or two minutes. ISPs know that a large majority of Internet activities are of a short duration – things like opening a web page, downloading a file, reading an email, or taking a speed test. The burst technology increases the priority of a customer during the burst time window and the Internet connection then slows down when the burst is over. This raises an interesting question – what's the Internet speed of a customer that gets 100 Mbps during the burst and something slower than that after the burst – there is no consensus in the industry.

Latency. In addition to upload and download speeds, the speed tests also measured latency. Latency basically means delay in receiving a signal from the Internet. There are a lot of underlying causes for delays that increase latency – the following are primary kinds of delays:

- Transmission Delay. This is the time required to push packets out the door at the originating end of a transmission. This is mostly a function of the kind of router and software used at the originating server. This can also be influenced by packet length, and it generally takes longer to create long packets than it does to create multiple short ones. These delays are caused by the originator of an Internet transmission.
- Processing Delay. This is the time required to process a packet header, check for bit-level errors and to figure out where the packet is to be sent. These delays are caused by the ISP of the originating party. There are additional processing delays along the way every time a transmission has to "hop" between ISPs or networks.
- Propagation Delay. This is the delay due to the distance a signal travels. It takes a lot longer for a signal to travel from Tokyo to Baltimore than it takes to travel from Washington DC to Baltimore. This is why speed tests are usually created to find a nearby router to ping so that they can eliminate latency due to distance. These delays are mostly a function of physics and the speed at which signals can be carried through cables.

- Queueing Delay. This measures the amount of time that a packet waits at the terminating end to be processed. This is a function of both the terminating ISP and also of the customer's computer and software.

Total latency is the combination of all of these delays. You can see by looking at these causes that poor latency can be introduced at multiple points along an Internet transmission, from beginning to end.

The technology of the last mile is generally the largest factor influencing latency. A few years ago the FCC did a study of the various last mile technologies and measured the following ranges of performance of last-mile latency, measured in milliseconds: fiber (10-20 ms), coaxial cable (15-40 ms), and DSL (30-65 ms). These are measures of latency between a home and the first node in the ISP network. It is these latency differences that cause people to prefer fiber. The experience on a 30 Mbps download fiber connection "feels" faster than the same speed on a DSL or cable network connection due to the reduced latency.

It is the technology latency that makes wireless connections seem slow. Cellular latencies vary widely depending upon the exact generation of equipment at any given cell site. But 4G latency can be as high as 100 ms. In the same FCC test that produced the latencies shown above, satellite was almost off the chart with average latencies of 650 ms.

A lot of complaints about Internet performance are actually due to latency issues. It's something that's hard to diagnose since latency issues can appear and reappear as Internet traffic between two points uses different routing. But the one thing that is clear is that the lower the latency the better.

Results of the Speed Test. 125 people took the speed test. With the above caveats in mind, following are the results of the speed tests we received:

Comcast

As would be expected, since most homes in the community use Comcast, most of the speed tests were from the Comcast network.

There was a wide range of speeds reported on Comcast – more of a range than we usually see on cable company broadband networks. The results for the 114 speed tests for Comcast are as follows:

Comcast Download Speed	
0 – 10 Mbps	5
11 – 20 Mbps	9
21 – 30 Mbps	6
31- 40 Mbps	4
41 – 50 Mbps	8
51 – 75 Mbps	9
76 – 100 Mbps	12
101 – 150 Mbps	13
151 – 200 Mbps	10
201 – 300 Mbps	20

301 – 400 Mbps	6
401 – 500 Mbps	5
500 – 600 Mbps	1
600 Mbps +	6

We have been doing similar feasibility studies for years and we have never seen this kind of range of speed test results from a Comcast network. We know that Comcast has upgraded to DOCSIS 3.1 technology because 11% of those taking the speed tests are reporting speeds faster than 300 Mbps download.

But the results are still surprising. 23% of customers are getting speeds under 50 Mbps, with 18% of all customers getting speeds under 30 Mbps. 41% of everybody taking the speed test saw download speeds under 100 Mbps.

There are a few possible explanations for the slow speeds on the Comcast network. The most likely explanation is that Comcast has never upgraded some of the original network configuration since they purchased the network from Adelphia. When comcast first got the network, it was likely that neighborhood nodes were large with 400 up to 1,000 customers in each node. Those large nodes are the primary reason that download broadband speeds bogged down in the evenings a decade ago – when people first started using the web to watch video the network would get overloaded since there were too many customers sharing the bandwidth.

Since then Comcast has certainly decreased the size of nodes. This is done by building a fiber to serve clusters of perhaps 150 homes or less. When nodes are that small it's rare to see video freezing – and we didn't hear reports of many problems in watching Netflix.

However, we think it's likely that Comcast didn't fully upgrade to small nodes. We are betting that they are still using a network configuration called cascading. This is where a fiber is brought to one neighborhood and then shared with a second, and perhaps even a third or fourth neighborhood. This configuration doesn't have the same characteristics of having large nodes. Instead, the customers in the first node where the fiber connects have good broadband speeds, but the subsequent nodes perform worse. We've seen this situation in HFC networks that demonstrate the speed issues we see in Falmouth. Some parts of the town have great speeds and others do poorly. This is something Comcast could fix by building more fiber so that each node has its own fiber connection.

It's also possible that the more basic characteristics of the Comcast network varies throughout the town. There could be neighborhoods with older coaxial cable and others that were built later or upgraded at some time in the past. There could be neighborhoods with high quality coaxial cable and others with problems that invite interference.

It's possible that some customers are grandfathered with older and slower products. For instance, a few people taking the speed test told us that they subscribe to 25 Mbps broadband. That product hasn't been available to a new customer for many years, but Comcast might be allowing customers to keep the slower speeds, and likely a lower price. Typically, if such customers change any product at Comcast they get upgraded to the current broadband speeds but also prices. The big cable companies don't have the same policies everywhere – there may be

Comcast markets that have grandfathered products while others do not – we think it's up to the discretion of the regional managers.

It's also possible that customers still have an old DOCSIS 3.0 modem that won't go any faster. Most cable companies are pretty good at swapping out modems with technology upgrades, but it's possible that there are customers paying for speeds over 100 Mbps who are stuck with old modems that can't deliver that much speed. We have not heard many complaints nationwide about Comcast doing this – but it's possible.

Finally, there will always be some customers in a speed test that get slow speeds because of issues in the home such as slow WiFi. For example, customers may have supplied their own WiFi and not upgraded for a decade. But it's highly unlikely this could explain the large number of customers who are getting slow speeds – we rarely see more than a few percentage of a market with this issue.

We also saw a range of upload speeds reported for Comcast as follows:

Comcast Upload Speeds	
0 – 5 Mbps	15
6 – 10 Mbps	45
11 – 15 Mbps	26
16 – 20 Mbps	7
21 – 30 Mbps	3
31 – 40 Mbps	5
41+Mbps	9

Like with download speeds, we were surprised to see 14% of customers with upload speeds under 5 Mbps, with some speeds as slow as 2 Mbps and 3 Mbps. 55% of customers reported upload speeds under 10 Mbps. 78% of all customers reported upload speeds of 15 Mbps or slower. This is pretty typical compared to what we see on other cable company networks in other communities. As described in several other places in this report, upload speeds have suddenly become a concern for homes where multiple people try to take office or schoolwork home.

Verizon

Verizon serves the community with what looks to be older early generation DSL over telephone copper wireless. We only got eleven speed tests from Verizon customers. All of the tests show slow speeds as follow:

DSL Download Speed	
0 – 2 Mbps	8
2 – 5 Mbps	2
11 – 15 Mbps	1

DSL Upload Speed	
Under 1 Mbps	11

The average download speed was 2.6 Mbps. One customer reported a download speed of 11 Mbps. The average upload speed was 0.6 Mbps. The average latency is 39 milliseconds.

D. Broadband GAP Analysis

A broadband gap is a situation where some customers have better broadband than others. This report will look at the different kinds broadband gaps as described below.

- The Gap in Broadband Speeds. How the broadband speeds in Falmouth compare to other places.
- The Gap in Broadband Availability. Homes that don't use the Internet.
- The Gap in Broadband Affordability. In every community there are households that don't subscribe to broadband because of the cost.
- The Gap in Computer Ownership. There are households that don't subscribe to broadband because they can't afford a computer.
- The Gap in Broadband Skills. There are citizens who don't buy broadband because they lack the skills needed to operate in the digital age.
- Future Broadband Gaps. Even where there is adequate broadband today, we can look forward to the natural progression of technology that will create new broadband gaps that don't exist today.

After describing the different broadband gaps, this report will look at the consequence of the broadband gaps and will ask the question if there are any practical solutions to the broadband gaps that the town could facilitate.

The Gap in Broadband Speeds

Duopoly Competition

Any discussion of a broadband gap in a town the size of Falmouth has to begin with a discussion of duopoly competition. Duopoly competition refers to a market with only two primary competitors. In broadband, markets that are divided between a telephone company and a cable company meets the classic definition of a duopoly.

A duopoly market often shares a lot of the same characteristics of a monopoly market. In duopoly markets the two competitors rarely compete on price, with the result being high prices from both competitors and good margins for both companies. Duopoly providers generally don't concentrate on customer service since customers only have two choices.

If you look back to 2000, there was true duopoly competition in urban areas. At that time, the capability of telephone company DSL and cable company modem service was similar in capability and it was hard at the customer end to distinguish one service from the other. The two competitors mostly advertised about how their broadband was superior to its competitor, but there were no price wars where telcos or cable companies dropped prices to try to win a share of the market. In most places in the US the telephone companies hit the broadband market first, and in the early days the telcos had more broadband customers than cable companies.

However, over time, the cable broadband products improved faster than telephone company DSL. Cable companies currently offer speed that approach gigabit speeds and the base broadband product is usually between 100 Mbps and 200 Mbps. DSL has improved a lot since 2000, but the fastest DSL today in most markets delivers a little less than 50 Mbps – in Falmouth, most DSL delivers speeds under 15 Mbps.

A lot of economists say that the cable companies have won the duopoly battle, due entirely to having faster broadband speeds. That can certainly be seen in Falmouth where the residential survey showed that Comcast has 83% of broadband market to only 8% for Verizon. Households in town have clearly migrated over time to Comcast. This switch from DSL continues and nationwide statistics show DSL customers continue to switch to the cable company.

Technology Matters

To a large degree, the broadband speeds available to customers is dependent upon the technology used to deliver the broadband. The report discusses various technologies in more detail in the engineering portion of the report.

The general speeds available on various technologies is as follows:

- DSL delivered on one copper pair can deliver speeds as fast as 25 Mbps for up to two miles from the DSL transmitter, assuming the copper is in good condition and other factors are ideal. There are slower versions of DSL deployed in the networks that might have maximum speed capability of 3 Mbps, 6 Mbps, 12 Mbps, or 16 Mbps. In Falmouth it looks like the DSL is older technology.
- DSL delivered on two bonded copper pairs can deliver twice the speeds. This technology usually only uses the latest types of DSL and has maximum speeds around 50 Mbps.
- The hybrid-fiber coaxial systems from cable companies can bring significantly faster broadband speeds. Networks using the DOCSIS 3.0 standard can deliver speeds up to perhaps 400 Mbps. Networks upgraded to the most recent DOCSIS 3.1 standard can deliver speeds up to a gigabit. Cable networks are limited due to the technology of offering upload speeds that can be not greater than 1/8 of the total broadband delivered. Most cable companies have elected to hedge the networks towards providing faster download, to the detriment of faster upload speeds.
- High orbit satellite broadband can deliver speeds as fast as 75 Mbps. The problem with this broadband is that the satellites are so far above the earth that there is a lot of delay (latency) in the signal and it's hard to do real-time web activities like streaming video, connecting to a corporate WAN or a school server, making VoIP calls, or even shopping on some web sites.
- Fixed point-to-multipoint wireless is capable of speeds up to 100 Mbps, although the equipment and configuration of most networks brings speeds significantly less than this, sometimes as slow as only a few Mbps. We are not aware of anybody offering this technology in Falmouth.
- Fiber networks deliver the fastest broadband. Fiber networks with the older BPON technology are limited to speeds of about 200 Mbps per system. More modern GPON technology can deliver speeds up to a symmetrical gigabit (same speed up and down). There are newer kinds of fiber-to-the-home technology that offer speeds up to 10 Gbps.

The speeds delivered by some of these technologies can differ by customer within a town. As an example, the speed of Verizon DSL to a given customer can be affected by:

- How far that customer lives from a DSL transmitter (called a DSLAM).
- The size of the copper wire serving the customer (sizes typically vary between 16-gauge and 24-gauge copper).
- The age and quality of the copper (copper wire slowly degrades over time, particularly if the copper comes into contact with the elements or with longstanding water).
- The quality of the telephone wiring inside of a home (this varies a lot, particularly for wires that were installed by the homebuilder rather than by the telco).
- The type of DSL electronics used to serve a customer. There are still older DSL technologies in use that have maximum download speeds of only a few Mbps and newer DSL that can deliver speeds as fast as 48 Mbps.
- The backhaul network used to provide bandwidth to a feed the DSL network. DSL is like most broadband technologies and bandwidth is shared between users in a given neighborhood. If the total usage demanded by the neighborhood is greater than the bandwidth supplied to the neighborhood, then everybody gets slower speeds while the network is over-busy.
- The DSL network has additional bandwidth choke points, which are places in the network that can restrict customer bandwidth if not engineered properly. For example, the neighborhood DSL hubs might contain older technology or not be fully stocked with the circuit cards needed to provide the best service.
- And finally, speeds can be impacted by how a customer gets broadband to devices. For example, an old WiFi router can cut down the speed between what is delivered to the home and what makes it to computers and other devices inside the home.

All of these factors mean that DSL speeds vary widely. Two adjacent homes can have a significantly different DSL experience.

FCC Definition of Broadband

In 2015, the FCC established the definition of broadband as 25/3 Mbps (that's 25 Mbps download and 3 Mbps upload). Prior to 2015 the definition of broadband was 4/1 Mbps, set a decade earlier. The FCC defines broadband in order to meet a legal requirement. Congress established a requirement for the FCC in Section 706 of the FCC governing rules that the agency must annually evaluate broadband availability in the country. Further, the FCC must take action if broadband is not being deployed in a timely manner. The FCC report the state of broadband to Congress every year.[3] In these reports the FCC compiles data about broadband speeds and availability and proffers an opinion on the state of broadband in the country. In every report to date, the FCC has acknowledged that there are broadband gaps of various kinds, but the FCC has never determined that the problems are so bad that they need to take extraordinary measures to close any broadband gaps.

The FCC didn't use empirical evidence like speed tests in setting the definition of broadband in 2015. They instead conducted what is best described as a thought experiment. They listed the sorts of

[3] The FCC report to Congress for 2019 can be found at https://docs.fcc.gov/public/attachments/FCC-19-44A1.pdf.

functions that a "typical" family of four was likely to engage in, and then determined that a 25/3 Mbps broadband connection was fast enough to satisfy the broadband needs of a typical family of four.

The FCC asked again in 2018 if 25/3 Mbps is an adequate definition of broadband. They concluded that 25/3 Mbps is still an adequate definition of broadband. There were numerous filings made in that docket that argued that the definition of broadband should be increased.

The Upload Speed Crisis

The COVID-19 pandemic has exposed a new broadband problem that was never much discussed before. Many homes that thought they had good broadband found that they were unable to function when multiple people in the home tried to simultaneously connect to work or school servers. We know that this is a problem in Falmouth because we heard directly from people who had problems working and doing schooling from home during the pandemic. Not every home has this problem – just homes with relatively slow upload bandwidth where multiple people try to work using the web at the same time.

Perhaps the easiest way to describe the problem is with a real-life anecdote. I have a colleague who was sent home to work along with her husband and two teenagers. The two adults are trying to work from home and the two kids are supposed to be online keeping up with schoolwork.

The family has a broadband connection from a cable company with a download speed over 100 Mbps, but an upload speed that hovers around 10 Mbps. On top of their normal broadband usage, the family suddenly had to make a lot of new connections. Each of them needs to create a VPN to connect to their office or school servers. They are also each supposed to be connecting to Zoom or other online services for various meetings, webinars, or classes. The family also needed to make several telemedicine connections during the pandemic. The home still continues to need bandwidth for normal functions like reading emails or backing up files up in the cloud. Each member of the family also has their cellphones automatically connect to WiFi when they walked into the home.

How Much Upload Speed is Needed? The upload speed crisis is relatively new and started to affect millions of homes after the onset of the pandemic when people tried to work from home and connect to schools from home. The problem has always been familiar to people who need fast upload broadband like doctors, photographers, engineers, architects, and others that have tried to work from home.

The problem is still so new that there is not yet any industry consensus about the amount of upload bandwidth that is needed in a home. But we understand many of the individual needs for upload bandwidth:

- Connecting to a work server or a school server can require between 1 Mbps and 2 Mbps, dedicated upload speed, depending upon the specific software used by a given school or business – meaning that upload bandwidth us used during the duration of the connection and can't be used for any other purpose in the home. These connections are usually, but not always made by creating a virtual private network (VPN) connection that locks in the connection for as long as there is sufficient bandwidth. Typically, if bandwidth falls below the needed amount the connection will drop.

- Ever online video service is a little different, but all require a stead upload signal to establish a video chat. Consider the bandwidth needs described by Zoom on its web page.[4] Zoom says that a home should have a 2 Mbps connection, both upload and download to sustain a Zoom session.
- Telemedicine connections tend to be even larger than the connections to work and school servers, and also require the simultaneous use of both upload and download bandwidth.
- Just before the onset of the pandemic several major gaming platforms moved games online into the cloud. Historically, gamers purchased or download software that ran games on local computers or game boxes. Moving games to the cloud makes them available to anybody on a wider range of devices. But putting the games in the cloud means that games are played in data centers and the command and images for the games are transmitted to gamers in real time over broadband.
- One of the biggest uses of upload bandwidth is still machine-to-machine traffic. This is communications generated by computers to the cloud. Most homes now use the cloud extensively to backup up everything done on home computers. Pictures, videos, and work files are automatically updated to web storage. Computer software constantly checks to see if updates are needed. Apps loaded onto computers and phones constantly send data about users to the cloud. This traffic is immense and Cisco estimates that by 2022 that 51% of all traffic on the web will consist of computers communicating with each other without any human direction.
- There has also been a big explosion in the use of home video cameras. Sending cameras images outside of the home to cloud storage or to be viewed when people are away from home requires significant upload bandwidth.

The simplistic way to quantify the bandwidth needs is to add up the various uses. For instance, if four people in a home each wanted to have a different Zoom conversation, the home would need a simultaneous connection of around 8 Mbps both up and down. But bandwidth use in a house is not that simple, and a lot of other factors contribute to the quality of bandwidth connections within a home. Consider all of the following:

- WiFi Collisions. WiFi networks can be extremely inefficient when multiple people are simultaneously trying to use the same WiFi channels. Today's version of WiFi only has a few channels to choose from, so multiple connections on the WiFi network interfere with each other. It's not unusual for the WiFi network to add a 20% to 30% overhead, meaning that collisions of WiFi signals effectively waste usable bandwidth.
- Lack of Quality of Service (QoS). Home broadband connections don't provide quality of service, which means that homeowners are unable to prioritize data streams. QOS is a technology that might let a customer prioritize a connection like a school connection. This would mean that connection would get priority, to the detriment of all other connections at the home. Without QoS, insufficient bandwidth affects all broadband usage within a home. This is easily demonstrated if somebody in a home tries to upload a big data file while somebody else is using Zoom – the Zoom connection can suddenly not have enough bandwidth available and will either freeze or drop the connection – as millions of Zoom users experienced.
- Shared Neighborhood Bandwidth. Unfortunately, a home using DSL or cable modem broadband doesn't only have to worry about how others in the home are using the bandwidth, because bandwidth is also shared with everybody else using the same ISP in their neighborhood. As the bandwidth demand for the whole neighborhood increases, the quality of the bandwidth available

[4] https://support.zoom.us/hc/en-us/articles/204003179-System-Requirements-for-Zoom-Rooms

to every home degrades. It's possible for the bandwidth connection to a whole neighborhood to be maxed out – which result in the inability of anybody else to make an outgoing connection.

- Physical Issues. ISPs don't want to talk about it, but events like drop wires swinging in the wind can affect a DSL or cable modem connection. Cable broadband networks are also susceptible to radio interference – your connection will get a little worse when somebody is operating a blender or microwave oven.
- ISP Limitations. All bandwidth is not the same. For example, the upload bandwidth in a cable company network uses the worse spectrum inside the cable network – it uses the frequency that is most susceptible to interference. This never mattered in the past when customers cared about download bandwidth, but an interference-laden 10 Mbps upload stream is not going to deliver a reliable 10 Mbps connection.

The family in question quickly figured out that their bottleneck was upload speeds. They discovered that they could not all work at the same time – and so they had to take turns using the Internet for school or work. The problem was even more aggravating because they sometimes ran into problems even when only two of them were working at the same time. It appears that that the amount of upload bandwidth available to the home varies during the day, likely as the result of factors outside of the home.

Before the pandemic, this family thought they had great broadband. They never had a problem before the pandemic, except for a few times when the teenagers were running multiple games in the cloud at the same time. But suddenly, the broadband connection was not adequate, and the family looked around for alternatives. Unfortunately, they didn't find any broadband products available for their home that are faster than the cable company.

The nearest analogy to this situation harkens back to traditional landline service. We all remember times, like after 911, when you couldn't make a phone call because all the circuits were busy. That's what's happening with the increased use of VPN connections to school and work servers. Once the upload path from a neighborhood is full of VPNs, nobody else is in the neighborhood can grab a VPN connection until somebody "hangs up."

What Does the FCC Say About Upload Bandwidth? In August of 2020 the FCC adopted its *Sixteenth Broadband Deployment Report Notice of Inquiry*[5] that is used to report the state of broadband to Congress. On the opening page of that document the FCC makes the extraordinary statement that 85% of the home in the US can buy broadband with speeds of 250 / 25 Mbps.

The FCC makes this claim based upon the data provided to it by the country's ISPs on Form 477. We know the data reported by the ISPs is badly flawed in overreporting download speeds, but we've paid little attention to the second number the FCC cites – the 25 Mbps upload speeds that are supposedly available to everybody. I think the FCC claim that 85% of homes have access to 25 Mbps upload speeds is massively overstated.

The vast majority of the customers covered by the FCC statement are served by cable companies using hybrid fiber-coaxial technology. I don't believe that cable companies are widely delivering speeds greater than 25 Mbps upload. I think the FCC has the story partly right. I think cable companies tell

[5] https://docs.fcc.gov/public/attachments/FCC-20-112A1.pdf

customers that the broadband products they buy have upload speeds of 25 Mbps, and the cable company's largely report the marketing speeds on Form 477.

But do cable companies really deliver 25 Mbps upload speeds? We saw in Falmouth that most Comcast customers do not see upload speeds greater than 25 Mbps.

It's fairly easy to understand the upload speed capacity of a cable system. The first thing to understand is the upload capacity based upon the way the technology is deployed. Most cable systems deploy upload broadband using the frequencies on the cable system between 5 MHz and 42 MHz. This is a relatively small amount of bandwidth and it also sits at the noisiest part of cable TV frequency. I remember back to the days of analog broadcast TV and analog cable systems when somebody running a blender or a microwave would disrupt the signals on channels 2 through 5 – the cable companies are now using these same frequencies for upload broadband. The DOCSIS 3.0 specification assigned upload broadband to the worst part of the spectrum because before the pandemic almost nobody cared about upload broadband speeds.

The second factor affecting upload speeds is the nature of the upload requests from customers. Before the pandemic, the upload link was mostly used to send out attachments to emails or backup data on a computer into the cloud. These are largely temporary uses of the upload link and are also considered non-critical – it didn't matter to most folks if a file was uploaded in ten seconds or five minutes. However, during the pandemic, all of the new uses for uploading require a steady and dedicated upload data stream. People now are using the upload link to connect to school servers, to connect to work servers, to take college classes online, and to sit on video call services like Zoom. These are critical applications – if the broadband fails then the user loses the connection. The new upload applications can't tolerate best effort – a connection to school either works or it doesn't.

The final big factor that affects the bandwidth on a cable network is demand. Before the pandemic, a user had a better chance of hitting 25 Mbps upload because they might have been one of a few people trying to upload at any given point in time. But today a lot of homes in a neighborhood are trying to use uploading at the same time. This matters because a cable system shares bandwidth both in the home, but also in the neighborhood.

The upload link from a home can get overloaded if more than one person tries to connect to the upload link at the same time. Homes with a poor upload connection will find that a second or a third user cannot establish a connection. The same thing happens at the neighborhood level – if too many homes in a given neighborhood are trying to connect to upload links, then the bandwidth for the whole neighborhood starts to fail. Remember a decade ago that it was common for videos to freeze or pixelate in the evening when a lot of homes were using broadband? The cable companies have largely solved the download problem, but now we're seeing neighborhoods overloading on upload speeds. This results in people unable to establish a connection to a work server or being booted off a Zoom call.

The net result of the overloaded upload links is that the cable companies are not and cannot deliver 25 Mbps to most homes during the times when people are busy on the upload links. The cable companies have ways to fix this – and most fixes mean expensive upgrades. Meanwhile, if the cable companies were honest, they would not be reporting 25 Mbps upload speeds to the FCC.

Microsoft Speed Data

Microsoft is in an interesting position when it comes to looking at broadband speeds. The vast majority of computers in the country download sizable upgrade files from Microsoft. Even many Apple computers are loaded with Microsoft Office products like Word, Excel, and PowerPoint.

Microsoft decided a few years ago to record download speeds of software upgrades. There is probably no better way to measure a broadband connection than during a big file download. Most speed tests only measure broadband speeds for 30 seconds to a minute. A lot of ISPs in the country deploy a technology generally referred to as "burst." This technology provides a faster download for a customer for the first minute or two of a web event. It's easy for a customer to know if their ISP utilizes burst, because during a long download, such as updating Microsoft Office, the user can see the download speeds drop to a slower speed after a short time. This technology has great benefits to customers since the large majority of web activities don't take very long. When customers visit a website, open a picture, or even take a speed test, the customer only needs bandwidth for a short time to complete most web tasks. The burst technology gives customers the impression that they have a faster download speed than they actually have (or it could be conversely argued that they have a fast speed, but just for a minute or two).

Microsoft measured downloads starting in September 2018, and found:

- The 2018 FCC data claimed that 24.7 million people in the US don't have access to download speeds of at least 25/3 Mbps. In September 2018 Microsoft claimed that 162.8 million people were downloading data at speeds slower than 25/3 Mbps.
- The FCC claimed in 2018 that 98.6% of the homes in Barnstable County had access to broadband of at least 25/3 Mbps. In September 2018 Microsoft said that only 71.8% of Internet connections in the county were at broadband of at least 25/3 Mbps.

It's important to note that the FCC and Microsoft are not measuring the same thing. The FCC is measuring the percentage of homes that have access and can purchase 25/3 Mbps broadband. Microsoft is measuring the actual speeds of downloads. There are a few reasons why the speeds might be different. For example, some people opt to buy broadband products slower than 25/3, even when faster broadband is available. In Falmouth, everybody using Verizon DSL will be slower than the 25/3 Mbps speed. Some households receive slower speeds due to issues in the home like poor-quality WiFi routers.

The Gap in Broadband Availability

The FCC reports that broadband adoption for the country is around 87%. Falmouth is higher than average with 91% of respondents to the survey having a landline broadband connection. That means that 9% of the homes of full-time residents don't have a landline broadband connection. Numerous studies and surveys have asked people why they don't buy broadband when it's available.

John B. Horrigan published a paper[6] earlier this year titled *Measuring the Gap* that makes the point that the reasons that homes don't have broadband are complicated. There have been studies over the years that have tried to pin down the primary reason that homes don't have broadband, but by doing so the studies have glossed over the fact that most homes have multiple reasons for not having broadband.

[6] https://www.digitalinclusion.org/blog/2020/02/11/measuring-the-gap-by-john-horrigan/

A good example of this is a Pew Research Center survey in 2019 that explored the issue. In that survey:

- 50% of respondents said that high prices are a reason for not having broadband, but only 21% said price is the primary reason.
- 45% of respondents said they relied on smartphones that could do everything they need, but only 23% said that was the primary reason for not buying broadband.
- 43% said they were able to get access to the Internet from a source outside the home, but only 11% gave that as the primary reason.
- 45% said that the cost of a computer is too expensive, but only 10% gave that as the primary reason.

As Horrigan points out, sometimes there is bias in the questions being asked in a survey. A survey that has pre-conceived ideas about why folks don't have broadband will miss some of the reasons. Consider a 2017 survey from the California Emerging Technology Fund. This survey showed different reasons than Pew for why homes don't have broadband because the survey asked different questions. The survey showed:

- 69% said the cost of monthly access and of affording a computer or smartphone was too high. 34% listed this as the primary reason for not having broadband.
- 44% said it was too difficult to set up a computer and to learn how to use broadband, which 12% gave this as the primary reason.
- 42% said they were concerned about privacy and computer viruses, while 21% gave this as the primary reason for not having broadband.
- 41% said they had a lack of interest in being online, with 22% giving this as the primary reason for not having broadband.

The results of those two surveys are drastically different because the surveys asked different questions. If a survey doesn't provide the option to say that privacy is a reason for not having broadband, then that gets missed. People can only respond to the questions asked in a survey as presented to them. For example, there were 12% of respondents in the second survey above that worried about privacy as their primary reason for not having broadband. There had to be people that felt the same way in the Pew survey, but since that question was never asked, respondents were forced to pick from among the choices they were given.

There are numerous ways to compare the availability of broadband in the town to the rest of the state, country, and world.

FCC Adoption Rate

In the 2019 annual report to Congress the FCC reported on broadband adoption by various speeds by state. Adoption rate is the percentage of households that have purchased broadband that meets or exceeds various speed thresholds. For some reason that they don't explain well, in the 2019 broadband report to Congress the FCC reported broadband adoption rates for 2017. This means two things. The overall adoption rates are understated because we know that the overall number of homes buying broadband has been increasing every year. However, since the data used in the FCC report comes from the Form 477 data, the percentage that that buying a given speed is likely overexaggerated. That makes for some confusing results, but since the same issues affect every state, the overall rankings of broadband adoption by state is probably reasonable.

In the 2019 report to Congress, the FCC reported the following broadband adoption rates for Massachusetts (meaning the percentage of customers who are buying the listed speeds at their home):

Homes buying at least 10/1 Mbps	84.3%
Homes buying at least 25/3 Mbps	81.6%
Homes buying at least 50/5 Mbps	70.8%
Homes buying at least 100/10 Mbps	33.3%
Homes buying at least 250/25 Mbps	2.1%

To put the FCC numbers into perspective, the percentage of homes that get at least 10/1 Mbps broadband (84.3%) ranks Massachusetts as having the third highest adoption rate after New Jersey and Delaware.

FCC Availability of Broadband

The FCC also looks at the availability of broadband by county, meaning the percentage of homes that could buy broadband at various speeds. Here's what the FCC reported to Congress in 2019:

Barnstable County

Urban population:	197,419
% that can buy at least 25/3 broadband	98.6%
% with 4G LTE coverage	100.0%
% with both	98.6%
Rural population:	16,025
% that can buy at least 25/3 broadband	98.7%
% with 4G LTE coverage	100.0%
% with both	98.7%

All of the counties in the state except Dukes and Hampshire have similar percentages according to the FCC. It's likely that the FCC numbers are overstated. The way the collect data probably would not have identified the pockets of homes in Falmouth where Verizon is the only option.

How Does the US Rank with the Rest of the World?

Cable Company from the United Kingdom has been gathering data each year that compares broadband speeds and prices from around the world.

The most recent report on broadband speeds is from 2019.[7] The rankings are based upon many millions of speed tests, and 2019 average download speed for the US is based upon over 132 million speed tests. The US ranked 15th in the world in 2019 with a national average download speed of 32.89 Mbps. We are behind countries like Taiwan, Singapore, Sweden, Denmark, Japan, Netherlands, Spain, Norway,

[7] Broadband speeds around the world. https://www.cable.co.uk/broadband/speed/worldwide-speed-league/

Belgium, and others. The average speeds in the US have been increasing and was 25.86 Mbps in 2018 and 20.00 Mbps in 2017. During that time, the US climbed from 21st fastest to the current rank of 15th. The speed increases are largely due to upgrades in speeds in urban areas by cable companies, although there are also fiber-to-the-home builds in both urban and rural markets across the country.

The Gap in Broadband Affordability

The FCC reports that broadband adoption for the country is around 86%. Even after accounting for the rural areas that have no broadband option, there are many millions of customers that can get broadband at their homes, but that do not buy it. Numerous studies and surveys have asked people why they don't buy broadband when it's available. The number one reason that's always cited is price – people say they can't afford broadband.

Statistics on Affordability

In larger cities it's somewhat easy to equate broadband penetration rates to household incomes. This is due to the fact that a Census block in a city might be as small as a block or two, and it's easy to match Census data to broadband data from the FCC.

An analysis of recent FCC 477 data shows that there is a direct correlation between household income and buying a home broadband connection. Only about half (53%) of households with annual incomes under $30,000 buy broadband. This contrasts sharply with 93% of homes with incomes over $75,000 buy broadband. There is no clearer evidence that there is an affordability gap for broadband.

There are studies available for those who want to dig deeper into quantitative and qualitative research into broadband affordability for low income households. The first was published by the Benton Foundation and authored by Dr. Colin Rhinesmith.[8] The second report is issued by the Quello Center and is authored by Bianca Reisdorf.[9] This report looks at a study conducted in three low-income neighborhoods of Detroit.

Both reports say that low-income households with a limited budget appreciate the advantage of having broadband at home but can't fit it into their budgets. They find it difficult or impossible to prioritize broadband compared to paying rent or buying food. These studies indicate that a big part of the solution for getting broadband into homes without it is going to have to involve finding a way to pay for the monthly broadband access.

It's not easy to measure the affordability gap in Falmouth (or anywhere). Every community has low-income homes and senior on fixed incomes where affording broadband is out of reach. We know from talking to the libraries in Falmouth that there are residents who use the public computers since they can't afford broadband at home. Probably the best way to quantify the issue in Falmouth would be to ask the libraries to give a short survey to people who use the library's broadband. Affordability is not the only reason why people don't have home broadband. Later in the report we discuss ways to address the affordability gap.

[8] Digital Inclusion and Meaningful Broadband Initiatives. https://www.benton.org/publications/digital-inclusion-and-meaningful-broadband-adoption-initiatives

[9] Broadband to the Neighborhood. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3103457

Comparing US Broadband Prices to the World

Cable Company of the United Kingdom also tracks broadband prices around the world. The most recent comparison of prices is from 2020.[10] The average price of broadband in the US in 2020 is $50. It's worth noting that these prices were gathered from advertised prices, and most big ISPs in the country advertise special prices that expire after a one or two-year period. The price also doesn't include the cost of a modem or WiFi router. The average price of the US ranks as the 119th most affordable out of 206 countries. However, it's worth noting that most of the countries that are more expensive than the US are either third world countries or island nations. The few exceptions of first world countries that are more expensive than the US are New Zealand, Norway, and Switzerland.

In that same report, the US looks better when looking at advertised prices compared to advertised bandwidth. In that comparison the average cost per megabit of speed in the US is $0.26, placing the US 27th in terms of affordability. However, we know that many ISPs advertise speeds that are faster than what they actually deliver – but this may be true in other countries as well. We also know that many ISPs in the US charge prices t many customers that are higher than advertised prices. The real price of broadband in the US is higher than is shown in this analysis.

ISPs Bridging the Price Gap

Comcast Internet Essentials

Comcast has a low-income program called Internet Essentials that provides broadband to qualifying households. Comcast delivers 10 Mbps download speeds for $9.95 per month. The program was created as a condition by the FCC for its purchase of NBC Universal in 2011. For a long time, the program was lowkey and the company barely advertised it to customers. But over the years the company has embraced the program and in August 2019 announced that it had connected over 8 million people to the Internet with the program (not sure how that translates into households).

In addition to the low monthly broadband rate, those in the plan are eligible to buy a low-cost computer for $149.99. Comcast also offers broadband training in Internet basics, on online safety and security, on using basic computer tools and programs, etc. These training courses are available online or can be taken in person.

Comcast has widened the eligibility for the program over the years, and currently families participating in Medicaid; live in public housing; who participate in SNAP, TANF, SSI, National School Program, Headstart, LIHEASP, or WIC; are attending college under a Pell grant; receive a VA pension; or receive various kinds of tribal assistance.

Verizon

Verizon participates in the FCC's Federal Lifeline plan that is funded from the Universal Service Fund. The plan can provide a discount to low income households for either broadband or telephone service.

[10] Broadband prices around the world. https://www.cable.co.uk/broadband/pricing/worldwide-comparison/

Verizon only makes this available to FiOS customers, so this plan is not available to anybody in Falmouth.

The Homework Gap

In 2010 the FCC adopted the National Broadband plan, and one of the key provisions of that plan is that every American community should have gigabit broadband connections to public schools.

Since that time, the State Educational Technology Directors Association has increased that recommendation and recommend that large schools provide at least 1.4 Mbps of broadband per student for large schools and 2.8 Mbps per student in smaller schools in order to provide adequate bandwidth.

At the end of 2019, only 25 of 1,464 public schools in Massachusetts still don't have at least a 100 Mbps broadband connection (10% of the national goal). The group Education Superhighway[11] reported recently that most schools in Massachusetts have fiber connectivity. The schools in Falmouth are connected to gigabit fiber by OpenCape.

The bigger issue concerning education in the counties is what is being labeled nationally as the homework gap. This is the situation where students have broadband at school but don't have adequate broadband and/or computers at home to enable them to do homework.

The issue recently became a lot more serious when students were sent home due to COVID-19 and asked to finish the school year remotely. The Falmouth School District told us that they only needed to provide twenty cellular hotspots for students that didn't have home broadband. The schools also provided Chromebooks to students without home computers.

How much bandwidth is needed to do schoolwork at home? It varies according the specific set-up at a given school. The typical way for a student to connect to a school system network is through the creation of a virtual private network (VPN) connection. A VPN works by grabbing and reserving a dedicated data path between the home and a server, in this case a school server. While that student is connected to the school, that data path is dedicated to the student and can't be used for other purposes in the home without kicking the student off the VPN connection.

The VPN generally tries to establish both a download and an upload data path. The download path is used to download documents like homework assignments, with the biggest download being when the school homework involves viewing videos that are streaming from the school server. On the upload path the VPN is used when students send completed homework or else perform functions online line like taking a test. The biggest use of the upload connection comes if the students wants to connect with a video connection so that the teacher can see students and vice versa. A 2-way video connection uses both upload and download bandwidth simultaneously.

A downloaded video might use from 1 to 3 Mbps depending upon the amount of action in the idea. The upload stream for video conferencing will require at least 1 Mbps, sometimes a little more. These same

[11] https://www.educationsuperhighway.org/

VPN connections are carved out of the broadband path for each student trying to work from home at the same time along with any adult trying to connect to a server when working remotely.

The Quello Study

Teachers have understood for many years that students without broadband and/or computers at home don't perform as well in class. There was recently a definitive study that quantified the impact of the homework gap. The study was just released in March 2020 and was done by the Quello Center that is part of the Department of Media and Information at Michigan State University.[12]

I call this a definite study because it used study techniques that isolate the impact of broadband from other factors such as sex, race, and family incomes. The study involved 3,258 students in Michigan in grades 8 – 11 from schools described as being in rural areas. The study was done in such a way to get results of schoolwork concerning students without violating student confidentiality.

The study showed significant performance differences for students with and without home broadband. Students with no Internet access at home tested lower on a range of metrics including digital skills, homework completion and grade point average. Some of the specific findings include

- Students with home Internet access had an overall grade point average of 3.18 while students with no Internet access at home had a GPA of 2.81.
- During the study, 64% of students with no home Internet access sometimes left homework undone compared to only 17% of students with a high-speed connection at home.
- Students without home Internet access spend an average of 30 minutes longer doing homework each evening.
- The study showed that students with no Internet at home often had no alternative access to broadband, such as a library. 35% of students with no broadband also didn't have a computer at home. 34% of students had no access to alternate sources of broadband such as a library, church, community center, or homes of a neighbor or relative.

One of the most important findings was that there is a huge gap in digital skills for students without home broadband. To quote the study, "*The gap in digital skills between students with no home access or cell phone only and those with fast or slow home Internet access is equivalent to the gap in digital skills between 8th and 11th grade students*." Digital skills not only require competence in working with technology, but also means the ability to work efficiently, to communicate effectively with others, and managing and evaluation information. This is a devastating finding that students without home broadband fall three grades behind other students in terms of developing digital skills.

Students with lower digital skills translates directly to performance on standardized tests. A student who is even modestly below average in digital skills (one standard deviation below the mean) tends to rank nearly 7 percentiles lower on their total SAT/PSAT score, 5 percentiles lower in math, and 8 percentiles lower in evidence-based reading and writing.

The study also showed lower expectations for students without broadband at home. For example, 65% of students with fast broadband have plans to pursue post-secondary education. Only 47% of students

[12] http://quello.msu.edu/wp-content/uploads/2020/03/Broadband_Gap_Quello_Report_MSU.pdf

with no Internet access have such plans. Students who are even moderately lower in digital skills also are 19% less likely to consider a STEM-related career (that's science, technology, engineering, and math).

Another major study by the National Center for Education Statistics (NCES),[13] an agency within the US Department of Education looked at the homework gap. That study compared test scores for 8th grade students both with and without a home computer. The results showed:

- On tests of reading comprehension, students who have a computer at home had an average score of 268 compared to a score of 247 for students without a computer.
- In testing for mathematics, students with a computer at home scored 285, while those without scored 262.
- In testing science, students with a computer scored 156 compared to 136 for students without a computer.
- In testing competency in information and communication technology, students with a home computer scores 152, compared to 128 for students without a home computer.

Falmouth schools have temporarily solved this problem during the pandemic by providing WiFi hotspots and Chromebooks to students without home broadband connections or computers. The schools told us that they didn't think this was a huge problem and that they gave out 'surprisingly few' hotspots and computers during the pandemic. The Quello study's conclusion that there is a huge lag in academic achievement for students without home computers. This hopefully will prompt the schools and the community to continue to solve the after the end of the pandemic.

Other Uses of Broadband for Education.

The US Bureau of Labor Statistics reported earlier this year that the average American baby boomer held 12.3 different jobs between the ages of 18 and 52 - that was 12.5 jobs for men and 12.1 jobs for women. It's much harder to measure a change in careers, meaning a change to doing something drastically different than prior jobs, but researchers have looked at the data and said that most people change careers at least several times during their work life. The above statistics don't tell the whole story because many people are now working well past 65 years of age, including many older workers trying a new career at the end of their working life.

Many new jobs and careers today require online training. New employees are often expected to complete online training courses at the start of a new job. Many out-of-work adults pursue online training to learn a new career. Anecdotal evidence suggests that taking training or educational courses from a distance (across the country) requires more bandwidth since it's harder to hold a VPN session when the bandwidth varies.

The biggest group of online learners (outside of the COVID-19 crisis) are students pursuing a post-secondary education online. There are almost 20 million college and graduate students across the country, most of which have been recently been notified that most or all of the fall semester this year will be done online.

[13] https://nces.ed.gov/pubs2017/2017098/index.asp

Secondary education has already been in the process of migrating online. Eduventures estimated that the percentage of students already tackling an online degree before the pandemic was 29% of those pursuing an associate's degree, 42% for a bachelor's degree, 27% for a master's degree, and 3% of those working towards a doctorate. In the fall of 2020, nearly all secondary students will have some or all of the curriculum online.

The Computer Gap

One of the things that digital inclusion advocates have learned is that it's not enough to get affordable broadband to a home if they can't afford a computer or other devices to use the broadband. It's also now clear that cellphones are good tools for things like shopping online, but they are inadequate for students trying to do homework. Any plan to close the digital divide has to find solutions for closing the computer gap.

A survey by Pew Research Center in 2019 shows a huge disparity between income and technology adoption. Consider the following results of that poll:

	Less than $30,000	$30,000 to $100,000	Over $100,000
Home Broadband	56%	81%	94%
Smartphone	71%	85%	97%
Desktop	54%	83%	94%
Tablet	36%	55%	70%
All the Above	18%	39%	64%

Other studies have shown that the percentages of homes that have any these technology tools shrinks significantly for homes making under $25,000 per year.

A big problem for low-income homes is that they can't afford both broadband and the cost of buying and maintaining a computer or similar device. Computers are some of the shortest-lived electronics we can buy and typically have to be replaced every 3 or 4 years.

The above numbers highlight the problem of getting broadband into low-income homes – a solution is needed for both broadband and for a computer. As will be discussed below, low-income homes also often need computer training.

The historical solution to lack of computers was to put computers in libraries and public places. However, numerous studies have shown that computers in the home are better than computers in libraries and have a huge positive impact on students compared to any other alternative. Computers have the biggest positive impact on students when they are part of daily life and convenient to use when needed.

We can't forget that computers aren't only for students. Adults need computers today just to participate in the modern world. Computers are needed to hunt for a job. Computers are needed to pursue online training and education. Computers are needed to consider jobs that all employees to work from home. Computers are needed today to interface with many government programs.

There are a number of different approaches that communities have tried to solve the computer gap that will be discussed below in the section talking about solutions for the digital divide.

There is no easy way to quantify the number of homes in Falmouth that don't have a computer. For example, a home might buy broadband to watch Netflix and otherwise only use a cellphone connected to the broadband. We did learn from the schools that they didn't have to hand out very many computers to students during the pandemic.

The Digital Literacy Gap

The current US job market appears to be robust due to the low unemployment rate, which is low by historic standards. However, a closer look at the statistics tell a different story.

Workers with upper income jobs are faring extremely well. For example, starting jobs for new computer, engineering, and similar tech graduates are at an all-time high. It's a good time to be a high-tech worker. However, over half of all job openings in the country are classified as middle-skill jobs (with the three categories being high-skilled jobs, middle-skill jobs, and unskilled jobs). These jobs generally don't require a college degree. An analysis by the Benton Foundation a few years ago showed that over 80% of middle-skill jobs require some degree of digital literacy. Unfortunately, a lot of people seeking middle-skill jobs lack the digital skills needed to land these jobs.

This lack of sufficient digital literacy to find middle-skill jobs is perhaps the best way to describe the broadband skills gap. These are not jobs that need coders, but rather than need people to know basic computer skills like knowing how to use Microsoft Word or Excel. It means being able to type fast enough to do data entry, write-emails, or other expected tasks in the average workplace.

In the early days of the computer age the federal government operated many training programs that taught the basic computer skills. Today it seems to be assumed that students graduate from high school with these skills. However, a student who has never had a home broadband connection or a computer and who only did homework on a cellphone probably doesn't have the needed digital skills. Since the federal and most state governments don't offer any significant training programs in computer literacy, it's up to local communities to find their own solutions.

An example of a non-profit that has tackled this issue is the Enterprise Center in Chattanooga Tennessee. This is a non-profit that is looking for ways to solve the digital divide in the city. Chattanooga is a city that has invested in broadband and offers gigabit broadband on fiber to every resident of the city. However, like in all cities, they found out that low income homes couldn't afford the broadband, didn't have computers, and didn't have the digital skills needed to use a computer. The Enterprise Center began offering basic computer training a year ago and was overwhelmed by the huge number of people who wanted basic training. The Enterprise Center is now looking for ways to greatly expand the training to meet the demand.

Of course, not everybody agrees with that conclusion and there are a lot of people working on digital inclusion who say that the issue is a lot simpler – policymakers don't understand the struggle low-income homes have deciding between broadband bills and food bills.

A Pew Research Center survey in 2016 showed that a lot of adults were interested in digital training. 60% of adults were interested in learning how to use online resources to find trustworthy information. In today's world of misinformation, I would think that percentage is even higher today. 54% of adults were interesting in training that make them more confident in using computers and the Internet.

This is the hardest gap of all to identify because many adults don't want to admit that they don't know how to use a computer. Falmouth already tackles this issue to some extent through programs at the libraries. We've learned from other communities that offer training that they are always surprised at the number of residents who ask for training if it's available.

Future Broadband Gaps

The Future of Broadband Speeds and Capacity

This gap analysis so far has discussed existing broadband gaps. It's important to realize that there will be new broadband gaps coming in the future that we can already predict. One of the issues to consider when looking forward is that broadband speeds are a moving target – that is, the demand for residential and business bandwidth grows every year. This is not a new phenomenon and the need for bandwidth has been growing at nearly the same rate since the early 1980s. Home and business need for bandwidth has been doubling every three to four years since then.

As an example, 1 Mbps DSL felt really fast in the late 1990s when it was introduced as an upgrade from dial-up Internet. The first 1 Mbps DSL connection was nearly twenty times faster than dial-up, and many people thought that speed would be adequate for many years. However, over time, households needed more speed and the 1 Mbps connections started to feel too slow and ISPs introduced faster generations of DSL and cable modems that delivered speeds like 6 Mbps, 10 Mbps, and 15 Mbps. Cable modem speeds continued to grow in capacity and eventually surpassed DSL, and in most cities the cable companies have captured the lion's share of the market by offering internet speeds starting between 100 Mbps and 200 Mbps.

Bandwidth requirements are continuing to grow. Firms like Cisco and Opensignal track speeds achieved by large numbers of households by examining Internet traffic that passes through the major Internet POPs. Both companies estimate that home internet need for bandwidth downloading as well as the need for broadband speeds are growing currently at about 21% annually. Business use of bandwidth is currently growing at 23% annually.

This report earlier discussed how the FCC set the definition of bandwidth in 2015 at 25/3 Mbps. If you accept that speed as an adequate definition of bandwidth in 2015, then growing the requirements for speed every year by 21% would result in the following speed requirements by year.

Download Speeds in Megabits / Second

2015	2016	2017	2018	2019	2020
25	30	37	44	54	65

This is somewhat arbitrary because it assumes that the broadband needs in 2015 were exactly 25 Mbps. For example, if the actual broadband need for the average household in 2015 was 22 Mbps, then the

predicted speed for 2020 would be 57 Mbps. What is not arbitrary is that the need for bandwidth and speed increases over time.

If we accept the premise that 25 Mbps was the right definition of broadband in 2015, then it's reasonable to believe that the definition of broadband today ought to be at least 50-60 Mbps. That would infer that there is a broadband gap today for any customer who can't buy 50-60 Mbps broadband.

Broadband is not only measured by speed and there are firms that track the volume of data that households and businesses use. The firm OpenVault measures total usage by households using software deployed by the biggest ISPs around the country and around the world. They recently announced that the average US household in in the fourth quarter of 2019 used 344 gigabytes of data per month (downloads and uploads combined). That number leaped from 275 gigabytes in 2018 and 215 gigabytes in 2017. Further, OpenVault says that the average cord-cutting household now uses over 520 gigabytes per month – a number that would have floored any network engineer a decade ago.

As might be expected, home broadband usage has exploded to COVID-19. OpenVault reported that as of the end of March 2020 that the average US home used 402.5 gigabytes of usage, up 17% from the 344.0 gigabytes reported just 3 months earlier at the end of 2019, and up 47% from the 274 gigabytes measured a year earlier. OpenVault says that most of the growth was realized in the last two weeks of March as employees and students started working from home in earnest.

One of the most startling numbers to come from OpenVault is what they call power users – homes that are using more than 1 terabyte of data per month. At the end of March, 10% of all US homes were using a terabyte of data, an increase of 138% over the 4.2% of homes that used a terabyte of data just three months earlier at the end of 2019. Even more interesting, 1.2% of homes used 2 terabytes of data at the end up march, up 215% from the end of December. The big ISPs like Comcast are supposedly not billing for data caps during the pandemic – but they must be licking their chops at the flood of new revenues this is going to create if broadband usage doesn't return to pre-COVID levels.

We saw the demand for faster broadband products also leap upward. At the end of March, the percentage of homes subscribing to gigabit data products jumped to 3.75% of homes, up from 2.8% at the end of 2019 and up from 1.9% a year earlier. Amazingly, more than 1% of all homes in the US upgraded to a gigabit data plan in just the last three months – that's something that's been predicted for years. Those homes are not likely going to downgrade to slower speeds – so gigabit broadband is now becoming a significant segment of the market. OpenVault says that 12% of US homes now subscribe to speeds of 200 Mbps or faster.

The OpenVault data also validates what's been reported widely by ISPs – that the pattern of broadband usage is changing by time of day. In the recent past the peak period for broadband usage – the busy hour – was always in the evenings. In the first quarter the amount of usage in the evenings was flat and all of the increased usage came during the daytime as employees and students used broadband and video conferences to function.

OpenVault says that usage peaked in the third week of March. It will be interesting going forward to see the how home usage changes. OpenVault doesn't have any better crystal ball than the rest of us, but they are predicting that broadband usage will never return to the historic patterns. They predict that a lot of people will continue to work from home, meaning increased broadband demand during the day. They

believe there will be continued pressure on the upload data paths. People who have learned to videoconference during the recent months are likely to continue that practice in the future. Companies and employees that realize they can be productive at home are likely to work more from home, even if only on a part-time basis.

These various statistics are a clear indication that the FCC should be periodically increasing the definition of broadband. The agency looked at broadband speeds in a docket in 2018 and concluded that they were going to keep the definition at 25/3 Mbps. However, there was a lot of compelling filings in that docket that argued that the definition of broadband should be 50 Mbps to 100 Mbps.

The point of this section of the report is that we can't get hung-up on the FCC's definition of broadband when looking at the broadband gap. Practically every home that uses broadband would acknowledge that they download and upload a lot more data today than they did just a few years ago.

It's also important to look towards the future when considering broadband needs for the town. For example, if an ISP builds a new broadband solution today, that solution should be prepared to handle the broadband requirements a decade from now. Consider the following chart that predicts broadband needs moving forward. This applies the same 21% annual growth rate for bandwidth demand that we're currently seeing. Forward predictions are always criticized for being too aggressive, but when considering that the need for broadband has been growing at roughly the same rate since 1980, it's not a big stretch to predict broadband needs into the future.

Download Speeds in Megabits / Second

2020	2021	2022	2023	2024	2025	2026	2027
65	79	95	115	139	169	204	247

The download speeds in this table get really large if extended even further into the future. If the demand for broadband download speed continues to grow at 21% annually, then the need in 2030 would be 438 Mbps, in 2035 would be 1.1 Gbps, and in 2040 would be 2.9 Gbps. It's easy to say that such future speeds are not possible, but recall that just 20 years ago, a 1 Mbps DSL connection was considered a blazingly fast broadband connection. A fiber network will be able to keep up with this kind of future demand. There is already fiber gear today that can deliver 10 Gbps broadband to residential customers.

It's possible that the cable company networks could also keep up with this demand, but it would require several major upgrades in technology to do so. Comcast's network in Falmouth can deliver download speeds up to a gigabit today. However, the secret Comcast doesn't want to talk about is that they can't give that much speed to everybody unless they build a lot more fiber and further reduce node sizes. Comcast also would need to upgrade to DOCSIS 4.0 to get speeds faster than 1 gigabit.

It's not hard to put this prediction into perspective. Cable companies that serve over 60% of all broadband customers in the country already provide minimum speeds today of between 100 Mbps and 200 Mbps. That speed varies a bit by market due to the condition of local coaxial networks. But in markets where the coaxial cable in in good condition, big ISPs like Comcast and Charter provide 200 Mbps broadband today as the target speed for their introductory broadband product.

The above chart suggests that by 2027 (or some year close to then) that the Comcast 200 Mbps product will start to feel sluggish to many households. Comcast has unilaterally increased speeds over the years

and it would not be surprising to see them increase the basic speed again before 2027. The company seems to have a policy to stay in front of the demand curve. I'm sure this greatly cuts down on complaints and customer service issues. If the cable companies are staying ahead of this curve voluntarily, it raises the question of why the FCC isn't keeping up with the events in the marketplace.

It's not hard to imagine that seven years from now that the national definition of broadband ought to be around 250 Mbps. That doesn't mean that the FCC will continue to increase the regulatory definition. Last year they rejected numerous filing asking them to increase the 25/3 Mbps definition. There is a political downside if the FCC increases the definition of broadband – it would reclassify numerous homes as not having broadband. Today the 25/3 Mbps definition of broadband is lower than the reality of what many homes need, but my guess is that there will have to a big difference before an FCC will react and change the definition.

One of the conclusions that can be reached by this analysis is that any new network built today ought to be capable of meeting the expected broadband speeds of the next decade. The only technologies capable of meeting the projected future needs for bandwidth are fiber-to-the-premise, cable company hybrid-fiber networks, and some wireless technologies using millimeter wave spectrum that are just now being trialed in a few markets.

Cable companies are only going to able to provide speeds above 1 gigabit by implementing another round of expensive upgrades. There is a lot of speculation in the industry that cable companies would upgrade to fiber-to-the-home rather than make such an upgrade. Unfortunately, if Comcast ever decides that fiber is its future, the company is going to upgrade major metropolitan markets long before upgrading secondary markets like the Cape. Just as Verizon refused to bring fiber to the Cape a decade ago, it would not be surprising in the future to see Comcast reach the same conclusion. Realistically, a fiber network is the only solution that is going to bring the bandwidth that Falmouth will need in the future.

The Summer Population

Falmouth has an interesting summer population compared to many other resort areas around the country. A significant proportion of seasonal rentals in Falmouth are for the summer or for nine months. In many resort areas around the country, few tourists stay for more than a week. The nature of the length of stay for tourists in Falmouth is a good indicator that visitors are going to want the same quality of broadband in Falmouth that they have at home.

The FCC data shows that Massachusetts has the third average fastest Internet speeds in the country, and this is largely due to the prevalence of Verizon FiOS broadband service on fiber that is available in the Boston area. FiOS is also widely available in the cities and suburbs of neighboring states. The slowest broadband connection on FiOS is a symmetrical 200 Mbps connection that provides fast download and upload. It's been widely reported that the FiOS network largely delivers the subscribed speeds, while cable company networks often deliver less speed than advertised.

Comcast and a few other big cable companies serve the urban and suburban markets in Massachusetts and nearby states. When CCG has studied urban markets, we often see that cable company networks are of a higher quality than the network in Falmouth and customers get faster speeds. For example, in many urban markets where Comcast competes against FiOS, the basic Comcast's broadband product delivers

200 Mbps download. We also have studied Comcast markets where most homes get the broadband speeds that customers subscribe to. We don't see this in Falmouth. The speeds in Falmouth are slower than speeds in the Boston area. Further, the speed tests show that a significant number of homes in Falmouth are getting speeds much slower than what customers are paying for.

This all means that many visitors to Falmouth come from homes with faster broadband speeds than what they can get in Falmouth. As has been discussed earlier in the report, the amount of broadband used by the average home has been growing explosively. Even before the pandemic the amount of broadband used by homes has been growing more than 20% per year. Many visitors are going to come from a home where they use broadband for everything. They watch lots of video, people work from home, gamers use big bandwidth, and much of what the home does has migrated to the cloud.

While broadband won't matter to every visitor (just as it doesn't matter to every resident), a significant percentage of visitors are going to want the same broadband experience in Falmouth as they have at home, particularly if they are going to stay for a month or longer. We were told anecdotally by a number of people in Falmouth that many visitors view the broadband speeds in the community as sluggish, and we repeatedly heard from residents that the biggest problem with Comcast in Falmouth is inconsistent broadband. People suffer short intermittent broadband outages, or the speeds vary during the day.

Companies all across the company are having serious discussions about not reopening downtown offices at the end of the pandemic. Business are seeing that productivity hasn't waned when employees moved home, and they are questioning the high cost of expensive office space. Even before the pandemic it's likely that many long-term visitors work remotely while in Falmouth. In the future that's might become the norm.

I also live in a tourist community, in Asheville NC, and my town is currently seeing a real estate boom from people fleeing larger cities and moving here. Almost universally these are high-paid professionals who plan to work from here. The press across the country is full of stories of people in major metropolitan areas fleeing to other towns as they realize they no longer have to live in the expensive metropolitan areas.

A Comcast connection in Falmouth is going to be adequate for somebody working from home unless they need a fast upload connection. Households that want to support multiple people working from home are going to find the broadband in Falmouth to be challenging, and inadequate for somebody who comes to Falmouth from a home with faster broadband. Professionals that need big broadband like doctors, engineers, and architects are not going to happy working on a cable company connection if they are used to something faster at home.

One of the more interesting aspects of looking at broadband in Falmouth is that no town on the Cape has great broadband. For whatever reason, Verizon decided decades ago not to bring FiOS to the Cape. The first community on the Cape to get fiber is going to have a big economic advantage for a number of years. If working from home becomes the new norm, then people are going to want to live in places they love – and it's clear that people love the Cape. The first Cape community with fiber broadband is likely to see a real estate boom and also an influx of more high-paid professionals that will work from home. That kind of change will be transformational because it means that restaurants and other seasonal businesses will thrive all year long.

The Consequences of the Broadband Gaps

There was a time when academics theorized about the impacts of poor broadband. We don't need to theorize today because you can go to any community with poor broadband and residents and businesses will fill your ear with stories of the negative consequences of poor broadband.

Impact of Poor Broadband for Residents

Lower Property Values / Working from Home: We now know that housing prices are higher in communities with great broadband options. While everybody in Falmouth has the option to buy broadband from Comcast or Verizon DSL, there are numerous communities in the state that are served by Verizon fiber and the FiOS product.

Realtors have been reporting across the country that broadband is at or near the top of the wish list for most homebuyers today. During the pandemic there has been a lot of value placed on the ability to work from home – and much of that ability comes from fast broadband upload speeds.

The big question that has to be answered for communities like Falmouth is if people will walk away from homes in Boston that have fiber broadband to work in Falmouth with cable broadband? Some will, but there are many who will instead choose another community that is already served by fiber.

According to Bloomberg, before the pandemic about 4% of the full-time workforce, not counting self-employed people, were working from home. Adding in self-employed people means that work-from-home is becoming a sizable segment of the local economy. Your survey showed 13% of residents in the town working from home before the pandemic (5% full time and 8% part time). It's likely that that number further skyrocketed during the pandemic, and it also seems likely that the number won't drop back to the 13% level but will be something higher in the future.

There are a few communities that recognize the economic benefit of having good-paying employees that work from home. For example, there have been several programs to attract people to work from home. One such program was in 2018 where Vermont offered a cash incentive of between $5,000 and $10,000 for families with a home-worker to relocated to the state. The state has an aging population and wanted to attract families with good incomes to help energize the local economy. The state recognized that the long-term local benefits to the state from attracting high-paying jobs is worth a lot more than the cash incentive they are offering.

Since then other communities have tried the same thing. A similar effort was recently announced in Tulsa, Oklahoma, which has been watching its population drop since 2016. In Tulsa, a foundation is fronting the $10,000 payments used to attract home workers to the community. There is a similar program in Topeka, Kansas and in northwest Alabama.

One corollary of broadband enhancing the value of real estate is that

Education: Even before and after the pandemic, schools have been concerned about the ability to assign computer-based homework to homes with inadequate broadband. Most of the homes in Falmouth have adequate download speeds, and when the pandemic hit in the spring the schools only needed to supply about twenty cellular hotspots to ensure that every student had a home broadband connection.

The issue is not just download data speeds, but also the total amount of downloaded data that even elementary school students needs to do homework. We learned during the pandemic that upload speeds might matter more than download speeds. A student working from home needs to establish a solid and reliable upload link to connect to a school server. Most of the broadband connections in Falmouth can likely support one student or one adult working from home but might not support homes where more than one person wants to make these connections at the same time.

We heard from the schools, and also directly from residents that some homes had problems making connections to school and work servers. The problem mostly arose from homes where multiple people tried to connect outside the home at the same time – the upload speed was not sufficient to make multiple connections. We did not hear that homes with a single student were having any problems connection to school.

Medical / Telemedicine: Telemedicine is uses broadband to connect patients to doctors over the Internet. Patients can talk to doctors using a video connection if the home has adequate broadband. Before the pandemic one of the most common uses for telemedicine was allowing patients able to talk to specialists in distant locations. Another common use has been for holding regular non-intrusive visits for things like counseling so that patients can make a scheduled appointment without major disruption to a work schedule.

A growing area of telemedicine is the use of medical telemetry devices, which can monitor patients after they've had medical procedures. For example, Saint Vincent Health System in Erie, Pennsylvania has been using these technologies and has lowered readmission rates of patients after surgery by 44%. CoBank recently sponsored a trial in Georgia for rural diabetes patients and showed a significant improvement for patients who could be monitored daily and who could communicate easily with doctors.

Telemedicine usage soared during the pandemic. In the past months, telemedicine visits have skyrocketed. During March and April of this year, the billings for telemedicine were almost $4 billion, compared to only $60 million for the same two months in 2019. As soon as Medicare and other insurance plans agreed to cover telemedicine, a lot of doctors insisted on remote visits during the first few months of the pandemic. In those early months we didn't know a lot about the virus and doctor offices were exercising extreme caution about seeing patients.

It's going to be interesting to see the level of telemedicine after the end of the pandemic. There was a recent article about the topic in Forbes that postulates that the future of telemedicine will be determined by a combination of the acceptance by doctors and insurance companies. Many doctors have now had a taste of the technology. It seems likely that the telemedicine platforms in place now will get a lot of feedback from doctors and will improve in the next generation of software upgrades.

The recent experience with telemedicine is going to make a lot of doctor's look harder at their broadband provider. Like most of us, a doctor's office likely relied a lot more in the past on download speed rather than upload speed. It's likely that doctor offices making simultaneous telemedicine visits are unhappy with cable modem service. Doctor's will join the chorus of those advocating for faster broadband speeds – particularly upload speeds.

My prediction is that telemedicine visits will not stay at the current high level but will be here to stay. I think when somebody books a visit to a doctor that they'll be given a telemedicine option when the reason for the visit doesn't require a physical examination. The big issue that will continue to arise is the number of homes without adequate bandwidth to hold a telemedicine session. It's worth noting that the Cape has the highest percentage of seniors in the population in Massachusetts. This means that telemedicine is probably of higher importance in Falmouth than elsewhere in the state.

Possible Solutions for the Broadband Gaps

This section of the report looks at some of the solutions that communities are finding in closing some of these different broadband gaps. It would probably require a 1,000-page paper to cover all of the ideas being tried in different communities, so these are a sample of some of the more interesting and effective ideas being tried.

Bridging the Speed Gap

This feasibility study is being conducted in order to find ways to get faster and better broadband in Falmouth. The ways that communities pursue faster broadband networks are pretty much the same everywhere. Getting faster speeds means building new broadband networks built that can provide the speeds needed to bridge the speed gap. Attracting a new broadband network will require one of the following solutions:

Tackle a New Community-based ISP. There are still only about 200 communities that have built and are operating their own municipal ISP, and most of these communities are small. But it's possible to tackle a new ISP owned by the town, owned by the EDIC, owned by a non-profit corporation, or owned by a new cooperative. These options are all discussed in more detail later in this report.

Seek Partnerships with ISPs that Can Bring Solutions. Most communities want to attract an ISP to the community. Ideally an ISP would bring funding and build and operate a new fiber network, but in communities like Falmouth there aren't any obvious ISPs considering that business model.

The alternative is to partner with an ISP. This study provides the basis for opening discussions with ISPs since it quantifies the cost of a network in Falmouth and demonstrates that an ISP can be profitable in the community.

These options are also discussed in more detail later in the report.

Push State Legislators to Put More Money into State Broadband Grants. State broadband grants in Massachusetts have historically been aimed specifically at the western end of the state. There has been legislative efforts to make the funding available for the Cape. The town and others on the Cape need to keep pressuring the government to bring grants to the Cape – even grants for a fraction of the cost of building the project would make a difference in launching a broadband project.

Investigate Other Funding Opportunities. The EDIC found funding to undertake the downtown business fiber build. There are likely to be grants or low-interest loans for economic development purpose that might help to seed to creation of a fiber project. This will likely take creativity and turning over a lot of rocks, but you've already demonstrated that it's possible.

Consider A Town Grant / Loan to Get Started. We see communities that want fiber networks step up with seed funding. For example, in the last year we've seen towns and counties provide grants between $250,000 and $6 million towards finding a better broadband solution.

Push the Incumbents to do Better. This might sound like a lame suggestion, but we've seen cases where this has worked. For example, it might be possible to convince Comcast to bring the network in town up to snuff with the networks in larger markets.

The report discusses in more detail the possibility of luring Verizon to town to build the new FWA product that can deliver speeds up to a gigabit.

Bridging the Availability Gap

There are steps that other communities have undertaken to help close the broadband availability gap.

Lending Mobile Hot Spots. The schools already did this and provided temporary cellular hotspots to students that don't have home broadband. The library already started a pilot program to lend out Chromebooks and hotspots to citizens. You should consider making these programs permanent. There are always going to be students in the community without home broadband, and some homes in the community can't afford broadband.

Making this permanent requires two things. First, the town will have to fund and buy mobile hot spots in the future. You'd also need to partner with one of the big cellular companies to provide free or inexpensive cellular data to power the hot spots. Other communities have been successful in creating such partnerships.

Create More Public Hot Spots. The town offered good public broadband during the pandemic at the libraries. However, the pandemic showed us that this can't be the only solution. The town should consider funding additional public hotspots. This might most easily be done by starting with the many government buildings that have good broadband from OpenCape. Any of those buildings are a good candidate for the creation of an outdoor hotspot. Outdoor hot spots are particularly effective since they can be made available 24/7 and not just at times when the libraries are open.

Reward Businesses for Creating Hot Spots. We've seen communities that reward businesses for creating good public hot spots. The reward can be anything from public recognition and awards to some sort of break on local taxes and fees.

Bridging the Affordability Gap

This is one of the hardest gaps to solve. Broadband is priced too expensively for some homes, and affordability efforts look for ways to bring less expensive broadband to the homes that most need it.

Inform the Public About Available Programs from Incumbents.

Comcast has a decent low-income product that is available to homes that qualify for several federal low-income programs. Regardless of the press releases, Comcast doesn't widely advertise the availability of the lower-price plans and many homes that qualify for the plan doesn't know about them.

The town could undertake an education campaign to notify citizens about these plans. This would mean developing a fully understanding of the details of the plan – who qualifies and what documentation does a home need to enroll. Armed with that knowledge the town could mount an education campaign to get more subsidized broadband into homes that need it.

Find Broadband Solutions for Public Housing.

Falmouth has some affordable low-income housing complexes. Many communities have found ways to bring better broadband to public housing. A common model is to for the community to buy a high-speed connection to the public housing complex and then use WiFi to distribute broadband to individual living units. Such connections often include low-cost or even free connections from local ISPs as a public service.

There is one national non-profit that concentrates on this effort. ConnectHomeUSA[14] has helped communities find broadband solutions for public housing across the country.

Support Local Affordability Efforts.

There are non-profit organizations around the country that are tackling the affordability issue. One of the more ambitious such efforts is being done by Mobile Beacon.[15] This is a non-profit that works nationwide to bring low cost mobile broadband to non-profits organization around the country, and through those local non-profits brings low cost broadband to low-income people.

There are numerous solutions being used by the non-profits working with Mobile Beacon. One common effort was discussed above which is to provide portable WiFi hotspots that are distributed from libraries. Mobile Beacon has also negotiated a deal with Sprint to provide low-cost cellular broadband to students and others that is priced as low as $10 per month for an uncapped cellular broadband connection.

An interesting study[16] was done looking at the impact of bringing broadband to low-income homes for the first time in the Twin Cities in Minnesota through the Mobile Beacon effort.

- 94% of Mobile Beacon subscribers use the internet daily and 82% say they use the internet several hours a day.
- The average home with Mobile Beacon used 41 GB of data per month. Students used an additional 25 GB per month. People looking for jobs used 14 GB more per month.
- The Mobile Beacon broadband had an immediate impact on students. Parents report that students spend an average of more than 4 hours per week doing homework on the Internet.

[14] https://connecthomeusa.org/

[15] https://www.mobilebeacon.org/

[16] Bridging the Gap. https://www.mobilebeacon.org/wp-content/uploads/2017/05/MB_ResearchPaper_FINAL_WEB.pdf

- The new Internet connection allows adults in low-income homes to get training. 32% of adults in the Mobile Beacon program were taking online courses,

Bridging the Computer Gap

Many communities have solved at least some of the computer gap. During the pandemic, the schools sent Chromebooks home for students that didn't have a computer at home. But the studies we've citied in the report show that students without a home computer lag behind other students, so the community might want to look at a more permanent solution. The Falmouth library is also running a trial of allowing patrons to check out a Chromebook.

Take-Home Computers for all School Kids. It's becoming common for many school districts to send a computer home with every student. In some school systems these computers can only be used to connect to the school system network, making them homework-only computers. But other school systems have recognized that these might be the only computer in a home and let students and their family use the computer for other purposes. The biggest problem with school-provided computers are students that don't have a broadband connection at home.

Foster Programs to Get Computers into Homes

In many other communities, non-profits are finding computers for homes that need them. One such program is the non-profit E2D[17] (End the Digital Divide) in Charlotte, North Carolina. The organization refurbishes laptops contributed by businesses in the Charlotte area and gives them to students. The organization has taken a several-prong approach to making this happen:

- They solicit used laptops from businesses in the Charlotte area. Most big businesses replace laptops every few years and most of them have been ending up in the landfill. Now a number of businesses send all of their used laptops to E2D.
- Used laptops need to be refurbished and E2D started several computer labs in area high schools where they hire students at a decent wage to refurbish the computers and install new software. The purpose of these labs is not only to get the laptops ready to distribute, but they are providing technical training for kids that is helping them move on towards college or a technical career.
- Households that get a new computer also get a live tutorial and technical support to best take advantage of the new laptops.
- Finally, the Charlotte area has a lot of homeless families and there are thousands of homeless kids in the area. E2D has partnered with Sprint to provide mobile hot spots and data plans that are providing broadband access to homeless students and others with no broadband.

The whole concept got started in 2012 when 12-year Franny Millen asked her father how kids without computers can keep up with schoolwork. She wanted to know what could be done about the problem and resolved to fix it. Her father, Pat Millen, founded E2D as a result of her challenge.

Another organization that works nationwide to fund computers is Minneapolis-based non-profit PCs for People.[18] They provide PCs to households that need them and work with other entities including Mobile Beacon and E2D.

[17] https://www.e-2-d.org/

[18] https://www.pcsforpeople.org/

Bridging the Broadband Skills Gap

Every community has a lot of adults who are not comfortable in using computers. There are many cities and non-profits that have created programs to help citizens get basic computer literacy training. Some of the ideas that have worked elsewhere include:

Create a Computer Training Location. One of the most effective approaches we've seen is for the local government to provide a space for computer training. This might be a room that includes a number of computers – something many communities call a computer lab. Once such a training located is created, communities have found that it's not difficult to find volunteer trainers to teach computer skills courses. As mentioned above, when Chattanooga started their training program this way they got twice as many requests for training than what they expected.

Allow the Schools to be Used After hours for Training Adults. A number of communities use computer training centers that already exist in schools to hold after-hours training for adults.

Develop Training Course in the Libraries. A number of communities have developed computer training programs through their libraries. The Falmouth libraries works with citizens who need help with computer skills.

II. Engineering Design and Cost

A. The Technologies

The Technologies we Considered

The RFP for the project asked that we consider all possible technologies that might be used to bring better broadband to the town. Following is a discussion of the three technologies we considered. First is fiber technology that brings a fiber to each broadband customer. Second is fiber-to-the-curb that brings fiber deep into neighborhoods but then uses wireless between the street and homes and businesses. Finally, we considered a full wireless solution using point-to-multipoint wireless technology.

Fiber Optics

We considered two different fiber technologies. Active Ethernet technology has been in widespread use for more than 30 years; GPON has been used for over 15 years. These are both mature technologies that are widely used and well understood industry wide.

Gigabit Passive Optical Network (GPON)

This technology was chosen as the primary way to deliver broadband. GPON makes use of optical splitters so that as many as 32 customers can share the same fiber (i.e., light source). If fewer customers are served from the same light source there is more potential bandwidth for each customer.

A GPON network can be designed in numerous configurations, but all designs include the same key elements. All networks start at a network core where the connection is made to the Internet. At this core the ISP generally inserts the signals for the various products being delivered to customers.

From the core there are direct fibers to Optical Line Terminal (OLT), which are the devices that provide the light source for customers. These OLTs can be located in the same location as the fiber core or else can be spread around in neighborhood nodes, generally in huts or large cabinets.

There is one fiber leaving the OLT for each "PON" which is the local network consisting of up to 32 customers. These fibers go to splitter cabinets where each fiber is then "split" into the 32 separate fibers that go to customers. The splitter cabinets can be located at the same location as the OLT electronics, or they can be moved deeper into the network to be closer to customers. The name "passive" for the technology comes from the fact that the splitter site doesn't require electronics or power – the splitting is just what it sounds like – one fiber is spliced and split into 32 individual paths. The paths from the splitter are "home runs" meaning that there is a dedicated fiber between a splitter site and each customer.

One of the biggest benefits of the GPON network is a savings in fibers in the network. Only one fiber is needed to serve an OLT and one fiber goes from the OLT to each splitter. The fiber is only divided into individual customer fibers at the splitters, which can be deep into the network. The GPON technology chosen provides 2.4 Gbps down and 1.2 Gbps upstream from each group of 32 customers.

Another advantage of PON is the number of electronic interfaces is reduced by the split, since one laser at the OLT can communicate with up to 32 customers. Increased bandwidth can be gained by reducing the number of customers on a PON – reducing a PON to 16 customers would double the bandwidth available per customer. Most fiber builders today choose GPON for residential service because it provides acceptable bandwidth and is less expensive than competing technologies.

One consideration when designing PON networks is the optical distance from an OLT port to the customer ONT; the design of the 2.5 GPON network includes allowance for 1.32 split and a distance limitation of 20 km (12.4 miles) design limit. This design was selected based on current vendor optical transmission availability. Due to the limited size and distances within the electric service territory, the number of remote cabinets resulting from detailed engineering will be mostly constrained by cabinet capacity rather than distance.

Future expansion of the network could utilize several technologies such as course wave division multiplexing (CWDM) or dense wave division multiplexing (DWDM) to increase bandwidth without having to remove, rearrange, and/or replace equipment in the network.

The current vendors for PON equipment include Alcatel-Lucent, Adtran, Zhone, Nokia, and Calix. Today passive optical networks use the gigabit passive optical network (GPON) technology primarily, even though more advanced versions do exist and are discussed below.

Advantages.

- Lower Cost (typically 10-20% less than Active E for the core fiber electronics).
- Can support both RF Broadcast TV and digital IPTV.
- More efficient use of bandwidth at the customer premise. A GPON network delivers 2.4 Gbps of data to a small cluster of houses and an individual customer will normally have access to much of this bandwidth for data transmission, thus giving the customer a faster bandwidth experience at the home.
- For the most part the technology can utilize existing home wiring. The PON network is designed to tie into existing telephone and cable wiring as long as they are conveniently located and in good working order.
- Requires no field electronic devices. The key word about a PON network is that it is passive. This means that no power is needed except in those locations, generally at central offices and major hubs or huts, where the provider places electronics.
- Can easily provide traditional T1s for larger business customers using business ONTs.

Disadvantages.

- Customer must be within 12 miles of hub when using 1x32 splitter. This means with large installations that multiple hubs are required.
- More customers potentially are affected by a fiber failure in the field.

Active Ethernet (Active E)

Each network node in the design is capable of offering metro Ethernet services using active Ethernet technology. This technology provides a direct data connection to a single customer.

An Active E network is essentially a fiber "home run" from the Central Office or other node, meaning that one fiber goes from the electronics core directly to the customer. This technology has several advantages and is well-suited for serving large businesses where the customer requires more stringent network uptime and higher bandwidth. An Active E network also can provide symmetrical data capabilities (upstream and downstream data rates are the same) at high data speeds. The downside to Active E is that more fibers are required in the network since fibers are not shared between customers. Electronic costs are generally also higher since there is a dedicated laser at both ends of the connection to every customer. Active E also has higher data capabilities and can inexpensively provide for data rates up to 10 gigabits per second. Faster speeds are possible, but with significantly higher electronics costs. One of the biggest advantages of Active E is that it's easy to change the connection to a single customer as customer requirements change – the laser serving that customer can be changed without affecting any other part of the network.

The primary vendors in the Active E equipment market are Cisco, Calix, Adtran, and Nokia-Alcatel-Lucent. Since PON equipment has won a much greater market share than Active E equipment, this part of the industry has been in a bit of a decline for a few years. Active E is easier to engineer and expand and is useful for customizing solutions for small volume specialized applications.

Advantages.

- Can serve customers up to 36 miles from last active field device.
- Requires less pre-planning and engineering.
- A single point of failure will often affect fewer customers
- Offers true non-blocking 1 Gbps and faster speeds.
- Easily upgradeable to 10 Gbps by switching optics.

Disadvantages.

- Shares data and CATV bandwidth in the same data stream. Today an Active E system can cost-effectively deliver up to 10 gigabits of data to each home, but more typically these networks are designed to deliver 1 gigabit. This is not a shared pipe with neighbors and each customer can get a dedicated gigabit pipe. However, this one data stream must support CATV, data, and voice together. Thus, if a customer is watching multiple HDTV sets, the amount of bandwidth left for data will be something less than a gigabit.
- The technology has a higher operating cost than PON. It takes more power. Maintenance costs are higher since there are twice as many lasers in the network.
- More physical space is required for electronics because there are more fiber terminations onto the electronics. If the electronics are located in the field, the cabinets housing the electronics and fiber terminations can become relatively large. This means most cabinets need to be on private land and not on public rights-of-way.
- Fewer customers served per electronic chassis. Since only one customer can be served per laser then there are fewer customers that can be served from a single card.
- Larger fiber cables are typically used due to the requirement of a single fiber per customer from the ONT to the electronic chassis. The use of larger fiber cable in an aerial application may significantly increases make-ready costs.

Fiber-to-the-Curb

One of the most intriguing technologies to consider is fiber-to-the-curb. Currently, the company pioneering this technology is Verizon. Verizon refers to the technology as fixed wireless access (FWA). The technology consists of building fiber along streets and then beaming broadband wirelessly to customers using millimeter wave spectrum.

Verizon introduced the technology in 2018 and deployed small trials in Houston, Indianapolis, Los Angeles, and Sacramento. In June of 2020 Verizon introduced the second generation of the technology, with the first new market being Detroit.

The first-generation technology required mounting an antenna on the outside of the home to receive the signal. The new technology hangs a receiver on the inside of a window that faces the transmitter on the pole outside the home. Verizon claims the new technology can be self-installed by customers. One of the key requirements for using the technology is that there must be a good line-of-sight between the transmitter on the pole and customer, which means no intervening trees, shrubs, or other impediments.

Verizon claimed that the first-generation equipment technology could deliver speeds up to 300 Mbps for up to 2,000 feet from a pole. Many engineers in the industry guessed that the more realistic distance was 1,000 feet or less. Verizon claims the new technology can deliver speeds up to a gigabit, but Verizon is no longer making any distance claims. The industry consensus is that this new technology also is likely limited to perhaps 1,000 feet from transmitter to customer window. The receiver in the window needs to 'see' the see the transmitter on a pole, so this is a line-of-sight technology where only homes within sight range of a pole can receive the broadband.

Verizon publicly claims that the technology will meet all 5G specifications. However, currently there are no 5G features yet being used in the field, and so the current generation of technology is basically a millimeter wave radio path to a home. When 5G is finally introduced in the field this technology might benefit some if it can use the 5G features that tailor bandwidth paths to customer demand. But since most 5G features are intended to benefit cellular traffic, this specific technology is not likely to improve much even if layering on 5G features.

From a deployment perspective, this is an expensive technology. It requires building fiber deep into residential neighborhoods. The industry analysts at MoffetNathanson looked at the first-generation equipment and said they didn't see how the technology could be any cheaper than building fiber-to-the-home. The expensive part of a FTTH network is the fiber along a street, and that is still needed for this technology as well.

Verizon claims to have plans to pass 30 million residents with the new technology. The pricing on the product is simple, at $50 for Verizon Wireless customers and $70 for anybody else. This technology will compete well against cable since the cable companies currently sell gigabit broadband at prices of $100 or higher. This product should also have faster upload speeds than cable broadband, but Verizon isn't talking yet about upload speeds. Any neighborhood that gets this technology ought to see some price competition – and if not price competition, at least expanded customer choice.

This technology doesn't make sense everywhere. It's a technology aimed at streets with single family homes or rows of small businesses. It's not going to handle apartment buildings where there are units that don't have a street-facing window. The technology doesn't work well in neighborhoods where utilities are buried since this needs to be on poles. This could be placed on light poles, but it's more expensive to get fiber to light poles than it is to utility poles. The technology won't work well on streets with heavy vegetation or streets that are highly curved. This technology will be hard to justify in places with neighborhoods with large lots and lower housing density, and this technology makes no sense in rural areas.

This is a new technology and the only company currently offering it is Verizon. Verizon is currently using a proprietary technology it developed. There are likely to be commercial vendors offering this technology, but that could still be some years away. It's too early to have any customer or industry review to talk about how it really works. However, if it operates anything like how Verizon claims, it could be a serious competitor to cable company broadband.

There are a few clear pros and cons for the technology:

Advantages:

- If speeds are near to a gigabit as claimed by Verizon, this is a robust technology. Basically, the technology replaces a fiber drop with a wireless connection.
- There is a definite savings if customers can self-install the technology, and that lowers customer costs by at least $200 per new customer.
- This eliminates the issue of building fiber drops to customers who then later drop the service and strand the drop investment. Any customer within range of a given transmitter can quickly be added or dropped from the network.

Disadvantages:

- There are going to be homes that can't use the technology. Any home with significant shrubbery or blocking hedges might not have a clear sight of the transmitter on the pole.
- The technology also works best in neighborhoods with straight streets where one transmitter can see multiple homes.
- It's hard to know how this affects long-term operating costs. We know that fiber drops can operate without problem for decades. This technology replaces those drops with pole-mounted wireless transmitters, and those units are going to wear out and have to be replaced. But fiber drops can be stranded for customers that drop the service. We'll have to see over time if this technology is more or less expensive than fiber-to-the-home.
- The technology is not yet available, but it's likely that it will be available eventually.
- Verizon uses licensed spectrum to communicate between street and customer. There are some unlicensed bands of millimeter wave spectrum, but it's too early in the use of that spectrum to know if there will be any interference using unlicensed spectrum.

Point-to-Multipoint Wireless

This technology is widely used in rural America today and it was recently estimated that there are at last six million homes connected to the technology. The technology has been around for almost twenty years, but recent breakthroughs in wireless technology plus an expansion of the spectrum being used has made this a technology to consider.

The wireless network used to deploy the technology typically consists of radios placed on towers or other tall locations and connections to homes and businesses are beamed wireless. There are several current frequencies of spectrum that can be used for this purpose and more that will be coming on the market in the next few years:

- WiFi: WiFi is short for wireless fidelity and is meant to be used generically when referring to any type of 802.11 network. The FCC has currently set aside two swaths of frequency for WiFi: 2.4 GHz and 5.7 GHz. In a point-to-multipoint network, these two frequencies are often used together. The most common way is to use the higher 5.7 GHz to reach the closest customers and save the lower frequency for customers who are farther away.

  In practical use, in wide-open conditions, these frequencies can be used to serve customers up to about 6 miles from a transmitter, although speeds can be slow at the far end of six miles. Nationwide many wireless carriers advertising speeds in the range of 25 Mbps. We know of networks using only WiFi that can deliver up to 50 Mbps for short distances. Such a network must have fiber built to the radio transmitters and can't carry too many customers on a given radio system.

  The FCC has recently approved the use of 6 GHz WiFi spectrum for both for indoor use and for use in outdoor point-to-multipoint networks. This new spectrum should significantly boost the bandwidth that can be delivered to customers. There are around 100,000 existing outdoor microwave links using the frequency and any ISP that uses the spectrum must work around existing deployments.

- CBRS Spectrum - 3.5 GHz: In 2019 the FCC approved the use of the 3.5 GHz spectrum band known as the Citizens Broadband Radio Service or CBRS. This is a huge swath of spectrum covering 150 MHz of spectrum between 3550 and 3700 MHz.

  The FCC has set aside 80 MHz of this spectrum for public use, similar to WiFi, and just concluded an auction for the remaining spectrum of 70 MHz as this report was being written. In all cases this spectrum is shared with military uses and the military will always get priority to use the spectrum.

  The spectrum also must be shared among users in the public space – something that will be monitored by authorized SAS administrators. The FCC named five administrators in the docket: Amdocs, CommScope, Federated Wireless, Google, and Sony. It's expected that the cellular carriers are going to heavily use the public bandwidth for delivering 5G, so in many places this spectrum might be too busy for using in a point-to-point application. However, in some rural markets the public spectrum could go unused, in which case it would be available to boost the speeds for fixed wireless broadband.

  The FCC is also making it a little easier for smaller companies to win some of this spectrum in the coming auction. The spectrum will be auctioned by county, one of the smallest coverage areas ever used by the FCC. There is hope that the bigger carriers won't pursue the licensed spectrum in rural areas since they can use the free spectrum. The FCC has provided bidding credits to smaller entities to help them bid against the larger carriers.

There are already a few rural carriers using the public portions of the spectrum for fixed wireless service. This spectrum sits in the middle between the two WiFi bands used for fixed wireless today and has great operating characteristics.

- White Space Spectrum: The FCC has been doing trials in what is called white space spectrum. This is spectrum that is the same range as TV channels 13 through 51, in four bands of frequencies in the VHF and UHF regions of 54–72 MHz, 76–88 MHz, 174–216 MHz, and 470–698 MHz. The FCC approved greater use of these frequencies for point-to-multipoint radios.

  The FCC auctioned a lot of this frequency in 2018, with the buyers ranging from the big cellular companies to Comcast. This was called an incentive auction, because TV stations that gave up their spectrum for a TV station got a share of the sale proceeds. We've been expecting the FCC to make this spectrum available for point-to-multipoint radios, but that hasn't yet happened.

  There are two possible uses for the spectrum. On a broadcast basis, this can be used to make better hotspots for places like coffeeshops. A 2.4 GHz WiFi signal can deliver just under 100 Mbps out to about 100 meters (300 feet). But it dies quickly after that and there may be only 30 Mbps left at 200 meters and nothing much after that. Whitespace spectrum can deliver just under 50 Mbps out to 600 feet and 25 Mbps out to 1,200 feet.

  There is also potential for the spectrum to extend point-to-multipoint radio systems. White space radios should be able to deliver about 45 Mbps up to about 6 miles from the transmitter.

  One issue to be worked out is that the FCC rules require the radios using this frequency to use what is called cognitive sensing. This means that an unlicensed user of the spectrum will be required to discontinue any requests that interferes with a licensed user. This might make the spectrum hard to use in markets where there is a mix of licensed and unlicensed users.

  C-Band Spectrum. On February 7, 2020, the FCC announced an upcoming auction in December 2020 of C-Band spectrum. This spectrum sits between 3.7 GHz and 4.2 GHz. The spectrum has historically been used by satellite companies for communication between satellites and earth stations. This is prime spectrum for 5G cellular broadband, but also could provide a huge benefit to fixed wireless providers in rural America.

  The FCC is expected to hold an auction for this spectrum in December 2020. FCC Chairman Pai is asking Congress to approve using 10% of the proceeds of the auction to provide the spectrum for rural broadband. At this early stage there's no way to know if Congress will do this or how it might work.

  The C-Band spectrum sits next to the recently released CBRS spectrum at 3.5 GHz. Just as additional spectrum benefits 5G, fixed wireless technology improves significantly by combining multiple bands of frequency. Rural carriers have been arguing for years that the FCC should allow for the sharing of spectrum. Proponents of rural broadband argue that two uses of spectrum can coexist since most 5G spectrum is only going to be needed in urban areas. They believe that such spectrum can be used in a point-to-multipoint configuration without interfering with urban

5G. The big cellular carriers have always been reluctant to share spectrum mostly because it causes them extra effort, so only the FCC, and in this case Congress, can make it happen.

There are several factors that are critical to the success of point-to-multipoint radios for delivering broadband to homes and businesses:

- Using Multiple Frequencies. The newest radios are much improved over radios from just a few years ago because they use spectrum bands including 2.4 GHz, 3.5 GHz, and 5.0 GHz. Radios will get even better if they include white space spectrum, CBRS spectrum, and/or C-Band spectrum. Having more spectrum matters because each frequency band has different operating characteristics in terms of distance and ability to penetrate obstacles. Having multiple frequencies available means an increased opportunity to find a good solution for each customer in the service area.
- Adequate Backhaul. The best fixed wireless coverage comes when there is fiber at the transmitter. Customer broadband speeds are diminished if a tower doesn't receive enough bandwidth.
- Terrain/Topology. There are often physical barriers like hills or heavy woods that can limit or block customer bandwidth. Most of these technologies require a line of sight, meaning that there must be a clear unimpeded visual path between the tower and the customer. Customers that live in valleys or behind hills might not be able to get service. If the signal has to pass through trees or other obstacles the strength of the signal is diminished. In towns, a home might block a neighboring home from receiving the signal. The signal can also degrade with rain or snowstorms blocking some of the signal.

There are a number of downsides for using this technology in town setting, which are described in the following list of advantages and disadvantages.

Advantages:

- It's hard to know if this is an advantage or disadvantage, but the latest technology can deliver up to 100 Mbps broadband to customers that are within a few miles of a tower. In Falmouth that's not as fast as Comcast, but it's a lot faster than Verizon.
- It's likely that speeds will get a little faster, but this is not likely to ever be a technology that will deliver 200 Mbps, due to constraints of physics for the various spectrum bands being used.

Disadvantages:

- The biggest disadvantage is the maximum speed of the technology. In ideal conditions point-to-point wireless can deliver about 100 Mbps broadband. That would not compete well with Comcast, and within a few years will feel slow.
- There is an upward limit on how many customers can be served from a single tower. At best a tower can handle about 600 customers. This means in Falmouth it would take dozens of towers to reach everybody.
- The second big disadvantage is that the fastest speeds can only be delivered for about two miles, with speeds a little less at three miles and much slower after that.
- In a city environment, a configuration of dozens of towers would create interference between towers and would degrade performance for everybody.

- The frequencies most often used are unlicensed, which makes them generally open to interference. Further, some of the newer bands of frequency must defer to coverage by the government, the military, or licensed spectrum holders.

The bottom line is that the technology doesn't fit Falmouth. It might be possible to still incorporate the technology into a larger broadband infrastructure. For example, there might be a few homes in town that are tremendously expensive to reach with fiber and this might be a reasonable alternate. There are also a few ISPs that are using the technology to provide broadband to boats that are within a few miles of shore. From a recreation standpoint that would be a community advantage.

Why We Chose Fiber

After considering the above technologies, we finally chose GPON fiber as the technology that would best fit for bringing broadband to everybody in Falmouth. Following are the primary reasons we chose fiber:

Wireless Technology. The best commercially available wireless technology that could be provided today using unlicensed spectrum can deliver perhaps 100 Mbps download broadband. That's not a bad broadband product today, but it doesn't fit Falmouth for the following reasons:

- This matches the speed of the basic bandwidth product offered by Comcast but cannot be made to deliver faster broadband.
- In a town setting even the 100 Mbps speeds might be troublesome to achieve. The FCC has set aside a lot of free spectrum in rural areas that cannot be used in towns, and without the extra spectrum the speeds would likely be slower.
- At best, the future potential of the technology might eventually be 200 Mbps – so this product is not future-proofed.
- Biggest downside is that perhaps 200 homes can be served from a given transmitter. In a town like Falmouth this means the need for a lot of antennas.
- The technology also requires line of sight between transmitter and customer – it's hard to envision designing a network that could serve everybody because of the topography and the trees in many parts of the town.

Fiber-to-the-Curb. This is the technology that builds fiber on each street but then delivers bandwidth into the homes using wireless technology. We didn't choose this technology for the following reasons:

- Today the only company deploying this technology is Verizon, using proprietary equipment. However, it's likely that some vendor will eventually make this available to everybody else.
- Today this is more costly than building fiber. This requires building fiber everywhere, so that cost is the same. This also involves putting electronics on poles at and at the home to deliver broadband – which is currently a lot more expensive than just putting electronics at the home. But over time this could become cost-justified.
- This requires line-of-sight from street to homes. This means homes with heavy foliage might be hard to serve. You can guarantee bringing fiber to everybody – there will be homes that this technology will not reach.
- This is also a challenge on streets where utilities are buried. The transmitters (and the fiber that fed them) have to somehow be bright to light poles or other structures.

- For now, this technology delivers perhaps half the bandwidth as fiber-to-the-home, but that could get better over time. However, this technology may never take the next leap forward when fiber electronics are upgraded to 10 gigabits to each customer.
- This technology might eventually be a complement to fiber and fiber network owners might use wireless instead of fiber drops in some instances. But that easy interchangeability is probably a decade or more into the future.

So Why Fiber?

- Fiber can deliver a symmetrical gigabit product to every customer in the community today. No other technology today can match that. The network we've designed would also allow large customers to get 10 gigabit or 100 gigabit service today.
- Fiber technology evolves over time and 10 gigabit PON technology is already available. For now, it's a little more costly than 1 gigabit PON, but that price difference should disappear over the next few years. Vendors are already testing 40 gigabit fiber in the lab, which will probably hit the market in a decade. No other technology will ever be capable of the nearly unlimited speeds possible on fiber. Fiber is the gold-standard for being future-proofed.
- PON fiber technology is a mature product and can be operated without taking a technology risk.
- Since fiber is delivered to customers via wire, there are no customers in the town that can't be reached by a fiber network.

B. Network Design

We finally selected fiber-to-the-home as the only reasonably affordable technology that could bring fast broadband to everybody in Falmouth.

Passings

The telecom industry uses the term passing to mean any home or business that is near enough to a network to be considered as a potential customer. We used the town's robust GIS system to identify structures and potential customers. Our engineers settled on the following as the count of potential passings for the study.

Full Time Residences	14,232
Seasonal Residences	7,800
Business Passings	2,000
Total	24,032

The basis for each of these groups of passings is as follows.

- Residential. This includes single family houses, including apartments, condominiums, townhouses, etc. In Falmouth, the vast majority of residential passings are single family homes, although there are some apartments, townhouses, and condominiums.
- Seasonal Homes. The volume of seasonal homes creates a challenge for a broadband business plan. Most seasonal homes don't want to pay for broadband for the whole year.

- Businesses. This represents standalone businesses that could purchase broadband. We have not reduced this count for the businesses that use OpenCape since those businesses might eventually be served by a new fiber network.

Miles of Fiber Construction

Our engineers determined that the needed network requires 460 miles of fiber construction, as follows. There is a map showing the location of aerial and buried fiber construction in Exhibit III.

Aerial Fiber	390
Buried Fiber	70
Total	460

This does not build fiber on every street in the town. We avoided 92 miles of fiber construction that run through undeveloped neighborhoods, that follow utility roads, use bike paths, or for streets where there was a shorter way to reach homes.

Design Considerations

A FTTP network would bring fiber to homes and businesses. There are several key factors to consider in the design of a rural fiber network:

- Whether to use buried fiber, aerial fiber, or some mix of the two.
- The specific electronics design philosophy.
- Redundancy
- Connectivity to outside world

Fiber Design Considerations

Aerial versus Buried Fiber. The first decision that has to be made for building fiber is whether to put the fiber on existing poles or to bury it underground. There are a few key issues that usually drive this decision:

- Cost. If there is a big cost differential between the two construction methods, most fiber overbuilders will choose the lowest cost option, assuming it's a valid option. A general rule of thumb when designing a fiber network is to try to bury fiber where other utilities are buried and to try to construct on poles when other utilities are on poles.
- Maintenance. Aerial fiber is subject to damage from weather. In Falmouth that means the occasional nor'easter and ice storms. The owner of an aerial fiber network must be prepared to make repairs after storms and also face the occasional major outages that follow a bad storm. However, buried fiber is not without issues. The primary cause of outages for buried fiber is fiber cuts due to somebody excavating in the rights-of-way. The primary fiber cuts in towns usually comes from mistakes made by other utilities. There is a process for anybody working underground to locate existing utilities, but invariably other utilities or their subcontractors will shortcut the process to locate the fiber before digging.
- Access. There are circumstances where it's impossible to use one of the construction methods. For example, both municipalities and electric cooperatives are not required, by federal law, to allow fiber builders to use their poles. CCG Consulting is aware of one case in West Virginia

where an electric cooperative did not allow a competitive fiber builder to use their poles. Private landowners are not required to grant rights-of-way for fiber. This means owners of private roads can block aerial or buried fiber. Since most places want fiber, we don't see fiber kept out of many neighborhoods – but we have seen private subdivisions prohibit fiber if it means digging up their private streets.

- Impediments. There are special circumstances that can make it more expensive and time-consuming to build fiber. For example, it's often expensive and time-consuming to gain the needed rights-of-way to build fiber across bridges, under railroad tracks, or under freeway overpasses. There are often complicated rules that must be followed to build fiber through state and national parks and forests. We know of states where the Department of Transportation adds burdensome rules to build along state highways.
- Rights-of-Way. Most public roads already have a defined public right-of-way along the sides of a road. Such areas are usually designated by state laws or local ordinances that specifically define the right-of-way. Utilities are allowed to construct in existing rights-of-way, but only to the extent that they do so without harming existing utility infrastructure. Rights-of-way become an issue when building on private lands or roads.

Considerations for Burying Fiber. Buried fiber is constructed using several different methods. These are described in more detail later in this section of the report.

- Trenching. With trenching, a trench is excavated alongside of the road and hardened fiber is either laid into the trench or else conduit is placed in the trench and then fiber is pulled through.
- Direct Buried / Plowing. In places where the soil is soft and there are few rocks it's possible to use a heavy vehicle to "plow" fiber or conduit directly into the ground.
- Boring. With boring, a machine bores a horizontal hole through the earth at the suitable depth and a conduit is then pulled through the hole. Fiber is then pulled through the empty conduit.
- Microtrenching. The newest construction technique is microtrenching, where a one inch wide and 8 to 12-inch deep trench is cut into the street pavement.

The soil conditions vary throughout the town, but the soil condition in much of the town are considered to be at least somewhat rocky – a condition that adds to the cost of burying fiber. There may be existing roads where the substrate was excavated during the initial road construction, and in such places, it might be relatively easy to bury fiber. However, any buried construction in some parts of the town is likely to hit some rock – something that can easily quadruple the cost per foot to bury fiber.

Considerations for Aerial Fiber. There are a few issues that affect using aerial fiber, and it's not always the cheapest or easiest alternative.

Make-Ready. The most important aspect is something that the industry calls make-ready. There are national electric codes that define the spacing between the wires of different utilities. In rural areas most poles will already be carrying electric wires and telephone wires. There also could be existing fiber on some roads that is used for some purpose other than serving households and businesses.

The national electric codes include two important requirements that can affect the cost of getting onto poles. There must be sufficient space between the different providers on a pole. For example, a new fiber must be at least 18 inches above the cable below it (be that a telephone cable or wires from a cable TV company). There are also minimum clearance rules for the lowest

that any cable can be above ground for the safety of those beneath the pole. These rules are in place to provide safety for technicians that work on cables during and after storm damage.

When there is not sufficient room for a new wire, then an industry practice called make-ready is invoked. Make-ready is the process of moving the existing wires on poles, as needed, to make room for a new wire. The make-ready can be somewhat simple, such as moving an existing wire by a few inches, or it can be major, such as having to move all of the wires on a pole or possibly even replacing the pole with a taller one.

Make-ready is expensive for two reasons. First, the new attacher has to pay to make all of the needed changes, even if the old wires were out of specification. Second, there can be big time delays while other providers using a pole make their changes to make room. Make-ready can be so expensive that in some cases it's cheaper to bury a fiber rather than to deal with the cost and delays doing the make-ready to be able to add a new fiber.

One Touch Make-Ready. The FCC passed new rules that went into effect in May of 2019 that should make it easier to get onto poles. The new rules apply only in the thirty states that follow FCC pole attachment rules. Massachusetts has asserted jurisdiction over poles and this order doesn't apply. However, almost every state is adopting similar rules, so this is worth discussing.

The most significant change in the rules is a new classification of poles as either simple or complex make-ready. The order defines how to make this classification. In real life practice, the new attacher will suggest this determination, although it could get overturned by the pole owner.

There are new streamlined rules and timelines for completing the make-ready on simple poles. If the pole owner is unwilling to commit to fixing simple poles in the needed time frame, the new attacher is allowed to make the changes after properly notifying the pole owner. The new attacher is free to rearrange any existing wires as needed, again after having properly notified all of the parties. These new rules eliminate situations where a pole owner refuses to cooperate with a new attacher, as happened in a few cities where AT&T fought Google Fiber. Something to consider is that the rules require using a make-ready contractor that has been pre-approved by the pole owner – but there are ways around this in some circumstances.

These new rules can mean a big improvement in construction schedule where the needed changes are for simple poles. That would be poles where wires need to be moved to make room for the new attacher. However, the new rules are not necessarily faster for complex poles. Those are poles where the make-ready could cause damage to existing wires or where the old pole must be replaced. The make-ready process for complex poles has always been slow. The new rules tighten up time frames a little, but the time required to get onto a complex pole can still take a long time.

For complex poles the process will still allow the existing wire owners to work sequentially – meaning that they can invite each existing company on the poles to do their own work, one company at a time. This coordination has to be scheduled by the pole owner. The process could still take six months even if done perfectly. The new rules don't seem to provide a solution for when the pole owner or the existing attachers drag their feet on complex poles. Other than some

slightly improved timelines, the work on complex poles looks to still be as dreadful and slow as the old make-ready rules.

The Components of a Fiber Network

A fiber optic network that is designed to serve large number of customers generally has several major elements:

- Feeder Fiber. This is the fiber that starts at the core of the network and stretches to the various neighborhoods to be served.
- Distribution Fiber. This is the fiber that generally is then build up and down streets to pass each potential residential or business customer.
- Drop Fiber. This is the fiber that is built from the street to reach the premise of each customer served by the network.

Microtrenching

The RFP asked us to specifically address microtrenching. This is a relatively new construction technique that involves digging a narrow trench a few inches wide and a foot or so deep. These trenches can then hold multiple conduits for fiber.

The positives for this technique are significant, mostly dealing with cost. The alternative to microtrenching for traversing sidewalks, driveways and parking lots is boring. The boring technique involves digging a somewhat deep hole of 3 – 5 feet and then using equipment to bore sideways underneath the concrete. There is significant labor involved in the process and there is always a danger of hitting other utilities, particularly when boring away from public rights-of-ways.

But there are significant downsides. Probably the biggest downside is that the trench is a lot shallower than other kinds of underground fiber construction. Microtrenched fiber will be a problem any time a street is being repaved. When it's time to repave a street the typical construction process is to excavate between 18 inches to three feet depending upon local soil and substrate conditions. During a street repaving the fiber will be cut and removed and likely to be unable to be quickly replaced – meaning long outages for customers living along streets undergoing repaving.

Many vendors are recommending microtrenching for crossing big parking lots, campuses, or other private facilities. The question to ask is if it's realistic to think that some portion of the fiber won't be excavated for some unrelated purpose long after nobody remembers exactly where the fiber is at.

The most pressing issue with microtrenching is the likelihood of fiber being cut by other utilities working on problems like gas line or water main repairs. To use the example of my own city of Asheville, North Carolina there is typically a new cut made in the street somewhere in the city every day by crews digging to reach gas or water line problems. If there was microtrenched fiber everywhere in this city, then every cut from other utilities could result in a fiber cut – an outcome that customers would find to be unacceptable and that would result in significant costs for an ISP.

Microtrenching has also gotten a bad name in a few deployments. Google Fiber used microtrenching in Louisville Kentucky after they were unable to get access to poles. Within a year after construction the fiber began popping out of the microtrenches all over the city. Everybody I talked about the issue

blamed this on ice heaving. While a micro-trench is sealed, it's likely moisture somehow got into the microtrenches in Louisville. The first freeze would create tiny cracks, and with each subsequent freeze, the cracks would get a little larger until the trench finally fills up with water, fully freezes and ejects the fill material. The only way to stop this would be to find a permanent seal that never lets in moisture. That sounds like a tall task in markets where there is a daily freeze and thaw during the winter. Google Fiber ended up walking away from the Louisville market after the company had spent millions constructing fiber using microtrenching.

The Louisville deployment was the first time we've heard about microtrenching being deployed on a large scale and it was a disaster within a year. But even had the microtrenches not have failed due to ice heaving, the network was going to have constant outages caused by the street cuts that happen routinely in every city.

There are major metropolitan cities that have considered allowing microtrenching for sidewalks. That avoids the issue of losing fiber when routine cuts are made into street asphalt or when a street is repaved. But sidewalks are also routinely cut, and it would be an ISP nightmare if every sidewalk cut resulted in a fiber cut and outage.

Even if assuming that microtrenching can be done without ice heaving there are two big downsides to microtrenching. The first is routine fiber cuts. A normal buried fiber network in a city might only experience a handful of fiber cuts per year, mostly done by some other utility. If fiber is buried at 3 feet below street level, there aren't a lot of opportunities to cut the fiber. A city with widespread microtrenching might see a fiber cut almost daily as cuts are made in streets to make repairs to other buried utilities. A microtrenched fiber will be only 8-12 inches below the street surface, and so any cuts in the asphalt have a high likelihood of cutting fiber. This means pockets of customer taken completely out of service on a daily basis. In many cases, a cut made for a gas or water problem might stay open for days, or even weeks, and that means prolonged outages for affected customers.

Even worse is the consequences of repaving a street. In that process the street is generally excavated to a dept of 2 – 3 feet and then refilled and repaved. The repaving process could result in a fiber cut that lasts for many weeks.

Cities have standards about burying utilities are various depths for a reason. Deeply buried utilities are rarely disturbed, particularly from routine street cuts that are a part of urban life. Microtrenching falls outside of that norm and microtrenched fibers are highly likely to be routinely cut.

Cost Differential for Aerial, Buried, and Microtrenched Fiber

The biggest cost component of deploying fiber is labor. From a material cost perspective, the costs of materials are similar between aerial and buried construction. Buried construction costs include the cost of conduit, which can be between $1 and $2 per foot of added costs. However, there are also added costs for aerial fiber construction including the cost of pole mounting hardware and the cost extras like shielding against squirrel damage.

Labor costs vary around the country due to differences in hourly wages, but in general the labor cost of the various kinds of construction can be compared on a per foot basis. Following are the different types of fiber construction mostly seen in a market.

Trenching. This is buried construction where a ditch a 12-inch wide ditch is dug in the street or along the side of the road, the fiber is placed in the open ditch, and then the ditch is refilled. This is generally the most expensive type of construction, particularly if ditches have to be dug in city streets – the cost of digging and then replacing asphalt can be costly. Trenching is also disruptive and city streets must be blocked off until a new surface has been poured and cured in the ditch. Trenching is typically used only in situations where other methods of construction won't work. In a typical urban build, you would expect less than 1% of the total construction to involve trenching.

Boring. Boring is the most common method of burying fiber. In boring, a "pothole" is dug in the street, which means a hole approximately 2 feet by 2 feet. A boring machine is inserted into the empty pothole and laterally drills a hole through the substrate of the street. Empty conduit is then pulled through the freshly dug hole. Conduit is flexible and durable plastic tubing. Eventually the fiber building will push or pull fiber through the empty conduit. Boring costs can vary widely depending upon the composition of the substrate. If roads were originally dug out to a three feet depth when constructed, then it's relatively easy to bore through an area. Boring is much harder and expensive, and sometimes impossible in areas where there is native rock close to the surface of the street. There is often an intermediate condition called cobble the substrate under the street includes boulders that were put back into the hole when a street was repaved.

Plowing / Direct Burying. In rural areas where there is an unpaved shoulder along roads, a common construction method is to direct bury the fiber into the ground. This involves using a heaving truck that plows a furrow in the ground, just as would be done by a tractor on a farm. The plow pushes fiber into the ground at the same time that it buries. There is most often not even any follow-up construction since the plowed furrow naturally closes after the plow passes. Direct burying is rarely used in cities, but there might be a few roads in Falmouth, particularly along the ocean where this could be done for short stretches.

Microtrenching. This was described just above in the report and involves digging a 1 inch wide by 8- to 12-inch-deep trench in the street, putting in the fiber, and then refilling and sealing the hole.

Aerial Construction. The typical aerial construction of fiber includes three phases. First is make-ready, where work is done to make the poles ready for construction. This might mean tree trimming. It often involves having to move wires on existing poles to make room for a new fiber. In the worse cases, if poles are too full of wires it means replacing some percentage of the poles with taller poles.

Once the make-ready is done, the most common construction method is to install a "messenger" wire on the poles. This is a sturdy metal wire. Finally, the fiber is lashed onto the messenger wire.

Comparison of Construction Costs.

Again, these costs are illustrative, but come from real life examples. These costs can vary in a given community due to local conditions and can vary locally depending upon local wages. The following figures represent just the labor component of construction. These costs also account for the effort to splice in local access points where customers can be connected to the fiber.

Trenching in city streets	$50 - $60 per foot

Trenching in rural areas	$15 - $30 per foot
Normal boring	$20 - $30 per foot
Boring through rock	$30 - $50 per foot
Plowing	$ 8 - $15 per foot
Microtrenching	$10 - $15 per foot
Aerial construction (no make-ready)	$ 5 - $ 8 per foot
Aerial make-ready (may vary by street)	$ 5 - $25 per foot

Our Estimated Cost of Fiber Construction.

We've estimated the all-in cost for buried fiber construction to be $135,000 per miles. This price was derived by interviewing Open Cape and others familiar with the cost of burying fiber on the cape. This price includes:

- Construction labor. We've assumed that 10% of the construction in the town would mean drilling through rock. Many of the neighborhoods with buried fiber are on hills where the rockiest soils in the town are located.
- Fiber materials including fiber and conduit
- Installation of fiber access points for connecting fiber to customers. For buried fiber this usually means pedestals (small cabinets in yards that give access to the fiber) or handholes, a buried version where the access is in a cylinder buried in yards.

We've estimated the all-in cost for aerial fiber at $60,000 per mile. This includes:

- Pole make-ready. This is the effort required to make existing poles ready to accept a new fiber. We've estimated this to cost $25,000 per mile. Some of the make-ready cost could be avoided if the town can get the other utilities to trim trees before the start of fiber construction. This is described in more detail immediately below.
- Normal construction labor.
- Fiber materials including access points. For aerial construction, the access points are mounted on poles and pre-spliced so that it's easy to connect a fiber drop to connect to customers.

The $60,000 cost does not include engineering, permitting, construction management, or any construction contingency. Our analysis adds these costs to the cost of the fiber construction.

Are There Any Strategies for Lowering Construction Costs?

A lot of money can be saved during fiber construction if somebody is comparing the cost of these methods for each street in the construction area. If construction companies are allowed to operate unsupervised, they tend to choose the construction method that makes the most money – for example, a crew might push through with boring through rock when there might be a cheaper alternative. A crew might tackle expensive aerial make-ready when it would be cheaper to bore.

We observed that residential streets throughout the Falmouth have a lot of trees that would interfere with aerial fiber construction. A significant portion of our estimated make-ready cost is to undertake this tree trimming as part of the make-ready process. In Falmouth the electric company has done a good job of trimming trees along major roads. But in residential neighborhoods the tree trimming has either fallen behind, or else the electric company only trims to make sure its own wires are freed of the possibility of storm damage.

However, tree trimming is normally the responsibility of existing utilities. The specific responsibility for paying for tree trimming varies by locality. In most of the country the pole owner, which in your case is mostly the electric company is responsible for making sure that tree trimming is kept up to date. Tree trimming is important, because streets with poorly trimmed trees can result in a lot of damage and outages after a bad storm.

If the town were going to undertake building a fiber network, ideally, you'd want to have all the trees well-trimmed before starting construction. If that doesn't happen, then the cost of trimming would have to be borne by the fiber construction project. It sounds like there might be local issues with getting all of the existing utilities to pay their share of tree trimming, but those utilities should be bearing this cost.

Electronics Design Considerations

There are several key considerations when designing the electronics for a last-mile network. The electronics design is key because in can affect how the network is constructed.

- One of the first decisions to be made when looking at a fiber network is determining if you want to use active or passive fiber electronics.
- Another important decision is whether to centralize or distribute the electronics in the network.
- Another decision is the topology of the network deciding between a star versus a ring configuration.
- A final design consideration is to determine whether to use distributed splitter locations or local convergence points for splitter locations.
- A fiber design should also account for the need for future capacity.

Choice of Technology. We elected to design with passive GPON electronics. The advantages of this technology were discussed above. From cost perspective this technology made the most sense in Falmouth because it decreased the size of the fiber bundles in each neighborhood. The electronics for a passive network are also less expensive since this is the primary technology used in the world to deliver residential fiber. In today's market, the cost of using active Ethernet adds at least 15% to the cost of the network electronics.

However, our design also allows for the use of active electronics and every fiber is designed with extra fibers that could be used to bring a dedicated fiber signal up to 10 gigabits to a customer that wants large bandwidth. Effectively, the network design incorporates the best of both fiber technologies.

Distributed Design. Since Falmouth covers a large geographic area, we elected a distributed fiber network design. We subdivided the town into nine construction sectors. In many cases these geographic divisions were based upon the topography of the town where each of the sectors is bounded by geographical barriers.

There were a few reasons to choose the distributed network:

- The so that no customer was more than 12 miles away from neighborhood hut. This distance limitation means 12-miles of fiber along a road, not a 12-mile circle.
- This design makes it easier to activate neighborhoods as the fiber is built. Once one of the nine nodes is completed service can be offered to everybody in that area.

- A distributed network also allows for more redundancy in case a fiber is cut. This will be discussed more below.

We elected to utilize large cabinets for each of the nine neighborhood hubs. This could be upgraded to huts where employees could work indoors by adding perhaps $30,000 to the cost. The huts come as prefabricated units that are already filled with racks and electronics. Each hut includes batteries that provide up to eight hours of emergency power in case of a power outage. Each hut can also be easily connected to a portable electric generator in the case of a prolonged power outage. The huts house the OLT, which are the core electronic platform for communicating with customers. This acronym and the technology will be explained more below.

One of the design decisions to make with a GPON network is the number of customers to place on a single PON. The technology allows up to 64 customers to share a single feeder fiber. We elected to limit each neighborhood PON to 32 customers. The primary reason for this is to ensure that each customer can be provided with a gigabit broadband product if desired. There is enough bandwidth on a single PON (2.4 gigabits download) that there is almost always a gigabit of bandwidth available to any customer at a given second. It's unlikely that most PONs will ever carry 32 customers, because that would require streets where every home subscribes to fiber – but it can happen. This study uses the assumption that the average penetration rate is likely to be between 50% and 60%, and if that was the case, then the neighborhood PONs would be 50% to 60% full on average for the 32 slots possible.

Distributed Splitter Design. We elected to use a distributed splitter design. A splitter is a passive device that splits one fiber to connect to 32 fibers to reach customers. This is the "passive" device in a GPON network because there is no power needed at locations where the fibers are split. The primary advantage of using distributed splitters is that the number of fibers needed to reach each residential street is smaller. If the splitters were all at the neighborhood hut, a fiber would need to go from that hut to each home and business in the sector.

Redundancy. When possible, a good network fiber design should include some consideration for fiber route redundancy. This can most easily be accomplished by the use of fiber rings that include self-healing electronics. A fiber ring is just what it sounds like – this is fiber built to complete a full circle (but that doesn't have to shaped like a circle). Fiber rings are most normally part of the feeder fiber network so that cutting a fiber feeding one neighborhood doesn't knock out service for other neighborhoods. But redundant rings can also be built into distribution fiber serving homes. This is usually only done when there are specific neighborhoods or large business customers willing to pay extra for redundancy.

The big advantage of a fiber ring is that the fiber does not drop out of service from a single fiber cut. The electronics on a ring send all data transmissions in both directions around a ring, meaning that a fiber cut cannot disrupt the flow in data across the ring. In this design we put all of the nine neighborhood cabinets on a fiber ring. This means that if any fiber is cut between the huts that all of the huts will continue to function.

Fiber cuts are inevitable, so the money spent on redundancy pays dividends in the long run. Adding fiber rings and redundancy adds costs because this configuration requires an additional set of electronics to light the redundant ring. This uses a different technology than the fiber used to serve customers. The

electronics needed to light the ring require power, which is why these electronics are all included inside the neighborhood cabinets.

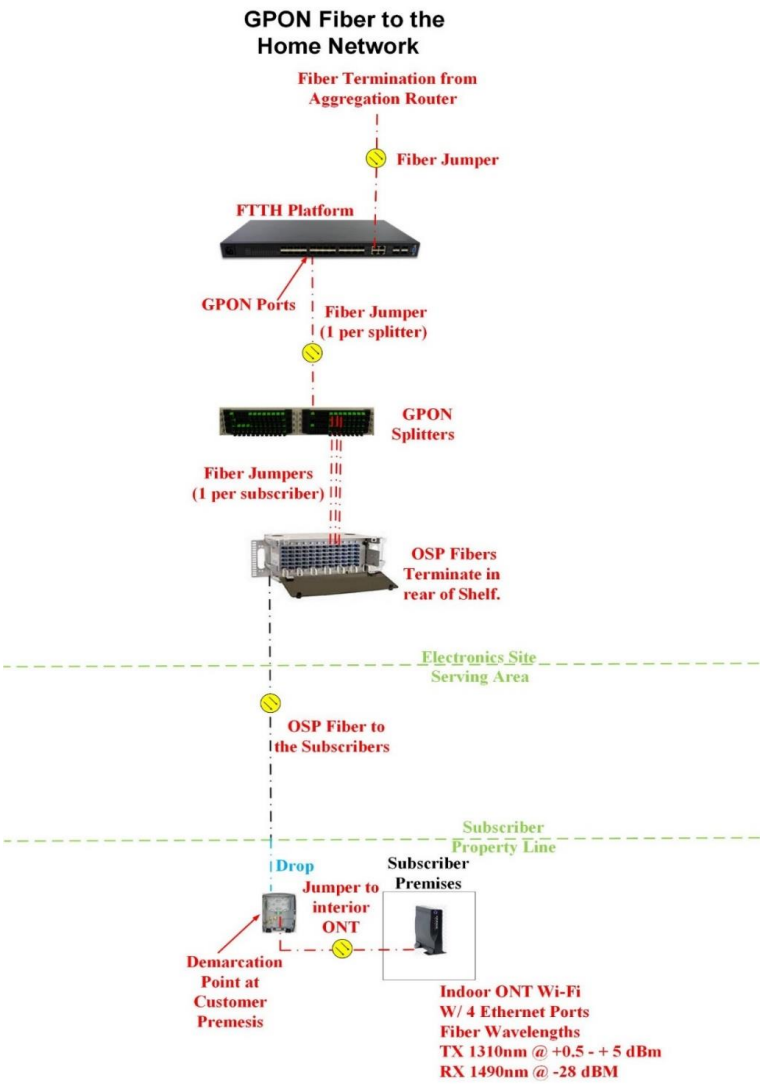
Future Growth. Our design also anticipates future growth. A fiber network might last 50 – 70 years, so the network needs to be robust enough to add on more homes or new neighborhoods in the future. The design provides a 20% buffer to account for future growth. That quantity of extra fibers would be sufficient to handle almost any amount of extra growth. In fiber networks, extra capacity can always be added by beefing up electronics to a higher capacity – so the extra fibers are in place to reach new homes and new neighborhoods. If any of the new neighborhoods grew really large, the combination of extra fibers and faster electronics could handle any growth scenario imaginable.

Connectivity to the Outside World. Every local fiber network must be connected to the outside world where connections are made to the Internet. Falmouth is lucky in that OpenCape has already created the connections from the Cape to Boston and Providence. However, to some degree the entire Cape is somewhat vulnerable to broadband outages since there are only two routes off the Cape to reach the Internet hubs in Boston and Providence. Should a bad storm ever cut both fibers leaving the Cape, the Internet to the whole Cape would go dark.

OpenCape is not the only option for connectivity to the Internet. These same connections could be purchased from Verizon or Comcast, but likely at a higher cost. We've been told that all web traffic leaving the Cape follows the same roads, so there might be no extra safety from buying a connection from the big ISPs – the fibers go along the same roads and might even be in the same fiber bundles.

Components of a GPON Network

The following diagram shows the configuration of the network starting with one of the neighborhood cabinets and ending at a customer.



Core Hub and Connection to the Internet

In Falmouth, any one of the neighborhood cabinets could act as the primary core hub. This would be the hub where a connection is made to reach the internet. Most ISPs would set the core hub nearest or at the location where the employees and technicians work.

We have included a typical map of the backbone network for Falmouth in Exhibit III. This map shows the location of electronics hubs, with one hub in each voting district. For our design purposes we placed each cabinet at the address for voting in each district – but the cabinets can be placed anywhere. The map also shows a theoretical path of the backbone fiber that connects the cabinets. Note that the routing of the backbone could use other streets and that this map is showing only one possibility for the backbone fiber routes.

If an ISP decided to locally provide ISP functions, such as DNS routing to the lnternet, those servers could likely be located near to the core hub. However, an ISP that is already in business probably would not locate these electronics in a new network such as Falmouth. Many ISPs outsource these functions, which are provided from some remote data center.

The core hub would likely be the locations where technicians can connect into the network through network management servers that give technicians access to look at the network. This software gives the technicians the ability to troubleshoot problems and to activate customer products and services such as broadband speeds, telephone service, smart-home services, or other future services.

Optical Line Terminal (OLT)

The electronics used to light the fiber to customers is called an optical line terminal (OLT). This is the top piece of electronics shown on the diagram. Our design places an OLT cabinet in each neighborhood. A typical PLT cabinet is shown below. These range in size from four to six foot tall. These cabinets can be placed outdoors, and if so it's good to put them at secure locations behind fencing. Communities that build networks often place the cabinets inside city-owned buildings. OLTs must be powered, so each cabinet contains equipment needed to provide power, including batteries and other back-up power to keep the network functioning in case of a power outage.

An OLT functions using circuit cards, each of which can serve between 128 and 256 subscribers. Multiple cards can be installed in each OLT chassis and multiple chassis can be installed in each cabinet site if ever needed, meaning that it's easy to scale the network to accommodate future growth. There are multiple vendors that provide an all-inclusive PON solution combining the cabinet and FTTH equipment solution. All vendors meet industry standards and all of them are priced similarly.

PON Splitters

The next component on the network diagram above is a PON splitter. This is a device that can "split" one fiber in order to connect up to 32 customers. On the diagram you can see that there is only one fiber between the OLT and the GPON splitter. Our design places splitters in small cabinets scattered throughout neighborhoods. This design saves the need for significant fiber one fiber coming into a splitter cabinet can serve up to 32 customers. The splitters do not require power, which is why they are referred to as passive. The splitters can be located anywhere in the network where fiber splits are needed to reach customers. Our design would place the splitters as close to customers as possible.

PON Cabinet

If the final design places several splitters in the same location, it's often sensible to install a PON cabinet. The purpose of this device is to neatly arrange and manage the fibers coming into or out of the splitters to make it easy to identify which fiber serves which customer. The primary purpose of a PON cabinet is to accumulate customer connections at strategic points with the goal to minimize the size of neighborhood fibers. Splicing costs increase with the size of fiber bundles, and a good way to hold down costs are to arrange field splitters and PON cabinets to minimize the size of fibers. The need for and location of PON cabinets would be determined as part of a detailed fiber plant design.

Below are two examples of PON cabinets. The first is a large cabinet that would contain enough splitters for a large neighborhood.

More typically, smaller PON cabinets are used, as shown in the following picture. Distributing multiple smaller cabinets maximizes the savings on fiber construction. These cabinets can be placed on the ground, as shown, but also can be mounted on poles where there is aerial fiber.

Fiber Drops

Customer fibers start at PON cabinet sites or small splitter cabinets and reach to every potential customer location. The initial fiber design builds a distribution fiber for every potential customer, plus extra fibers to serve new homes that are built.

To connect a customer to the fiber network, a fiber drop is built from the street to connect to a customer premise. The customer drop is a typically two-fiber cable. Fiber drops can either be fusion spliced to the distribution fibers, and these splices are done inside of a splice case. This is a device that is mounted on poles for aerial fiber or places into pedestals or handholes for buried fiber. The fiber intended for a given customer is terminated at these splice cases and it's relatively easy to splice a drop into the appropriate fiber.

A newer technology replaces a splice case with a connector device that allows drops to be quickly plugged place for the fiber drop. These pre-connectorized drops can save significant installation labor time and the drop snaps into place much like Ethernet cables snap into computers and other devices.

At the Customer Location

The piece of customer electronics used to serve customers is referred to in the industry as an ONT (Optical Network Terminal). This is an electronic device that contains a laser which communicates with the OLT in the neighborhood cabinets. The ONT receives optical light signals from the fiber network and converts the signal to traditional Ethernet on the customer side of the device.

Originally the ONTs were only placed on the outside of buildings in a small enclosure and powered by tapping into the electricity from near to the power meter. But today there is also an ONT that can be placed indoors and that is powered by plugging it into an outlet, much like the cable modems used by cable companies. The cost of the two kinds of units are nearly identical and so the study doesn't choose between the two types of units.

Some companies still put the ONT on the outside of the home to give their technicians 24/7 access to the units. Other providers are electing internal units since they are protected from the weather. The industry is split on this choice, but it appears that internal units are becoming the most predominant choice for new construction. One of the major contributing factors that favors indoor ONTs is that ISPs are tying the ONTs to indoor WiFi routers to provide good wireless connectivity within the home.

ONTs are available in multiple sizes that can be categorized into units designed to serve homes and small business and units designed to serve large businesses. The study assumes that the smaller unit will be used for most customers, including most small businesses. These small ONTs provide for up to four Ethernet streams, which is sufficient for most customers.

Historically, many FTTH networks have been designed with battery back-up for the ONT. However, many small fiber providers have stopped providing batteries. The batteries were historically installed to power telephones in the case of a power outage at the home. Old copper phones received power from the line and could be used when the power was out. However, there is no power in a fiber and thus a battery backup is required to maintain phone service. In 2015 an FCC ruling declared that every voice provider must offer a battery back-up solution for customers that buy telephone service that is not delivered on copper. That ruling said that fiber ISPs only have to make these units available and that customers could be charged the full cost of the unit.

Regardless of the type of ONT (indoor or outdoor), it will be necessary to drill through the side of the home to bring wiring into the premise. ISPs have widely differing ideas on the best way to do this – but most ISPs look for the installation method that requires the least amount of work inside of the customer premise. In the early days of GPON technology there were separate wires run from the ONT to connect to computers, TVs, and telephone wiring. Today, most devices are connected using WiFi, and so the effort to connect to inside wiring is greatly reduced or even eliminated in most homes.

Multi-Dwelling Units (MDUs)

There are just over 1,000 living units in Falmouth that can be characterized as being part of multi-swelling units, meaning that are apartment buildings, condominiums, or townhouses. Many of the MDU units in Falmouth are arranged in such a way that each living unit could be reached as if it was a single-family home. From a broadband perspective, ISPs treat duplexes, small apartment buildings, and townhouses as individual units and use the same electronics and same installation techniques as other homes.

Structures larger than six to eight units must be constructed and served differently. For example, instead of building multiple drops to reach each unit, there would more typically be single larger fiber drop terminated to the inside or outside of an MDU building. Conduit and fiber would then be routed from this splice point to reach each individual unit. There are a number of issues that ISPs face when trying to serve larger MDUs. Following is a discussion of the primary kinds of roadblocks that we see in the MDU market. This is not an all-inclusive list and there will be some MDUs with issues not listed here, but this list should cover most of the kinds of issues encountered with bringing fiber to MDUs.

Exclusive Arrangements. A few years ago, the FCC put some restrictions on cable companies and ISPs from entering into certain kinds of exclusive arrangements with property owners. It was a fairly common practice, for example, for an ISP to share customer revenues with a property owner in exchange for a long-term exclusive right to serve the building. The FCC largely forbade the most egregious practices where ISPs forced exclusivity. However, the FCC did not ban all such practices. For example, exclusive arrangements are still possible when prompted by the property owner, and under FCC rules and various court rulings, property owners are not required to allow access by ISPs to their building.

Financial Roadblocks. Property owners can create financial roadblocks to ISPs, including such practices as:

High Access Fees. Property owners can charge a significant fee to an ISP to gain access to their buildings. This could include excessive fees to connect facilities into basements or rooftops. Alternatively, they might charge high rent to use communications spaces.

Forced Revenue Sharing. Property owners might demand that any ISP entering their building must share customer revenue with them. This is of particular concern for a municipal provider because there is a good chance that such practice wouldn't be allowed. CCG has numerous municipal clients that could not find a way to pay commissions in the same manner as is done by commercial ISPs.

Partial Services Allowed. Sometime property owners include some basic level of telecommunications service in the rent. For example, they might already include a video package that they receive from satellite and distribute to apartment units. Such arrangements might be a financial roadblock if they make it hard for ISPs to profitably provide other services to tenants.

Ownership of Existing Communications Infrastructure. Property owners don't always own the existing telecom infrastructure in a building. Sometimes such infrastructure was installed by the cable company or other ISP and those entities maintain ownership through a contractual

arrangement with the property owner. There are several categories of assets where ownership by somebody other than the property owner can be a roadblock.

Existing Wiring. A cable company, telephone company, ISP, or CLEC might own the existing telephone copper, coaxial cable, category 5 cables, or fiber. Private owners don't have to make their facilities available to anybody else. In some cases, businesses within multitenant buildings own their own wiring inside their rented space, but that is rarely a roadblock for the business owner to choose to change service providers.

Normally a fiber overbuilder is not going to want to use the existing wiring if they want to offer gigabit speeds. However, there are times when that might be desirable. For example, one of the technology options explored in this report is using G.Fast, which can be delivered over telephone copper or coaxial cable. While this doesn't deliver a full gigabit, it can deliver 300–400 Mbps broadband, which many property owners would find desirable. However, that technology can't be used if the wires are owned by somebody other than the business owner. There are also buildings which will be 'pre-wired' for broadband. Most of these will have category 5 or category 6 cable, although new building might luckily have fiber. However, there is the same issue if this wiring is owned by somebody other than the MDU owner.

Existing Conduit. An existing ISP may have installed conduit or ducts within a building and won't allow access to other ISPs. This could be conduit between floors of a building (referred to as riser infrastructure), conduits between different buildings in a campus environment, or conduit distributing cables along hallways and other pathways.

Other Existing Infrastructure. An existing ISP might own other key telecommunications infrastructure. This might include communications cabinets or boxes that tie into existing wiring. It might mean they own the racks that take up all of the existing space in a telecommunications closet. Alternatively, it could mean towers or other rooftop infrastructure.

Entrance Facilities. Larger buildings will often have an existing entrance facility of some sort used to provide access to all utilities from the street into the building. This could be owned by the property owner or owned by one or more of the existing utilities, including non-telco utilities such as the electric or water utility. It's sometimes an issue to gain access to these entrance facilities. For example, an electric utility might be leery of allowing more than one ISP into their existing facility due to perceived safety or risk issues.

Pathways to Reach Units. One of the biggest issues faced in multi-tenant buildings is how to provide the broadband connection between the building entrance and individual tenants. There are numerous issues associated with this access.

Unusable Existing Wiring. Even when there is usable wiring in a building it might not be usable for a new ISP. For example, there are many different ways that a building can be wired—there can be "home-run" wiring that has a separate path from a central hub to each tenant, or at the other extreme wires can be strung in series through multiple

apartment units. Some existing wiring schemes create technical roadblocks for using the existing wiring for G.Fast.

Riser and Other Conduit. Often the pathways to tenants are blocked due to lack of usable infrastructure. For example, there might be existing riser conduit between floors that is already full, with no room for additional cables. Moreover, there might not be room to add another riser conduit.

Owner Requirements. Property owners often have other restrictions that make it difficult to enter and wire buildings.

Buried Utilities. Property owners might not allow any outdoor wires above ground. This would mean that drops and connections between buildings must be buried. In many cases, that would mean boring connections under driveways and parking lots—which is not always a safe process since the locations of other utilities are not always well known or marked on private property. The expected industry requirements for utilities using public rights-of-way may not be followed on private property. For example, buried conduit and fiber in public rights-of-way generally require some use of a technology that allows the infrastructure to be detected by anybody trying to locate existing technology. However, infrastructure without such marking technology would be invisible to a locator.

Aesthetic Issues. Probably one of the biggest roadblocks encountered when wiring MDUs is the aesthetic requirements of the property owner. For example, one of the more common techniques for adding new fiber in hallways is to place the wiring in the corners of the ceiling and cover it with some kind of protective strip. Sometimes the only path to reach units might be to string wires in some manner on the outside of the building. If a property owner won't allow the use of these techniques for aesthetic purposes then it either means the building can't be wired with fiber, or it can be wired only at a much higher cost than expected.

Boxes on the Outside of Buildings. Property owners might not allow boxes, cabinets, or other equipment terminals to be attached to the outside of buildings or even to rooftops.

Access Issues. Another impediment encountered by ISPs is one of access, or the ability to undertake the steps needed to best serve tenants. This includes:

Type of Building Construction. There have been numerous construction techniques used over the years in building MDUs, and some of the methods used in older buildings can add significant costs to serving the buildings. For example, older buildings might have old wood and plaster walls between units and for ceilings that can add cost or make it impossible to drill holes for new wires. Some old buildings have solid concrete slabs between floors through which the property owner might not allow drilling of new holes.

Access to Communications Space. ISPs generally need a space within a multi-tenant building to place hub electronics needed to serve the building. Such equipment is most commonly placed in a space reserved for telecommunications equipment that might be in

a small room or closet. Problems can arise when existing communications space is full and there isn't room for a new ISP.

Access to Power. ISPs need access to power. This can present a problem if it's hard to provide separate electric meters or to otherwise supply the specific power needs of the ISP.

24/7 Building Access. Property owners often make it a challenge for an ISP to gain access to their equipment.

Access to Apartment Units. Property owners sometimes create roadblocks making it hard to ISPs to install or repair facilities inside of apartments. Some property owners only allow access when accompanied by an MDU employee. That's something the MDU might charge for. More commonly there can be costly delays when there is nobody available to accompany a technician.

Restrictions on Sales and Marketing. It's fairly routine that ISPs are not allowed to sell or market inside MDUs in the same manner that is done for single-family homes. For example, there might be no solicitation rules in MDUs that don't allow for door-knocking sales campaigns.

Security Issues. ISPs want their equipment to be kept safe from the public and from other ISPs. This means providing secure space. Ideally that means being able to put a cage or lockable box around gear in space used by multiple service providers. Sometimes this is not possible to do because of space or other limitations.

Administrative Issues. ISPs have identified administrative issues that present challenges such as:

- Business Requirements. Property owners often have specific legal or other issues they expect ISPs to follow:
- Surety. Property owners may require ISPs to be bonded or to have a set level of insurance. This kind of bonding or insurance is not something that many ISPs are able or willing to obtain, making it a challenge to satisfy such requirements.
- Contracts Required. Property owners may require ISPs to agree to a standard contract before entering a building. This can be a problem because there are often some legal terms in standard commercial contracts that municipalities are unable to legally agree to.
- Dispute Resolution. Property owners might want an ISP to agree to arbitration or some other way to solve disputes that might be a problem for a municipality.

Conclusions. It's important to understand these various roadblocks because almost any item on this list could add to the complexity and cost of bringing fiber to an MDU. For example, there might be a willing MDU owner that wants fiber, but then once they realize that adding the fiber will violate their aesthetic requirements, it may turn out that it's too costly to get fiber to the building.

However, sometimes it's even smaller issues that might make it impossible to serve a given MDU. For example, it can be impossible to serve a building if the overbuilder doesn't have a secure location to place core electronics or doesn't have access to building entrance facilities.

Most ISPs that serve MDUs have a detailed checklist listing the specifics of the above issues. An ISP will generally walk through the MDU and determine the best wiring plan and then go over the checklist with the MDU owner. It's not uncommon to find one or more issues that are a roadblock to implementation. Sometimes roadblocks can be overcome by the ISP spending more money to solve the issue. It's also the case that sometimes the roadblocks cannot be overcome.

It is all of these reasons that make it impossible to discuss the "typical" cost to rewire an MDU. Until the full checklist and design are done, an ISP won't understand the issues present at a given MDU. In the analysis as part of this report we used "typical" costs for wiring MDUs. However, these costs only represent the costs of getting to buildings where the access is reasonable. Our analysis assumes that there are some buildings where an ISP will not gain access. That could be for the reasons discussed above—there might be an arrangement with another ISP that keeps out the overbuilder, there might be a physical impediment that makes it too costly to rewire, or a property owner might have aesthetic, financial, contractual, or other requirements that can't be made to work for a municipal network provider.

5G and Fiber

The RFP asked the question of whether there is an economic case and benefit from leveraging a fiber network to provide better 5G coverage in a community. It's a great question and is one that fiber network owners everywhere are wrestling with.

Elsewhere in this report we discuss how the term 5G is used to describe several completely different technologies, so this discussion needs to start by defining the 5G use being discussed.

One use of 5G is to provide fiber-to-the-curb and provide gigabit broadband to homes. That technology builds fiber on streets and then used wireless transmitters to beam the broadband for the last 100 feet to reach homes or businesses. It's possible that by the time that you build a fiber network in Falmouth that this could become an option for the way you build the network. For now, this technology is not readily available to a new fiber builder. Verizon is the only company in the US doing this to any extent and they are using a proprietary technology and licensed spectrum – two things other ISPs can't mimic. But this will eventually become a commercially available technology, and at that point, it would be an alternative to the PON technology used in our analysis.

If there was a new fiber network built in the town it would be extremely unlikely that the fiber owner would lease fiber capacity to another ISP that wanted to offer this form of 5G. That would be allowing a rival ISP to benefit from your new fiber. This would be the equivalent of Comcast allowing their rival Verizon to somehow offer faster broadband in Falmouth. This is likely to never happen and it would be a bad decision to enable a competitor.

Another use of 5G is the way that Verizon and AT&T are offering 5G hotspots in downturn urban centers. This technology places outdoor hotspots, fed by fiber, and then beams gigabit speed broadband for a few hundred feet around each hotspot. These companies are using millimeter wave spectrum to

transmit the broadband, and that means customers using this service must but special phones or devices that can use the specific frequencies.

There may come a time when this becomes a standardized product, and perhaps this will be built into cellphones, or at least built into dongles that could support a laptop or tablet. If it becomes standardized, the new fiber provider could either offer this directly or else could lease fiber bandwidth to support an ISP that specializes in this technology. There is a good chance this technology fades into history because the broadband delivered is extremely squirrelly. The frequencies used won't even pass through a human body and you can block the signal by being turned the wrong way away from the transmitter. But if this ever becomes a mature, workable technology, then there would be the opportunity to monetize it.

The predominant use of 5G is always going to be 5G cellular traffic delivered to cellphones. Anybody building a new network should explore the possibility of providing transport to cellular sites. The big cellular companies have always provided cellular service from transmitters located on tall towers. However, for 5G to be most effective, the cellular companies are already installing small cell sites scattered throughout a town. It would be surprising if there are not already small cell sites in Falmouth since the cellular network must be under big stress in the summer when all of the tourists are in town.

What is not known for a given community is if the cellular companies would be interested in using a new fiber network. For example, Verizon has largely adopted the strategy of building their own fiber for 5G, particularly in places where they are already the incumbent telephone company. Verizon already owns some fiber around Falmouth that is used to feed DSL huts or used to reach to other large customers. Verizon might be able to construct a 5G network based upon that existing fiber, supplemented by additional fiber construction.

For now, the only two other cellular companies are AT&T and T-Mobile. Verizon and AT&T have a nationwide arrangement to swap tower space, and it's possible that if Verizon builds small cells in Falmouth that AT&T might share the same locations. For every cell site that Verizon provides in Falmouth, AT&T would provide one in some other city where AT&T is the incumbent telephone company. In the past, T-Mobile was not a big participant in these shared cell site locations, but they recently purchased Sprint that widely shared cell sites with AT&T. That means that it's conceivable that all three companies share cell sites in the town and wouldn't be looking to lease additional fiber. All of the cellular companies are working hard to eliminate fiber leases, which are their biggest expense.

There is one new cellular player. Dish Networks is building a nationwide cellular network and it's almost certain that they will appear in the next three or four years in Falmouth. At this early stage there is no way to predict how they will get cell sites, since the company is starting from a position of having zero cell sites.

There is one other wild card in that Comcast is now in the cellular business. The company currently resells cellular signal purchased from T-Mobile, but Comcast has announced that they will deploying cell sites in markets where it can save them money and increase margins. Comcast likely has more fiber in Falmouth than Verizon, so Comcast is likely going to be able to deploy small cells in Falmouth if that's a market they plan to migrate to facility-based 5G. This means it's unlikely that Comcast would lease fiber space from a new network, but instead Comcast might sell capacity to T-Mobile or Dish Networks.

This means that there is a wide range of possibilities for the way that a new fiber network might benefit from 5G. It's possible that one or more of the cellular carriers would choose to lease capacity on a new fiber network, particularly if the cost of using the new fiber is a lot less than the cost of building fiber. But the other extreme is also possible in that there may be no cellular companies interested in using a fiber network in Falmouth even if it was in place today. The margins on the cellular business have been tightening due to price competition between the carriers. It's expected for price competition to intensify, particularly when Dish Networks enters the market. That means the cellular companies will try hard to not have to lease fiber transport. They would prefer to build, share, or swap fiber rather than pay outside fiber networks for access.

Using the OpenCape Backbone Fiber

OpenCape owns a fiber network today that reaches into various corners of Falmouth. OpenCape has built fiber to serve the largest broadband users in the community such as the hospital, schools, the business park, the downtown business corridor, and other larger businesses throughout the community. The RFP asked if the project would benefit by using that existing fiber..

The new fiber network anticipated by our analysis would be built to pass every home and business in the town. That means that new fiber would have to be built down every street to reach homes and businesses along the street. That is going to mean that the new network is going to have to be built along the same roads as the existing OpenCape fiber.

It's possible that there could be some savings for sharing in OpenCape fiber. Most OpenCape fiber on main routes in Falmouth have 128 fibers and secondary later fibers mostly have 72 fibers. This means that there are likely a significant number of open fibers on OpenCape that could be made available for a fiber network to reach every home and business.

To be conservative, in our study we assumed that that a new fiber network would build on all of the streets in the city. There are both operational and financial issues involved with using fiber on somebody else's network. The following list of issues would have to be considered if some entity other than OpenCape is the operator of a new fiber network. Some of these issues go away if OpenCape is the ISP chosen to serve the whole city.

- OpenCape is using some of the fibers on its network and likely would want to reserve other fibers for future uses. It's also prudent to always keep unused fibers on every route which can be used in the future to replace fibers that go bad over time. The first step in deciding to use OpenCape fibers would be to determine how many fibers could be made available on each route for a new citywide network. On any route where more fibers are needed than are available on OpenCape, the right path forward would be to build a new fiber on the route.
- There is always a question of cost. OpenCape would either want to sell or lease the fibers to the new venture, and such costs would have to be carefully weighed against the cost of building new fiber. Fiber projects already have slim cash margins for the first ten years, so any payment for fibers would need to be done in such a way as to minimize early-year cash outlays. That means that an outright purchase of fiber, or else long-term leases that pre-pay the lease are probably the most attractive option, assuming that cost is lower than the cost of building new fiber.
- There are always going to be operational issues between carriers sharing a fiber sheath. The most common practice in the industry is for a fiber owner to not allow any outside technicians to touch its fiber – meaning the fiber owner must do all work that involves touching a fiber. This can

create major operational concerns if the fiber owner is not as responsive as the ISP serving customers in the city.

This means that the idea of using OpenCape's fiber would have to examined on a route-by-route basis. There are likely some routes where it will make sense for a new ISP to use the OpenCape fiber and there will be cases where it won't make sense.

One of the most obvious ways to take advantage of the OpenCape fiber would be to use it as the backbone that already reaches into many of the neighborhoods in the town. If a core backbone could be established in the OpenCape fiber the construction process would be accelerated across the city as new construction could connect customers in multiple parts of the town at the start of construction.

There is the final complication that OpenCape and a new fiber builder would be rivals. In the interviews we conducted, many OpenCape customers told us they are paying a premium price for broadband. The OpenCape pricing is premium because it provides dedicated access to most customers – meaning broadband dedicated fully to the use of a given customer. If a new ISP builds fiber everywhere it will also offer dedicated bandwidth, but the predominant product on a new network will be shared bandwidth. Many OpenCape customers might be willing to swap to a lower-priced product on the new fiber network. The businesses using OpenCape today are willing to pay a premium prices for fiber broadband because that's the only alternative – but it's likely that at least some of those customers will be clamoring for a new fiber builder to bring them a cheaper alternative. Of course, there is also the possibility that OpenCape becomes the partner ISP – and all such issues disappear.

C. Competing Technologies

Existing Technologies

There are several technologies used in the town today to deliver broadband. Each of these technologies will be explained below.

- Verizon serves the town with copper telephone wires using DSL technology.
- Comcast uses hybrid fiber/coaxial (HFC) technology to provide the triple play services.
- OpenCape and the incumbent providers use active Ethernet technology to bring fiber directly to large businesses, schools, etc.
- OpenCape is using GPON fiber-to-the-premise technology to serve small businesses. This is the same technology we considered for a whole-town build.
- Some homes get broadband using the data on their cellphone plans.

DSL over Copper Wires

Verizon uses DSL (Digital Subscriber Line) to provide a broadband path over a copper network. The copper networks were built between the 1950s and early 1970s. The copper networks were originally expected to have an economic life of perhaps forty years and have now exceeded the economic life of the assets. The copper networks are deteriorating as a natural process of decay due to sitting in the elements. Maybe even more importantly, the copper networks have deteriorated to some extent due to neglect. Verizon and the other big telcos started to cut back on maintenance of rural copper in the 1980s as the companies were deregulated from some of their historic obligations. At some point the copper networks will die even though regulators continue to act like they will keep working forever.

DSL works by using frequency on the copper that sits just above the frequencies used for telephone service. There are different kinds of DSL standards, each of which has a different characteristic in terms of how much bandwidth they deliver and how far the signal will travel. The most efficient forms of DSL can deliver up to 24 Mbps service over a single telephone wire. Verizon is able to bond two telephone wires together and offer speeds up to 48 Mbps. Most of the DSL in the town is of older varieties and delivers slower speeds.

The most important characteristic of DSL is that data speed delivered to customers decreases with the distance the signal travels. This means that the DSL speeds differ throughout the town, and even within a neighborhood.

The general rule of thumb is that most of the types of DSL can deliver a decent amount of bandwidth for 2 to 3 miles over copper. Verizon transmits DSL from their historic central offices. They also might transmit DSL from deeper in the copper network from field cabinets placed in various neighborhoods around the town.

DSL signal strength is also affected by the quality of the copper. The newer the copper and the larger the gauge of the copper wire, the better the signal and the greater the bandwidth. Many of the copper wires in the town are old and have gotten water damage over the years and won't carry the full amount of bandwidth.

Hybrid Fiber Coaxial Network

Comcast is the incumbent cable company in town. The technology used in the Comcast network is referred to as Hybrid Fiber Coaxial (HFC). Hybrid refers to the fact that an HFC network uses a fiber backbone network to bring bandwidth to neighborhoods and a copper network of coaxial cable to deliver service to customers. HFC networks are considered lean fiber networks (meaning relatively few fiber strands) since the fiber is only used to deliver bandwidth between the headend core and neighborhood nodes. At each node is a broadband optical receiver that accepts the fiber signal from the headend and converts it into a signal that is sent over coaxial cable to reach homes and businesses.

The coaxial copper wires in the Comcast network are also aging, similar to the telephone copper wires. The coaxial network in Falmouth was likely built in the 1970s. Coaxial cable networks exhibit signs of aging sooner than telephone copper networks because the wires act like a huge antenna, and older networks attract so much interference and noise that it become harder to transmit the signals through the wires.

An HFC system handles delivery of customer services differently than an all-fiber network. For example, in an HFC network, all of the cable television channels are transmitted to every customer and various techniques are then used to block the channels a given customer doesn't subscribe to.

In an HFC network all of the customers in a given node share the broadband in that node. This means that the numbers of customers sharing a node is a significant factor - the fewer the customers, the stronger and more reliable the broadband signal. Before cable systems offered broadband, they often had over 1,000 customers on a node. But today, the sizes of the nodes have been "split" by building fibers deeper into neighborhoods so that fewer homes share the data pipe for a given neighborhood. The

architecture of using neighborhood nodes is what has given cable companies the reputation that data speeds slow down during peak usage times, like evenings. However, if nodes are made small enough, then this slowdown doesn't have to occur.

The amount of bandwidth available to deliver Internet access that is available at a given node is a function of how many "channels" the cable company has dedicated to data services. Historically a cable network was used only for television service, but in order to provide broadband the cable company had to find ways to create empty channel slots that no longer carry TV programming. Most cable systems have undergone a digital conversion, done for the purpose of freeing up channel slots. In a digital conversion a cable company compresses video signals and puts multiple channels into a slot that historically carried only one channel.

The technology that allows data to be delivered over an HFC system follows a standard called DOCSIS (Data Over Cable Interface Specification) that was created by CableLabs. Likely around a decade ago Comcast upgraded to the DOCSIS 3.0 standard that allows them to bond together enough channels to create broadband speeds as fast as about 250 Mbps download. A few years ago Comcast upgraded most of their networks nationwide to a new standard, DOCSIS 3.1, that theoretically allows all of the channels on the network to be used for data and which can produce broadband speeds as fast as 8–10 Gbps if a network carried only broadband and had zero television channels. Since there are still a lot of TV channels on a cable network, most cable companies have increased the maximum broadband speeds to between 500 Mbps and 1 Gbps using DOCSIS 3.1. We can tell that Falmouth was upgraded due to the availability of broadband products being sold that vary between 400 Mbps and gigabit speeds.

One limitation of a DOCSIS network is that the standard does not allow for symmetrical data speeds, meaning that download speeds are generally much faster than the upload speeds. This is an inherent design characteristic of DOCSIS 3.0 and 3.1 where no more than 1/8 of the bandwidth can be used for upload. Earlier in the report was a lengthy discussion about the upgrade speed crisis that has arisen during the pandemic. The cable companies are likely hoping that issue will diminish in importance at the end of the pandemic.

CableLabs has developed an upgrade being called DOCSIS 4.0 that will allow for symmetrical gigabit data speeds. This will require even more empty channel slots on a cable network and the new standard assumes that cable company will increase total system bandwidth of the network to at least 1.2 GHz of bandwidth. The gear needed to upgrade to DOCSIS 4.0 won't hit the market for at least two or three years. Most of the big cable companies have already said they are not interested in upgrading immediately to the new standards since the upgrades are expensive. Cable companies will ultimately face a big decision, because if they are going to upgrade to DOCSIS 4.0 they also might instead consider the leap to fiber. Most analysts think that upgrade is likely decades away, but most think that cable companies will eventually migrate to fiber. That's not quite so obvious to me – cable companies strive to minimize capital costs and are likely to milk the current networks for as long as possible. Like with any big upgrade, Comcast would be far more likely to upgrade the big urban markets before secondary markets like the Cape.

There is a distance limitation on coaxial cable. Unamplified signals are not generally transmitted more than about 2.5 miles over a coaxial network from a network node. This limitation is based mainly on the number of amplifiers needed on a single coax distribution route. Amplifiers are needed to boost the signal strength for coaxial distribution over a few thousand feet. Modern cable companies try to limit the

number of amplifiers on a coaxial route to five or less since adding amplifiers generally reduces broadband speeds.

Metro Ethernet

Metro Ethernet is the primary technology used to deliver large bandwidth to a single customer over fiber. This is the technology used by OpenCape to deliver broadband to some of the larger businesses and anchor institutions in the community. The technology is likely used by Verizon and Comcast also. This technology is often also referred to as active Ethernet.

Metro Ethernet technology generally uses lasers that are capable of delivering 1 gigabit or 10 gigabit speeds, although lasers as fast as 100 Gbps are available. ISPs can choke these speeds to slower levels based upon what a customer is willing to pay for.

Many ISPs dedicate a fiber for each metro Ethernet customer, but that's not mandatory. For example, an ISP could light a fiber to deliver 10 Gbps and string that fiber to multiple customers each buying 1 Gbps service.

Cellular Broadband.

The survey showed that about 4% of residences use only their cellphone for home broadband. There are obvious limitations on cellphone for home broadband. The amount of broadband capacity is small compared to wireline broadband. Most standard cellular plans provide 10 gigabytes of broadband usage per month or less. Even the unlimited plans offer only 20 – 25 gigabytes per month of broadband. One of the limitations on unlimited data plans is that they can only be used to tether to computers or other devices for a limited amount of capacity per month – most of the data in the plan must be consumed by the cellphone.

Customers can buy more broadband when they exceed the subscribed capacity, but this is some of the most expensive broadband in the world, typically priced at $10 per extra gigabyte. While it would unusual for somebody in the town to spend a lot for cellular data plans, CCG has talked to rural customers across the US who have monthly cellular data bills in excess of $500 per month if they use cellular data to support students doing homework.

AT&T and T-Mobile have started to offer what they call fixed cellular data plans. With these plans the carriers place a small dish on a customer home and use cellular frequencies to deliver fixed wireless broadband. The fixed broadband is for normal home consumption – it uses cellular frequency but is not delivered to cellphones. These plans have much larger data caps than on regular cellular plans. For example, the AT&T fixed cellular plan has a monthly data cap of 215 gigabytes. It's not likely that they are offering these plans in the town today. Currently, AT&T only offers this plan in places where they are the incumbent telephone company. T-Mobile has said they will offer this product nationwide if they are allowed to merge with Sprint – that merger was approved by the courts in February 2020, so perhaps this will become available in the next few years.

Fixed 4G Cellular Wireless

As this paper was being written, Verizon announced a new wireless broadband product that might show up in the Falmouth market. The product is called "LTE Home Internet." The product is easily explained. Verizon will be delivering unlimited data using the cellular 4G LTE network. Customers must buy a receiver from Verizon for $240, although for now they are offering a $10 discount for 24-months which returns the cost of the box over two years. The product is $40 per month for a household that is buying a Verizon wireless product that costs at least $30 per month. Non-Verizon wireless customers pay $60 per month. There is free tech support for setup issues for 30-days, implying that tech support will entail a fee after that.

Verizon touts the product as delivering 25 Mbps download speeds, with bursts as high as 50 Mbps. Verizon is launching the product in three markets – Savannah, GA, Springfield, MO, and the Tri-cities area at the area near the borders of Tennessee, Virginia, and Kentucky.

It appears that the product is intended to help Verizon replace rural DSL customers, and to let Verizon compete for broadband customers anywhere they operate on a cellular tower. Verizon has made it known for many years that the company wants to walk away from rural copper networks. But the company has also been busy decommissioning copper networks in suburbs up and down the east coast. In cities Verizon can walk away from copper networks by expanding FiOS on fiber. But the company is highly unlikely to be looking at building new FiOS network on the Cape. Verizon largely stopped building FiOS fiber in 2010, although the company built small amounts since then. Verizon has repeatedly said that they don't anticipate building more fiber-to-the-home.

There is speculation that Verizon will walk away from all copper within a decade. If they do that in Falmouth, then the only real ISP left would be a Comcast monopoly.

This new product could be Verizon's answer of what follows DSL on copper. The product just needs a strong cellular signal, and if the signal isn't strong enough in a community like Falmouth it wouldn't be that expensive for Verizon to beef up the cellular network. This product offers speeds that are promised to be around 25 Mbps with burst up to 50 Mbps. That's superior to the DSL speeds we saw in Falmouth during this study.

The only question is if Verizon's cellular network is robust enough to maintain the cellular network while layering on fixed broadband – particularly during the summer when the cellular network is stressed.

But Verizon needs to have a replacement product before state regulators would allow them to tear down copper – and this new product might be an experiment with that product.

T-Mobile is supposedly launching a similar product. As part of its merger with Sprint the company promised to provide fixed 4G wireless broadband that will cover over 50% of the homes in the country. This would be similar to the Verizon product and would be offered in many places where T-Mobile has cellular towers. However, I've already seen articles saying that T-Mobile is trying to wriggle out of its merger promises, blaming the pandemic. However, there is a long tradition in the country of carriers not fulfilling promises made the FCC and the States during merger talks.

Future Technologies

This section looks at new technologies that are likely coming within the next few years to the US.

Next Generation Fiber Technologies. There are two next-generation and competing fiber-to-the-home technologies that will allow connections to customers to be upgraded to 10 Gbps broadband and even faster - NG-PON2 or XGS-PON. The current widely deployed GPON technology will eventually hit a technology wall. The technology delivers 2.4 Gbps downstream and 1 Gbps upstream for up to 32 customers, although many networks are configured to serve 16 customers at most. This is still an adequate amount of bandwidth today for residential customers and can easily provide a gigabit product to every customer if desired.

GPON technology is over a decade old, which generally is a signal to the industry to look for the next generation replacement. This pressure usually starts with vendors who want to make money pushing the latest and greatest new technology - and this time it's no different. After taking all of the vendor hype out of the equation it's always been the case that any new technology is only going to be accepted once that new technology achieves an industry-wide economy of scale. That means being accepted by at least one large ISP.

The most talked about technology is NG-PON2 (next generation passive optical network). This technology works by having tunable lasers that can function at several different light frequencies. This would allow more than one PON to be transmitted simultaneously over the same fiber, but at different wavelengths. That makes this a complex technology with multiple lasers and the key question is if this can ever be manufactured at price points that can match other alternatives.

The only major proponent of NG-PON2 today is Verizon, which recently did a field trial to test the interoperability of several different vendors including Adtran, Calix, Broadcom, Cortina Access, and Ericsson. Verizon seems enamored with the idea of using the technology to provide bandwidth for the small cell sites needed for a 5G network. However, the company is not building much new residential fiber. They announced they would be building a broadband network in Boston, which would be their first new construction in years, but there is speculation that a lot of that deployment will use wireless 60 GHz radios instead of fiber for the last mile.

The market question is if Verizon can create enough economy of scale to get prices down for NG-PON2. The whole industry agrees that NG-PON2 is the best technical solution because it can deliver 40 Gbps to a PON while also allowing for great flexibility in assigning different customers to different wavelengths. Still, the best technological solution is not always the winning solution and cost is the greatest concern for most of the industry. Today the early NG-PON2 electronics are being priced at 3 - 4 times the cost of GPON, due in part to the complexity of the technology, but also due to the lack of economy of scale without any major purchaser of the technology.

Some of the other big fiber ISPs like AT&T and Vodafone have been evaluating XGS-PON. This technology can deliver 10 Gbps downstream and 2.5 Gbps upstream—a big step up in bandwidth over GPON. The major advantage of the technology is that is uses a fixed laser which is far less complex and costly. In addition, these two companies are building a lot more FTTH networks than Verizon.

While all of this technology is being discussed, ISPs today are can deliver 10 Gbps data pipes to customers using Active Ethernet technology. For example, US Internet in Minneapolis has been offering

10 Gbps residential service for several years. The Active Ethernet technology uses lower cost electronics than most PON technologies, but still can have higher costs than GPON due to the fact that there is a dedicated pair of lasers, and a dedicated fiber for each customer. A PON network instead uses one core laser to serve multiple customers.

It may be a number of years until this is resolved because most ISPs building FTTH networks are still happily buying and installing GPON. One ISP client told us recently that they are not worried about GPON becoming obsolete because they could double the capacity of their network at any time by simply cutting the number of customers on a neighborhood PON in half. That would mean installing more cards in the core without having to upgrade customer electronics.

The bottom line of this discussion is that we decided to not consider NG-PON2 for the primary technology to deliver FTTH services. The technology is still too expensive and since it has not yet been accepted widely in the industry it might never get long-term support by vendors.

However, our network design allows for an eventual migration to XGS-PON or NG-PON2 through what is called an overlay. That means introducing the new technology while maintaining the current network. This would allow for an orderly transition over time while bringing faster 10-gigabit connection to customers that need it immediately. The fiber network design can accommodate these future technologies and faster speeds.

5G Cellular Technology. Today's cellular network uses a technology called 4G LTE, although there are still many rural cell sites using 3G technology. Nationwide, the cellular carriers in the US average data speeds for 4G LTE is around 25 Mbps download, with the fastest cell sites usually located in major metropolitan areas. Like with all radio technologies, cellular data speeds drop in relation to the distance a customer is from a cell site and good cellular data speeds only are available for around 2 miles from a cellular tower. A customer that is more than 3 miles from a tower will get slower cellular data speeds.

The cellular carriers are in full 5G marketing mode. If you believe the TV commercials, you'd now think that the country is blanketed by 5G, as each cellular carrier claims a bigger coverage area than their competitors. However, almost all of their claims are marketing hype.

In 2020 there will be no cellular deployments that can be legitimately called 5G. Full 5G will not arrive until the carriers have implemented the bulk of the new features described in the 5G specifications. For now, none of the important features of 5G have been developed and introduced into the market. 5G deployment will come in stages as each of the 5G features reaches markets – the same thing that happened to 4G. For now, all of the major 5G improvements are still under development in the labs.

From what is discussed in the IEEE forums, most of the 5G features are 2 - 5 years away. The same thing happened with 4G and it took most of a decade to see 4G fully implemented – in fact, the first US cell site fully meeting the 4G standards was not activated until late 2018. Over time we'll see a new 5G features implemented as they are released from labs to field. New features will only be available to those that have phones that can use them, so there will be a 2- to 3-year lag until there are enough phones in the market capable of using a given new feature. This means every 5G phone will be out of date as soon as a new 5G feature is released.

Most of what is being called 5G today refers to the introduction of new bands of spectrum. New spectrum does not equal 5G – the 5G experience only comes with 5G features. Existing cellphones cannot receive the new spectrum bands, and so the carriers are selling new phones that can receive the new spectrum and labeling that as 5G.

Even when 5G is fully implemented, the cellular data speeds are not going to be blazingly fast. The 5G specification calls for a goal for 5G cellular speeds of about 100 Mbps – which was also the specification for 4G, but never realized. There will be reports of fast speeds using new spectrum, but that will die down quickly. At first, anybody lucky enough to grab new spectrum will likely have a great experience. This will mostly be because almost nobody else is using the spectrum at a given cell site. As more phones can use the new spectrum, the performance will drop back to normal 4G speeds – and maybe even a little slower. Much of the first wave of spectrum being released is in lower frequency bands such as 600 MHz for T-Mobile and 850 MHz for AT&T. These lower frequency bands don't carry as much data as higher frequencies.

5G Hot Spots. There are commercials on TV showing cellphone speeds of over a gigabit. This is not 5G. This is a phone equipped to use a new frequency band called millimeter wave spectrum. This is an ultra-high frequency and is 10-30 times faster than traditional cellular frequency.

It's easiest to think of this technology as a 5G hot spot, similar to a hot spot that might be found in a coffee shop, only mounted outdoor on a pole. The signal only travels a short distance, mostly under 1,000 feet from a transmitter. It needs line-of-sight and can be easily blocked by any impediment in the environment. The signal won't pass from outdoor transmitters into buildings. This technology only makes sense where there are a lot of people, such as downtown urban corridors, stadiums, and business hotels.

There is a lot of speculation in the industry that this is a novelty product being deployed to convince the world that 5G will be blazingly fast everywhere. The cellular carriers seem desperate to deploy something they can call 5G, and super-fast cellphones are a good way to get headlines. However, it's extremely unlikely that any carrier is going to invest in cell sites that close together outside of major downtown business districts. This technology is likely to never reach to residential neighborhoods in cities, suburbs, small towns, or rural America. A lot of industry experts are asking why anybody needs gigabit broadband for cellphone, and only outside since there are no high bandwidth applications for cellphones.

The need for Small Cell Sites. Communities of all sizes are seeing requests for adding small cell sites. These are small cellular sites that are placed on poles rather than on the big cellular towers. It's likely that when a cellular company, or one of their subcontractors makes such a request they will tell you this is for 5G.

The fact, is, for now these cell sites are being added to bolster the 4G networks. It's not hard to understand why the 4G cellular networks are stressed. The cellular companies have embraced the 'unlimited' data plans, which while not truly unlimited, have encouraged folks to use their cellular data plans. According to Cisco the amount of data on cellular networks is now doubling every two years – a scorching growth rate that would mean a 60-fold increase in data on the cellular networks in a decade. No network can sustain that kind of traffic growth for very long with becoming congested and

eventually collapsing under the load. While this is a definite problem in major cities, it might also be happening in Falmouth, particularly during the summer tourist season.

The cellular companies have a 3-prong approach to fix the performance problems for 4G. First, they are deploying small cell sites to relieve the pressure from the big cellular towers. A small cell site a busy neighborhood eliminates a lot of stress from the big cellular tower in the neighborhood.

The cellular companies also have been screaming to the FCC asking for new mid-range spectrum, because adding spectrum to cell sites and cellphones expands the data capability at each cell site. Unfortunately, it's a slow path between the FCC approving new spectrum until the time when new spectrum is installed in cell sites and enabled in smartphones. The FCC has awarded several bands of mid-range spectrum in the last year and are looking at more.

Finally, the cellular carriers are counting on 5G. There a few aspects of 5G that will improve cellular service. The most important benefit comes from frequency slicing that will right-size the data path to each customer and will get rid of today's network that provides a full channel to a customer who is doing some minor broadband task. 5G will also allow for a customer to be connected to a different cell site if their closest site is full. Finally, the 5G specifications call for a major expansion of the number of customers that can be served simultaneously from a cell site. Unfortunately for the cellular carriers, most of the major 5G improvements are still five years or more into the future.

There is a fourth issue that is a likely component of the degrading cellular networks. It's likely with expanding broadband needs that the backhaul links to cell sites are overloaded at times and under stress. It doesn't matter if all of the above changes have been made if the backhaul is inadequate – because poor backhaul degrades all broadband services. The big cellular carriers have been working furiously to build fiber to cell sites to eliminate leased backhaul. But much of the backhaul to cell sites is still leased and the lease costs are one of the major expenses for cellular companies. The cellular companies are reluctant to pay a lot more for transport and bandwidth, and so it's likely that at the busiest times of the day that many backhaul routes are now overloaded.

Low Orbit Satellite Technology

We almost didn't include this technology in the report since it is extremely unlikely that the companies selling broadband out of satellites will be selling services in urban areas. The technology is best suited to provide broadband in remote and rural locations. However, there has been so much hype about the satellites that it's worth discussing to dispel ideas that these companies could become a serious competitor in the cities. There are several major companies planning on providing fleets of low-orbit satellites to provide broadband service. This includes efforts by SkyLink (Elon Musk), Project Kuiper (Amazon), and OneWeb that have announced plans to launch swarms of satellites to provide broadband.

In March, OneWeb filed for Chapter 11 restructuring when it was clear that the company could not raise enough cash to continue the research and development of the satellite product. In July, a bankruptcy court in New York approved a $1 billion offer to take over the company filed jointly by the British Government and Bharti Airtel. Airtel is India's largest cellular company. The restructured company will be owned with 45% stakes by Britain and Bharti Airtel, with the remaining 10% held by Softbank of Japan, the biggest original shareholder of OneWeb. Other earlier investors like the founders, Intelsat,

Totalplay Telecommunications of Mexico, and Coca-Cola have been closed out of ownership by the transaction.

There is speculation that the British government purchased the company to create tech jobs in the country and that all R&D and manufacturing for OneWeb would immediately shift to England from Florida. There is also speculation that the mission of the company will change. Greg Wyler, the original CEO of the company had a vision of using the satellites to bring broadband to parts of the world that have no broadband. He chose a polar orbit for the satellites and was going to launch the business by serving Alaska and the northern territories of Canada like Nunavut. I've seen speculation that the revised company is likely to concentrate instead on wholesale connections to telcos and ISPs, such as providing backhaul for rural cell sites.

Elon Musk's satellite venture StarLink was recently in the news when the company said it was going to raise "up to $1 billion" to continue the development of the business. The company still has a long and expensive road to success. The company has raised over $3.5 billion to date before this latest raise, but a recent Bloomberg article estimates that the company will need to raise an additional $50 billion between now and 2033, which is when the company is projected to be cash-positive.

StarLink now has over 540 satellites in orbit, but the business plan calls for over 4,000 satellites in the first constellation. Keeping the first constellation in place will be an ongoing challenge since the satellites have an estimated life of 5 to 6 years. StarLink will forever have to be launching new satellites to replace downed satellites. StarLink has even more ambitious plans and has told the FCC that it might eventually launch over 30,000 satellites – but they need to fund and launch the original batch first.

The US government and the FCC seem to be in StarLink's corner. It's still not clear if the FCC will allow StarLink to participate in the upcoming RDOF grants auction in October. It would be incredibly unusual to award giant federal grants for a product that is still on the drawing board and for an ISP that hasn't raised 10% of their needed funding.

Just as this paper was going to press, we learned more about StarLink. The company announced that broadband connections would be priced at $99 per month and were expected to deliver speeds between 50 Mbps and 150 Mbps download. StarLink reemphasized that this is a rural technology and they don't expect to offer it in towns.

The last LEO player that is still active is Jeff Bezos venture that is still using the preliminary name of Project Kuiper. The FCC recently approved the concept of Project Kuiper to move forward and FCC Chairman Ajit Pai recently said he supported the company's plans to start the process of FCC licensing of the technology. Project Kuiper has one advantage over other competitors in that Jeff Bezos could self-fund much or all of the venture. It was reported that just for the month of July that Bezos's net worth had climbed by $9 billion. Funding is going to be a constant hurdle for the other two major competitors, but Project Kuiper might be the fastest to deploy if funding is not an issue.

The most recent announcement made at Christmas 2019 is that Apple is considering launching satellites that will provide only data for cellphones. This could free apple phones from having to rely on a cellular carrier.

Skeptics are doubting if the companies can launch all of the planned satellites. To put their plans into perspective, consider the number of satellites ever shot into space. The United Nations Office for Outer Space Affairs (NOOSA) has been tracking space launches for decades. They report at the end of 2019 that there have been 8,378 objects put into space since the first Sputnik in 1957. As of the beginning of 2019 there were 4,987 satellites still in orbit, although only 1,957 were still operational. There was an average of 131 satellites launched per year between 1964 and 2012. Since 2012 we've seen 1,731 new satellites, with 2017 (453) and 2018 (382) seeing the most satellites put into space.

While space is a big place, there are some interesting challenges from having this many new objects in orbit. One of the biggest concerns is space debris. Low earth satellites travel at a speed of about 17,500 miles per hour to maintain orbit. When satellites collide at that speed, they create a large number of new pieces of space junk, also traveling at high speed. NASA estimates there are currently over 128 million pieces of orbiting debris smaller than 1 square centimeter and 900,000 objects between 1 and 10 square centimeters.

NASA scientist Donald Kessler described the dangers of space debris in 1978 in what's now described as the Kessler syndrome. Every space collision creates more debris and eventually there will be a cloud of circling debris that will make it nearly impossible to maintain satellites in space. While scientists think that such a cloud is almost inevitable, some worry that a major collision between two large satellites, or malicious destruction by a bad actor government could accelerate the process and could quickly knock out all of the satellites in a given orbit. It would be ironic if the world solves the rural broadband problem using satellites, only to see those satellites disappear in a cloud of debris.

III. FINANCIAL PROJECTIONS

This section of the report looks at the detailed assumptions that were made in creating the financial business plans. The business plans created are detailed and contemplate all aspects of operating a broadband business. The business plan assumptions represent our best estimate of the operating characteristics for such a business. As a firm, CCG consults to hundreds of communications entities that provide rural broadband. This has given us a lot of insight into how rural ISPs operate. We believe that the financial results shown in these models are characteristic of similar operations elsewhere and we believe our assumptions are realistic.

The primary goal of the business models is to look at the various scenarios from the perspective of an ISP that would operate the business. The purpose of these models is to provide a way for ISPs to understand the broadband opportunities in the county. We've learned with experience that almost every ISP is theoretically interested in expanding. However, no ISP is really interested until they understand the numbers. Only then can they decide if the opportunity is something they can get financed and that meets their requirements as an investment opportunity. These studies help the ISPs understand the opportunity of expanding broadband into the rural parts of the counties.

A. Operating Models

CCG considered the following business plan scenarios. Every scenario used fiber-to-the-premise technology, described earlier in the report.

Retail Model – Single Provider as the ISP

This scenario considered the network being built and operated by a single entity. The results would be similar if the operator were the town or a single ISP.

We always study this scenario to understand if there are reasonably achieved scenarios that result in a sustainable business plan – defined as permanently cash self-sufficient. CCG has learned from experience that if a market can't be profitable with one provider, then other options like partnerships and open access also can't be successful. By definitions those scenarios divvy up profits among multiple entities. If there's not enough profit for one provider, there's not enough to support multiple parties.

A retail ISP is a single entity (could be the public entity or a single ISP) that operates a retail broadband network. A retail ISP normally owns the network, hires the staff, operates the business, and benefits from any profits.

Advantages

Profits. A single owner/operator can make all of the profit from a fiber business.

Flexibility. A single owner/operator can make instant decisions to change products or prices or to respond to competition that seem needed.

Disadvantages

Risk. The flip side of the ability to make all of the profits is that a single owner/operator also takes all of the risk. If the business doesn't succeed the ISP can lose their investment.

Financing. The primary impediment to building and operating a fiber ISP is the cost of building the fiber network. Cities often wonder why commercial ISPs don't build fiber network if the business plan to do so looks profitable. The fact is that there are not many entities capable of borrowing the money needed to finance multiple fiber networks. Most small ISPs are limited by the amount of equity they can bring to a new market and by the collateral they can pledge to a borrower.

Open Access

This scenario would open up the market to multiple ISPs, which would then provide retail products to customers. Under this scenario a municipal entity would build and operate the network and the ISPs would sell to and provide services to customers. A town's only source of revenue is fees collected from the ISPs for providing access to the fiber network. ISPs have the relationship with customers – ISPs sell, provide services, bill, and provide customer service.

The open-access model thrives in Europe but has had a more difficult time succeeding in the US. Europe has seen success with open-access networks because a significant number of the large ISPs there are willing to operate on a network operated by somebody else. This came about due to the formation of the European Union. Before the European Union, each country on the continent had at least one monopoly telephone company and a monopoly cable TV company. The formation of the European Union resulted in a change in law that opened up existing state-run monopolies to competition. All of the state-owned telecoms and ISPs found themselves in competition with each other and most of these businesses quickly adapted to the competitive environment. This contrasts drastically with the US market where there is no example of any large cable company competing with another and only limited competition between large telephone companies.

When a few cities in Europe considered the open-access operating model they found more than a dozen major ISPs willing to consider the model (large companies that would be equivalent of getting Comcast, AT&T, or CenturyLink agreeing to use the new fiber network). There are now open-access networks in places like Amsterdam and Paris as well as in hundreds of smaller towns and cities. The biggest networks have over a hundred ISPs competing for customers—many of the ISPs with niche businesses going after a very specific tiny slice of the market. Due to that level of competition, the European fiber networks get practically every customer in their market since even the incumbent providers generally jump to the new fiber network.

That hasn't happened in the US. There is not one example in this country of a large telco or cable company agreeing to operate competitively on somebody else's network to serve residential customers. The large ISPs in the US will lease fiber outside of their footprint to serve large business customers, but they have never competed for smaller businesses or residents in each other's monopoly footprints.

This means that open-access networks in the US must rely on small ISPs. These small ISPs are generally local and mostly undercapitalized. The small ISPs have all of the problems inherent with small businesses. They often don't have the money or expertise to market well. They often have cash flow issues that put restraints on their growth. In addition, many of them don't last beyond the career of their founder, which is typical of small businesses in general.

Open access network operators have struggled in this country due to the nature of the small ISPs on their network. Consider the example in Chelan County, Washington that today has only one primary local ISP that is selling to residential customers. The network originally had almost a dozen ISPs, but over the years the ISPs either folded or were purchased by the remaining ISP. It's hard to even call the Chelan County network open access any longer.

A similar thing happened in Provo, Utah before the city sold the network to Google Fiber. The network had originally attracted eight ISPs, but over time they ended up with only two. It's hard to make an argument that a network with so few choices is open access—because the whole purpose behind open access is to provide customer choice.

Examples of Open-Access Networks. Following is a list of some of the other municipal open-access networks in the country.

- The Public Utility Districts (PUDs) in Washington State. These are countywide municipal electric companies. The PUDs are restricted to offering open access due to legislation passed a number of years ago. There are numerous different open-access models being tried at various PUDs, with the largest networks in Chelan County PUD, Grant County PUD, Douglas County PUD, and Pend-Oreille PUD.
- Utah has a similar law that applies to municipalities. This led to the creation of an open-access fiber business in Provo and another network called Utopia that serves a number of small towns. The Provo network was losing a lot of money and the city decided to sell the network to Google Fiber for $1. Utopia is still operating a wholesale business but had significant financial problems since inception.
- A similar law was passed in Virginia after Bristol Virginia Utilities (BVU) built a retail fiber network. The legislation grandfathers BVU as a retail provider but only allows other cities to operate open-access networks. So far, the wholesale model has been adopted by a few cities, the largest being Roanoke, which offers open access on a limited basis to only parts of the city.
- Tacoma, Washington chose an open access model where the city is the retail provider of cable TV, but connections to the network for telephone and broadband are sold wholesale to ISPs.
- Ashland, Oregon operates an open-access network, but the city also operates as a retail ISP on the network and competes against a few local ISPs that sell on the network.
- There are a number of municipal networks that have built fiber rings, and which are promoting "open access" to carriers. For the most part these networks only service business customers.
- Other communities have tried to build open-access networks but then were unable to find any ISP partners. For example, Longmont, Colorado tried to launch an open-access network, but when they were unable to find ISP partners, they now offer full retail services directly to residents.
- One of the most interesting open access network stories is in Ammon, Idaho. The project is funded by asking homeowners to contribute $3,500 up front to pay to connect to the network. This has significantly lowered the cost of the network such that broadband prices are relatively low. The downside to this model that only homes that can afford the payment are connected –

and only neighborhoods where there are enough homes willing to pay the fee get connected. This results in a network where homes that can afford fiber get it while others don't. It's a model that works, but most other communities that have considered the model have decided that they must find ways to bring fiber to every neighborhood and to every home – many communities are aghast at the idea of the local government creating broadband 'haves and have-nots'.

Advantages

Customer Choice. The most appealing aspect of an open-access network for a community is that it offers a variety of choices to customers over the same fiber network. The further hope on an open access network is that having greater competition will lead to lower prices and better customer service.

Disadvantages

Retail/Wholesale Revenue Gap. There is a big difference in the revenue stream between collecting the retail revenue stream from customers versus collecting only the fees charged to ISPs. For example, the average retail revenues on a fiber network serving residential customers might be over $120 per customer per month. The average revenues on an open access network are far smaller, at perhaps $30 per customer per month.

There are some cost savings for the network owner in an open access environment. They don't have to provide the triple play products. They don't have to see, bill customers, or provide customer service. But it's still extremely difficult for the network owner to be profitable with open access. The network owner still has to cover the full cost of debt. The network owner still has to maintain the fiber network and provide the core electronics. In most scenarios the network owner has to continue to install fiber drops and/or customer electronics.

Not Many Quality ISPs. Every open-access network that has been tried in the US has had trouble finding and retaining ISPs. Some examples are discussed above. The ISPs willing to operating in this environment are generally small and undercapitalized. Open access forces these ISPs to compete against other small competitors, which holds down end-user rates, but which then also puts pressure on ISP earnings. Two of the largest open-access networks in Chelan County, WA and Provo, UT essentially lost most of the ISPs on their network over a decade of operations.

Leads to Cherry Picking. The open-access model, by definition, leads to cherry picking. If ISPs are charged a fee to use the network, then these fees will generally lead them to not want to sell to low-margin customers. All of the open access networks listed above report this as an issue. The only way to get broadband to everybody in an open access network is for the network owner to lower their fees – and that makes it impossible to pay for the network. CCG has never seen an open access network that has a customer penetration rate as high as would be expected if the same community had a municipal retail provider. Cherry picking means fewer customers on the network.

No Control over Sales Performance. The network owner in an open-access network has no control over the customer sales process. That means they only do as well as the ISPs on the network. In CCG's experience, having talked to many of the ISPs that operate on open access

network, the ISPs tend to not have the resources for major marketing efforts or else they only want to serve a niche market and don't try to mass market. A retail ISP that owned the same network would try to sell to everybody – but that never happens on an open access network.

Stranded Investments. One interesting phenomenon that especially affects open-access networks is stranded investments at customer premises. When a customer moves or stops service with a network operated by one entity there is usually a big push to reestablish service at that location. However, in an open-access network many ISPs don't make this same effort. Therefore, over time there grows to be an inventory of homes and businesses with a fiber drop and ONT that are no longer used and are not contribution to the cost of the business. CCG knows of one of the larger open-access networks with 25,000 active customers that has 5,000 locations where the fiber has been abandoned with no current service.

Public-Private Partnership (PPP)

In this scenario a municipality would partner with a single commercial ISP to operate the business. There are almost endless variations on this concept and the studies examined a few of the most common relationships:

- At one extreme, the municipality builds the whole network but hires an ISP to operate the network.
- The municipality builds the fiber network and fiber drops and the ISP partner provides customer electronics and everything inside the home.
- The municipality builds only the fiber and the ISP supplies everything from the street to connect to the customer.
- There are some claimed PPP arrangements that really aren't partnerships. For example, some cities have taken steps to help an ISP succeed. That might mean being an anchor tenant and giving all of your business to the ISP on a long-term contract. It might mean contributing land, building space or other hard assets. It might mean relaxing construction requirements such as permitting, locating, and inspections to lower the cost of building the network. But if a municipality doesn't put any assets or funding into a fiber network, then it's really not a partnership.

PPPs initially arose internationally as a way to finance infrastructure needs that local, regional, or national governments could no longer pay for up front or could only insufficiently finance from taxes, bonds, or other methods of raising government monies. Taken as a whole, governments in the US are today unable to fund all of the needed infrastructure and so more and more PPPs are being formed to finance infrastructure. There have been estimates that collectively there are several trillion dollars more of needed infrastructure projects in the country than could be financed by the combined borrowing power of all of the state and local governments added together.

There are three major ways that a fiber PPP can be structured depending upon who pays for the network. A fiber network could be mostly funded by the government, mostly funded by a commercial entity, or funded jointly by both.

PPP Funded Mostly by a Government. There are not many examples of this in the US. This scenario means that a government takes all of the financial risk of building a network and then hands the operations to somebody else. This is the arrangement that is in place in the Google

Fiber partnership with Huntsville, Alabama. Reports are that Google Fiber is responsible for the costs inside the customer premise and the city for the rest. There are similar partnerships between Ting and Charlottesville, VA and Westminster, MD. CenturyLink has reached a similar arrangement with Springfield, MO.

PPP Funded Mostly by the Commercial Provider. There are many examples where a commercial provider built a fiber network and doesn't consider the venture to be a PPP. Generally, any ISP that uses the normal avenue of obtaining rights-of-way and then adheres to the franchise and permitting processes in a city are free to build fiber.

It's also not a PPP if a government gives concessions to attract an ISP. The first few markets for Google Fiber are reported to have this arrangement. It's widely believed that Kansas City granted major concessions to Google Fiber to get them to build fiber there. This may have been things like free rights-of-way, expedited permitting, use of city land for placing facilities, etc.

For this kind of arrangement to be a traditional PPP, a municipal entity would have to get something in return for the concessions they make to an ISP. This could be almost anything that is perceived to be of value. It might be free or reduced telecom prices provided to government buildings or fibers connecting government locations together. It could also be the ISP agreeing to help the city meet some social goal, such as building out to poorer parts of the city that a normal commercial ISP might otherwise would not have considered.

PPP Funded Jointly. When a municipality and an ISP both contribute cash or hard assets to a venture then it's clearly a PPP. There are a number of examples of telecom PPPs working in the country today. Such partnerships are structured in many different ways and following are a few examples.

- Zayo partnered with Anoka County, MN. This is a suburban county just north of the twin cities. Each party contributed money to build a fiber network together. The county received access to a 10-gigabit network connecting all of its facilities and Zayo received connections to all of the major business districts. Zayo owns the network, but each party has affordable access to the whole network as needed. Each party is also allowed to build outward from any point on the jointly built network at their own cost.
- Nashville, TN partnered with a commercial fiber provider to build fiber to city locations as well as to commercial districts. Both parties made capital contributions. The city eventually sold its interest in the network but still retains fiber to most city buildings.
- There are dozens of small cities where the city built an initial fiber network to connect to schools, water systems, etc. and now allows commercial providers to build spurs from the city-owned ring. The financial arrangements for this vary widely. Sometimes the two parties just swap access to various locations on each other's network and in other cases they each pay to lease access on the other's network. However, both parties share the same network, portions of which each has funded.
- In Sibley and Renville Counties, MN, the counties, cities, and townships together contributed an economic development bond which is being used to fund 25% of the cost of a fiber-to-the-premise network.
- Several of the Public Utility Districts (PUDs) in Washington have built fiber into business and residential neighborhoods but then allow ISPs to build fiber loops and electronics and connect to the core network.

- Google Fiber recently reached an agreement with West De Moines, Iowa where the city will build empty conduit up to the side of each home and business, and Google Fiber will pull fiber and offer service to everybody in the city. The network is also open to other ISPs and is the first example we know of a dark conduit open access network.
- There are hundreds of examples of government entities that have built fiber routes jointly with some commercial enterprise. This is referred to in the industry as fiber sharing and generally each contributor to the fiber route will get some specific number of pairs of fiber for their contribution. For example, this is a common practice with school system that build fiber networks.

There are several kinds of contributions that a government can make to somebody else's fiber network. This could include cash, real estate, excused fees, or sweat equity. Governments can allow a commercial provider to use parcels of lands or give them an existing building. Excused fees might mean not charging for something that would normally be due such as permitting fees or property taxes. The government could excuse payments for poles, conduit, existing fiber, or towers. It could mean the commercial provider might not need to pay taxes or fees for some period of time, as is often done in many economic development projects. Sweat equity is assigning a value to the time contributed by the city. For example, we've seen a city assign extra employees for free for tasks like the permitting process during a major fiber construction project.

There are almost unlimited ways to model and form a public-private partnership. The underlying requirement is that the business must be profitable for the private commercial partner. Commercial providers expect a healthy rate of return on any investment they make in the business. Most commercial companies won't invest in a business that doesn't return at least a 20% to 30% return on their investment.

Advantages

Smaller Government Investments. The extent to which a private partner funds even a portion of the network reduces the needed investment from the public partner. A private equity partner can bring cash to the business that might be hard to raise elsewhere.

Disadvantages

Matching Goals and Expectations. One of the primary reasons why there are not a lot of telecom public-private partnerships is that it's often difficult to reconcile the differing goals of the two sides. The commercial partner is generally going to be very focused on the bottom line and returns while the community part of the business often has goals like community betterment and lower rates. One of the biggest sticking points in creating PPPs is that cities want fiber built past every home, which ISPs prefer to build to only selected neighborhoods. It's often very difficult to put together a structure that can satisfy all of the different goals.

Expensive Money. Commercial partners often have a goal to make at least a 20% return on equity, and that makes external equity an extremely expensive source of funding.

Tax Free Funding Issues. It's difficult to obtain tax-free bond funding to support a PPP. Tax free financing can't be used for a project that benefits a commercial entity.

Process Driven by Commercial Partner. Communities seeking equity partners for a public-private partnership fiber optics project will have fewer choices for the structure of the business since the external partner will probably demand a for-profit business structure as a likely pre-condition for investment.

Length of Partnership. Many commercial investors only make investments with a mind to eventually sell the business to realize the cash value. This may be difficult to reconcile with the long-term desires and goals of a community-based fiber optics project that might want to own the network forever.

Governance Issues. It's a challenge to develop a governance structure that can accommodate the government decision-making process. Governments generally have to go through a defined deliberative process including holding open meetings to make any significant decisions. This does not match well with the decision-making process and timeline for a commercial partner. A commercial partner might want to make a decision in days when the public process might not be any faster than several weeks.

Maintaining Local Control.

One of the biggest issues faced by any municipality that enters into a broadband partnership is maintaining control. If a community is going to spend millions to finance a fiber network, it's natural to want to be able to control things like setting broadband rates or determining products and policies intended to provide broadband to low income households.

However, entering into a partnership invariably is going to mean partnering with a commercial ISP. That's going to be an entity that has already successfully operated a broadband business before. Partner ISPs are going to automatically assume that they are going to get to call all of the shots related operating the business – and most ISPs are not going to be interested in entering into a partnership where that is not the case. ISPs have a natural mistrust of government entities because they assume that government will make decisions based on pleasing politicians or pleasing the public, and not based upon being profitable. And ISPs are generally right in that assumption. Municipal ISPs operate with different goals than commercial ISPs. There are numerous examples of municipal ISPs with super-low rates or with policies that provide big discounts to disadvantaged households – things that commercial ISPs are not easily willing to do.

There are only a handful of ways for a municipality to maintain operating control of a broadband business:

- Go it Alone. It's intimidating for a municipality to contemplate operating a competitive ISP business alone. But there are cities that have successfully done so. There are many keys to being a successful ISP, but the two most important ones for a new municipal ISP are to hire the expertise needed to operate the business, and to find a way to isolate the business from politics.

  Expertise is vital because there are dozens of mistakes that a new ISP can make, all which may lead to financial disaster. While new commercial ISPs also make some of these same mistakes, most commercial ISPs that have been successful have found a formula for success that works for them. An experienced ISP is far less likely to make any big or fatal mistakes.

The harder step is to isolate the business from politics. A municipal ISP has to have a structure that makes it hard for politicians to do things like cut rates to be popular during an election. The easiest way to do this is to structure the ISP to have a separate Board that makes operational decisions. Such a Board must be given the legal authority to take steps like setting rates – and that can provide a cushion against interference from elected officials.

- Operator for Hire. An operator for hire is just what it sounds like. A municipality could build a fiber network and hire an ISP to operate the business. An operator for hire would have no ownership and would be a vendor and not a partner. They would be paid to operate the business in a way directed by the municipal owner.

  The hard challenge of this is that there aren't many ISPs willing to accept this role. Most ISPs want a partnership relationship where they can share in upside profits. Unfortunately, if an ISP wants to share profits, they are not going to want a municipal partner making policies that cut profitability.
- Partner with Other Municipalities. The other way to maintain some control would be launch the business as part of a consortium of other municipalities. A municipality might not have total control in this situation, but they would likely be part of a governing Board comprised only of other municipalities. It's likely that such a business is going to have policies that the member municipalities will like.

It's hard to picture a true public-private partnership option where a municipality would retain control. It's unrealistic to want to benefit from the experience of a commercial ISP partner but then not respect their goals which are to be profitable. This is why it's so challenging to create partnerships for any purpose between municipalities and commercial entities. Eventually the differing goals of the two parties tend to cause major friction.

B. Services Considered

Following is a discussion of the products and services considered in the study.

Telephone Services (VoIP)

Voice over IP (VoIP) is a digital telephone service that transmits a telephone call to customers using their broadband connection rather than establishing a more traditional analog telephone connection. VoIP has been around the industry for a few decades. The first major seller of VoIP was Vonage, which still delivers VoIP over the open Internet. Most VoIP arrangements now use secure private broadband connections rather than the open Internet.

The study assumes that the retail provider of telephone service will purchase wholesale VoIP. This product is available from numerous vendors. These vendors own a digital telephone switch and they deliver calls to and from customers from that switch to the ISP. Our clients tell us that offering voice is still mandatory when selling to businesses since many businesses insist on having a vendor that delivers all of their communications needs.

The alternative to using VoIP is to buy a telephone voice switch and then establish connection between that switch and the public switched telephone network. These connections are referred to in the industry

as “interconnection.” We’ve found through a number of studies that it’s hard to justify buying a switch and paying for interconnection costs unless a service provider expects to serve at least 5,000 telephone lines.

High-Speed Bandwidth (in excess of symmetrical 100 megabits)

The network design for the studies can deliver a symmetrical gigabit bandwidth product to every customer in the service area. Additionally, the network can provide speeds up to 100 gigabits for the largest businesses, although there are probably none that want more than 10 gigabits. It’s anticipated that there would be residential and small business broadband products at speeds less than a gigabit. The study assumes the basic product is 100 Mbps, but that could easily be changed some other speed.

Internet Services (ISP, email, web hosting, etc.)/Security and Authentication Requirements for Business

It was traditional in the industry for an ISP to provide all services related to the Internet as part of their ISP service. This included such things as email, DNS routing, virus checking, spam filtering, etc. Most ISPs also offered services like helping customers create web sites and then hosting them at the ISP headend. A decade ago, there was also a booming ISP business line of providing off-site storage for customer data.

The majority of small ISPs now outsource these functions and product lines. None of these functions are profitable when considering the cost of labor to perform them. In addition, all of the basic ISP functions are now available as a cloud service or from a large centralized help desk company. Most small ISPs have decided that their primary function ought to be maintain a network designed to provide minimal downtime and leave these various ancillary services to somebody else.

A good example of this is virus checking and security. Virus checking today means not only trying to keep viruses away from customers, but today it means protecting against larger threats to the ISP such as denial of service attacks or the many other kinds of hacking. Most ISPs have found that they can buy better protection from a company that does this function for a hundred small ISPs rather than trying to do this themselves. They’ve found that there is no particular glory from doing these functions well, but there is a huge liability if they perform these functions poorly.

The feasibility studies assume these functions are outsourced. There is nothing to stop an ISP from tackling some or all of these tasks, but that would be contrary to where the rest of the industry is headed.

Managed WiFi

Many small ISPs now offer managed WiFi, which means that the ISP installs and controls the WiFi network at the customer premise. It’s become obvious over the past several years that a large percentage of the problems experienced by customers have been due to poor WiFi networks rather than to the broadband connection. ISPs began selling a product where they would install a high-quality WiFi modem. If a house is large, the ISP installs a meshed network with several networked WiFi routers. Since these routers are part of the ISP network, they can monitor the performance to make sure they are

operating properly. Many ISPs also offer related services like helping customers connect new devices to the WiFi system – something that can be done easily from the ISP end.

This is a profitable product. A quality WiFi router costs around $100 and ISPs are charging between $5 and $10 per month for the service. CCG know of ISPs that have already sold this product to more than 70% of their customers.

Other Future Products

Today many ISPs are expanding their product lines to add additional product lines that rely upon broadband. Perhaps the best example of this is Comcast. They now offer a wide range of new products. For example, they have sold home security monitoring to many millions of customers. They are now probably the largest single nationwide provider of smart home products and they have a line of products such as smart lighting, smart watering systems, smart door locks, smart thermostats, etc. Comcast has also been selling a cellular product to compete with the big wireless carriers. Comcast even recently tested bundling solar panels with their other products in a few markets.

CCG finds it likely that any ISP operating a fiber network will eventually offer some of these same kinds of products along with products that have yet to be developed. This could include things like medical monitoring to help the elderly live in their homes longer. It might involve intensive gaming connections, including virtual reality and holograms.

It's impossible to build a business case for products that have yet to be developed, but it's reasonable to believe that any sizable ISP will offer new products over the time frame of this study. Our business plans incorporate a generic small future revenue for "new products" which is undefined. The assumptions used will be described under the revenue assumptions below.

Wholesale Bandwidth Products

Wholesale bandwidth products are those sold to other carriers or to large business customers. Such products can be a major source of revenue for ISPs in larger cities. For example, CenturyLink is one of the biggest sellers of wholesale bandwidth products in the country after their merger with Level 3.

Following are the kinds of customers that buy wholesale connections:

- Cellular towers in most markets buy fiber connectivity and bandwidth to connect to the regional cellular hubs. However, there has been a big effort by both Verizon and AT&T to build fiber to cellular towers in many markets.
- Nationwide businesses like hotel chains, banks, manufacturers, etc. usually have an arrangement with a single ISP to serve all of their locations nationwide. These ISPs will consider buying from a new fiber network.
- Complex businesses like hospitals or the government labs in Falmouth. These entities generally have complex needs and look for ISPs that can provide more than just bandwidth. Most entities want to buy a second fiber connection from a different provider if it's available.
- Businesses with multiple locations in the same community like to have a locally interconnected network, much like what OpenCape has provided for the town government. This might include grocery stores, local banks or other businesses that might operate multiple locations.

- Giant bandwidth users. This could be things like data centers or large stock trading houses that want large bandwidth with low latency.

Products

Following are the typical wholesale products that are sold to the above kinds of businesses:

- Dark Fiber. This involves selling a fiber that is not connected to electronics. The ISP buying the dark fiber is responsible for providing and operating the electronics necessary use the fiber. Dark fiber might be sold by the mile of fiber, or else by a set fee per dark fiber connection.
- Transport. Some wholesale providers only sell connections between points A and B. This might mean the retail ISP might need to buy several transport paths to serve a customer – for example, there might be one transport connection between and end-user connection and the wholesale hub and a second transport connection between the wholesale hub and the ISP hub.
- Dedicated Bandwidth. Dedicated bandwidth means that the customer doesn't share it with anybody else. The typical products on an FTTP network share bandwidth at some point in the network, but some businesses are willing to pay to buy raw, unshared bandwidth. The network is capable of delivering speeds up to 100 Gbps.

We've included a small amount of wholesale revenues included in the studies. For now, many such entities, but not all are served by OpenCape, but even those entities would likely be interested in a redundant connection.

Offering Voice and Video

One of the questions asked by the RFP is if its reasonable for a new ISP to offer voice and video service. A new ISP can be intimidated by the complexities of these products.

Offering Voice. Until a decade ago, anybody that wanted to offer telephone service had to go through the process of becoming certified as a voice provider and buying and activating a telephone switch that would provide these services to customers. This option is still available to any ISP today and CCG still helps a few ISPs enter the voice business each year.

However, the more common approach today is to buy wholesale voice products, where some outside entity does all of the technical and backoffice work necessary to offer the voice product and the ISP then delivers the wholesale voice product to customers. There are a few different ways this can be done:

Wholesale Voice over IP (VoIP). There are a number of entities in the country that offer wholesale VoIP. The best vendors make this as easy as possible for the ISP, and the wholesale product usually includes all of the following:

- The VoIP provider will be a regulated CLEC (competitive local exchange carrier) and will take care of all needed regulations. In this case the ISP will not need to be certified by the state regulatory body (even though a few states would still encourage the ISP to do so).
- The VoIP provider supplies the voice switch. This is the device that makes and receives calls. For most VoIP providers today the voice switch is located in the cloud and the ISP communicates to and from the voice provider using a dedicated VPN through the normal connection to the Internet. It's also possible to a VoIP provider to place a small switch

box at the ISP that would allow local customers to talk each other inside the ISP network if the connection to the IP backbone is severed.

- The VoIP provider provides all interconnections to the world. This means that the VoIP provider will make the needed connections to 911. The VoIP provider will provide for ancillary services like operator services or calls to information. The VoIP provider will bundle in a long-distance service to place and complete long-distance calls. The VoIP provider will also make the needed connections to complete local calls within the ISP's market.
- VoIP products are generally simplified compared to traditional telephone service. For instance, a VoIP might only offer two residential products – one with no long-distance and one bundled with unlimited long distance. The VoIP provider will likely offer the most common types of telephone service used by businesses such as vanilla business lines, or trunk lines to support a key system or PBX. But VoIP providers do not usually support complex business phone systems such as the phone systems that might be used by a university or a big hospital.
- The VoIP provider will take care of functions like number portability that allow a customer to keep an existing phone number when changing to the ISP. The VoIP provider will tie into the national databases so that caller ID will identify the name of calling parties. They will also connect to databases that enable calls to 800 numbers and other similar industry routing databases.
- The VoIP provider will make sure that customers are listed in the white pages and are listed in caller ID databases.
- VoIP providers typically make it easy to integrate their product into the ISP. For example, they will provide software that can be tied into the ISPs billing system so that an order taken by a customer service rep is automatically schedule for the VoIP provider.

Resold Traditional Voice. ISPs sometimes buy traditional voice service from a nearby telephone company that is willing to sell their voice products wholesale. This might be a small regulated telco or another CLEC. These arrangements can be all-inclusive like the description above for VoIP service – but they usually are not. Each item on the above list would be negotiated and the ISP might take on some of the functions. It would be common in this case the ISP to become a regulated CLEC.

The drawbacks to the kind of arrangements is that the process is not likely automated and integrated since the seller of the voice provider probably doesn't sell enough of the service to justify spending the money to automate. This means that it will require more work from the ISP to install, change, or deactivate a telephone customer.

But there are upsides for connection to a more traditional voice switch. A traditional switch contains dozens of types of telephone lines and thousands of types of features that can be offered to business customers. VoIP providers often won't support things like Fax lines. A traditional voice switch product is often the preferred choice for ISPs that sell primarily to businesses since they can usually match any product that customers already have and want to keep.

Offering Video. There is no mature market for buying wholesale video. That makes it much more of a challenge for a new ISP to offer video. But there are still new ISPs that offer video, particular those who sell predominantly residential service to a customer base that expects video from their ISP.

Traditionally, cable TV is delivered to customers though a set of electronics the industry calls a cable TV headend. The headend performs several functions. First, it has satellite dishes that pull national programming from satellites. The headend also needs to find a way to connect to local network stations to be able to air the local channels. The headend then changes the format as needed of the signals to deliver to customers. Signals from satellites are generally compressed the signals must be decompressed and then formatted into whatever format the ISP's technology requires. The headend communicates with customers to deliver only the channels that a customer has subscribed to and wants to watch at a given time. The headend makes special connections with customers that want to buy one-time programming like wrestling matches. The headend generally communicates with a billing system to deliver the records needed to bill each customer.

We haven't heard of a new ISP that has purchased a new video headend in the last decade. The minimum cost of a headend is at least $2 million and can be a lot more depending upon the technology used to communicate with customers.

There are also other requirements that an ISP must meet to be considered as a cable company. The must register with the FCC and comply with some annual reporting requirements. They must obtain a franchise agreement in order to provide cable TV service in most towns. The process of buying programming is extremely complicated and most small ISPs join the National Cable Television Cooperative (NCTC) which buys programming for hundreds of small ISPs. It's not cheap to join the cooperative, and even if somebody joins the cooperative, they will sign a stack of programming contracts several feet tall that layers on numerous obligations due to programmers. It can take well over a year for a new ISP to negotiate contracts directly with programmers, and in doing so they generally pay the highest prices and get the most unfavorable terms. Finally, an ISP that wants to deliver video must sign a contract with each local network station that is within airwave reach of the market. This process is called the retransmission consent process.

If the ISP offers some form of traditional cable TV, the ISP will have to provide settop boxes to customers. Most ISPs charge at least $5 per month for each settop box, and since the boxes generally cost about $130, there is a decent margin if customers keep the boxes for a long enough time.

The worst thing is that after jumping through all these hoops, there is little or no margin in the cable TV product, and many small operators are losing money on video. This has convinced several small ISPs to drop the cable product.

But there are still a few ways for a new ISP to get into the video business:

> Buy Programming from a Nearby Headend. This is similar to ISPs that buy voice from a nearby telco. It's fairly common for ISPs to pay an existing headend to receive the signals from satellites for them. In the industry that function is referred to as transport.
>
> Under this arrangement, the ISP must go through all of the steps described above. They must join the cooperative or otherwise arrange to buy content. They must execute a franchise agreement in the local market and must negotiate a retransmission agreement with every local station in the region.

There is also a cost to this arrangement. An ISP must have at least a 10-gigabit data connection to the headend in order to transmit all of the programming. The ISP also might have to buy gear to remodulate the signal if they use a different customer technology than whatever is used by the headend provider.

In this arrangement and ISP is generally stuck with the same channel lineup that is carried by the headend owner. However, channel lineups don't vary a lot for small cable programmers because the programmers dictate a lot of the lineup, including channel placement.

Buy Wholesale Programming. There is a fledgling wholesale programming market developing and there are a few wholesale providers of programming. The vendors providing this service are trying to make it easier for ISPs, much like is done by the VoIP wholesalers. The cable wholesaler might obtain the need regulatory status and negotiate the cable franchise and the retransmission agreements. The obtains all of the programming and the ISP would not need to sign programming contracts or join the cooperative.

Under this arrangement the ISP will have the exact line-up offered by the wholesaler, since that vendor is the regulated cable provider. Generally, the ISP would be required to mention the wholesaler on customer bills, with something like, "Cable TV powered by X."

Offer OTT Service. This means offering an Over-the-Top video service like Sling TV or YouTube TV. There was a recent announcement that Windstream, a fairly large telco, is now offering Sling TV, Fubo TV, or YouTube TV to new customers instead of traditional TV. Customers must have a Roku stick or box to receive the service. This basically takes the ISP out of the cable business. There are no regulations to comply with. There are no programming contracts. There are no settop boxes.

The downside to this is that there is likely also little or no margins in the product. However, it does allow an ISP to offer a video product to those that want to buy everything from an ISP rather than subscribe individually.

For now, these products are not yet available to smaller ISPs and Windstream is the smallest company we've heard that offers this. However, we expect that to change and within the next year we're hopeful this could be an option for small ISPs that want to act more like large ISPs.

C. Financial Model Assumptions

Incremental Analysis

It's important to note that all of the projections were done on an incremental basis. This means that the studies only consider new revenues, new expenses, and new expected capital costs. This is the most common way that businesses of all sorts look at potential new ventures since the incremental analysis answers the question of whether any new business line will be able to generate enough revenue to cover the costs.

It's important to understand what an incremental analysis shows and does not show. An incremental analysis is basically a cash flow analysis. It looks at the money spent to launch and operate a new venture and compares those costs to the revenues that might be generated from the venture.

An incremental analysis is not the same as a prediction of what the accounting books of a new venture might look like. For example, if one of the existing ISPs in the area was to undertake one of these business plans, they would allocate some of their existing overhead costs to the new venture. The classic textbook example of this is that some of the existing cost of the general manager of the ISP would be allocated to the venture in the accounting books. However, the cost of the salary of the existing general manager is not considered in an incremental analysis since that salary is already being paid by the existing business. If these studies were to show an allocation of the general manager, then they would not be properly showing the net impact of entering the new market.

Timing

Timing is critical to any business plan. The faster that a business can start generating revenues the sooner it can cover costs. These studies are somewhat conservative in the predictions of the speed of the roll-out of the business venture. That means that if an ISP could get customers faster than predicted by the projections that they can have better results than we've shown.

All scenarios anticipate that the first customers will be added to the new networks in January of the second year after starting the project. It might be possible add some customers in the fall of the first year with careful planning and a smart construction plan.

Following are the major milestones as predicted by these forecasts:

- Financing: All of the forecasts assume that the financing is available in January 2021. This is illustrative only and could be changed to any other future date.
- Construction: Fiber construction is done during the summer and fall of the first year. Core construction of the network is done in the summer during the spring and summer after financing. In the fiber everywhere scenario construction carries through the second year.

Pricing Strategy

We assumed that the products would be as simple as possible. As the incumbent telephone company Verizon does not have simple pricing and offers hundreds of different variations of telephone products in the market. We assumed that a new business would offer only a few options. For example, for residential service we have assumed only two products - a basic telephone line and a telephone line with unlimited long distance.

There are a number of different pricing strategies used around the country by various ISPs for broadband. Following is a discussion of some of the more common models and a discussion of the pros and cons of the various approaches to pricing.

- Competition. When building broadband into a market that already has existing competition it's important to consider the prices of the competition as well as predicting how they might react to competition.

- Demographics. This asks the important question of what people are willing to pay for broadband. They residential survey showed that some portion of residents are price conscious, but that was not an overriding situation for the community as a whole. As somebody who works for a lot of ISPs, I observe that a lot of ISPs are not good at this. I regularly see ISPs that set prices too low based upon the assumption that nobody will buy – but I see other markets with higher prices and similar penetration rates.
- General Pricing Philosophy. ISPs often come to the market with predetermined notions of how prices ought to work. A pricing philosophy is often based upon the overall goals for the business and the way that an ISP thinks about business. For example, some ISPs have a goal of maximizing cash flow or of maximizing profits (not the same thing). Other ISPs are more community based and want to bring fast broadband to as many households as possible. These basic philosophies are often the driving force behind a pricing strategy.

  For examples, some ISPs believe in simplicity and only offer a few products. Other ISPs stress bundles and price accordingly. Some ISPs think that the way to sell a lot of services is by having low prices. Other ISPs think it's better to have higher prices and fewer customers. Some ISPs think it's important to the community to have a low-priced product for low-income households. Some ISPs charge the same prices to residents and businesses – others charge businesses a lot more.

Those various philosophies result in a couple of different pricing schemes that we see in the marketplace. A few key examples include:

- One Broadband Product. A few ISPs like Google Fiber, Ting, and a handful of smaller ISPs have one broadband product. They sell a gigabit of speed for a set price. Google Fiber had gone to a 2-product offering, but recently announced they are returning to the flat-rate $70 gigabit. Any ISP with this philosophy is likely not trying to capture a huge share of the market but is content to sell a high-margin product to a smaller number of homes.

- Low Basic Price. Some ISPs set the price for the basic product low. This is done more often by municipal ISPs, but there are small commercial ISPs with the same philosophy. As an example, in these markets somebody might set the price of the basic product on the fiber network as something like 50 Mbps for $40.

  CCG Consulting has access to the prices and the resulting customer counts from nearly 200 ISPs and what we have learned is that most customers will buy the basic broadband product as long as the speed is okay. A basic product set at 5 Mbps likely wouldn't sell, but in today's market a product with a decent speed like 50 Mbps will be perceived as acceptable to most households. Depending upon what we call the "steps" in pricing, a low-priced introductory product is likely to get 70% - 80% of all customers.

  The consequences to an ISP of low prices is that they likely get a higher penetration rate than an ISP with market rates, but they are also leaving a lot of money on the table. Consider the broadband rates in the market today.
  - The "basic" broadband product for a new Comcast customer that buys standalone broadband is $83. There are customers in the town that are likely grandfathered on older Comcast products with the most likely product being a 60 Mbps connection at $73. However, new customers can get a significantly lower rate through buying from the web.

As this report went to press Comcast was advertising a price of $49.99 for 200 Mbps for new customers. With the $14.00 WiFi Modem that product is priced at $63.99. Many customers repeatedly negotiate with Comcast over time for similar low rates.

- Verizon only product in Falmouth is DSL priced at $49.99 per month. Verizon typically also bills a $5 to $7 fee for use of a modem.

It's our opinion that a new ISP in the town would be competing against Comcast's "special" price, which is at $63.99. Comcast would likely widely offer that product in the town to compete against a new fiber overbuilder. We thus started our analysis with prices that start at $60, a modest discount from Comcast.

- Price Steps or Tiers. One of the key aspects of pricing other than the price of the lowest tier is the price steps between products. Consider a $60 starting broadband product and the following tiered price structures:

	Rate 1	Penetration	Rate 2	Penetration	Rate 3	Penetration
50 Mbps	$ 60.00	95%	$60.00	80%	$60.00	60%
200 Mbps	$ 90.00	4%	$75.00	15%	$70.00	30%
Gigabit	$120.00	1%	$90.00	5%	$80.00	10%
For 1,000 Customers:						
Revenue	$61,800		$64,000		$65,000	
Increase			4%		5%	

The difference in the steps or tiers is that "Rate 1" prices are set $30 between products, "Rate 2" is at $15, and "Rate 3" is at $10. The impact of smaller tiers is that it's easier to upsell customer to faster products. I derived the relative rate structure for the various tiers based upon what I've seen at various ISPs. Customers might voluntarily choose a fast product when the step between tiers is small, and they are more likely in the future to upgrade anytime they feel their speed is bogging down or inadequate. Conversely, when the steps are too large, customer buy and then stick with the lowest-priced tier rather than jump their bill too much.

It's an interesting phenomenon and to some degree is psychological. Consider in the examples above that more customers are likely to buy the gigabit product in Rate 3 for $80 than will buy the 200 Mbps product in Rate 1 for $80. Since both speeds are faster than what households likely need you might think there would be a small difference between the public reaction to the prices – but our experience is that penetration rates act much like the above tables. As a last note, the $60 base price in the above tables is still below market rate.

We have seen that multiple price tiers confuse customers. The above examples have tiers with three prices. We know of ISPs with seven to ten price tiers and in looking at their penetration rates we see that this confuses customers. We have seen the most effective rate structures having no more than four tiers, which can be explained to customers on a fiber network as fast, faster and fastest.

- Setting Business Rates. Philosophies vary widely on business rates. The incumbent telephone companies and cable companies generally charge a lot more to business than to residential customers. At one time the philosophy behind this is that businesses consume more resources

and cost more to serve than residential customers. That's still true for medium and large businesses, but most ISPs will tell you that the average home today uses considerably more bandwidth than the average small retail store. The exception might be a coffee shop supporting a public hotspot, or a business that deals in large files like photographers or engineers.

We know a few ISPs that charge the same rates to businesses and residences, although that is rare. Most ISPs follow the incumbent pricing practices but offer a decent discount from the incumbent prices.

One thing that a first-time ISP learns quickly is that incumbents don't have standard rates for businesses, but rather they negotiate them. It's not unusual to find two similar small businesses in the same neighborhood paying rates for the same products that are 50% apart. This creates a challenge for ISPs. Some ISPs set standard business rates that apply to all businesses and others set rates on a custom basis compared to what a business is currently paying.

The other thing that a new ISP learns quickly is that the large majority of businesses care more about reliability than price. They want their broadband and telephones to always work during business hours. They don't want to pay more than they can afford, but they are not afraid to pay for a quality connection. While a new fiber provider might see good appreciation for a fiber-based ISP saving them money, the chances are that they decided to change ISPs due to outages they have had in the past with their current provider – if they perceive fiber to be a more stable technology. One of CCG's clients recently did a survey of businesses in a new market and over half of them had experience a half-day or longer broadband outage during the last year. For most of them, this was the deciding factor they cited when they talked about the willingness to talk to a new network provider.

- Rate Bundles. The large cable companies are well-known for having bundles of products where they provide a discount to customers buying more than one product. Generally, customers have no idea which products the discount applies to. I would estimate that no more than 15% of the small ISPs that CCG works with provides a similar bundling discount. Most smaller ISPs set prices at rates they perceive to be competitive and don't discount them further. We know a few ISPs that built a business plan and forecasts upon straight rates and then found themselves in financial stress when a marketing person at the company decided they could sell more by offering discounts that weren't in the plan.

  Interestingly, Verizon recently announced that they are doing away with bundled rates for new customers. It will take a few years for customers with older plans to migrate to unbundled rates. Verizon describes the new rates structure as more open and honest and say that it is what customers want.

- Introductory Rates. The big telcos and cable companies are also well-known for advertising low introductory rates that increase dramatically after a term contract of one to three years. Most of the rates you'll see from these companies on the web or in advertising are the introductory rates, and the real rates of these companies are generally buried in the small print, if shown anywhere.

  Customers dislike the introductory rate process because they invariably get socked with a big unexpected rate increase when rates jump back to list prices. The time of big introductory

discounts might be starting to come to an end. AT&T decided last year to stop renegotiating customers to the low rates and when introductory offers end the company is sticking with the list rates. This has cost AT&T a few million customers on DirecTV, but the company says they'd rather have fewer customers that are profitable rather than maintain customers that don't contribute to the bottom line of the company. A few medium-sized cable companies have made this same change.

I don't know many small ISPs who have used this pricing philosophy. It requires having customers signing contracts and then ties up staff when those contracts end, and customers want to negotiate low rates again.

- Low-Income Pricing. This is covered in more detail Section I.D. of this report. Some ISPs, both giant ones and small ones offer products to low-income households. Most try to set rates to make it affordable, and most have some criteria for how customers qualify for the low rates, such as having students using the free lunch program. Most ISPs try to set the rates at a level that at least covers costs and perhaps returns a tiny margin.

Prices used in this Study

Telephone Rates

The studies used the following very simplified pricing for residential phone service:

Basic Local Line	$25.00
Line with Unlimited Long Distance	$35.00

We've assumed that both kinds of lines include a full package of features like voice mail, caller ID, etc. The above prices also include any extra fees that the incumbent telcos show separately on the bill, but which are part of the rate. These rates would not include true taxes on the service, such as the tax that supports 911.

Customers who buy the unlimited long-distance plans considered by these studies would be able to call anywhere in the country as part of their plan. Similar plans today often include Canada, Mexico, and even some other international locations.

The studies are less specific with business phone rates. The models have assumed an average monthly telephone revenue of $50 per business. There are a few larger businesses that would pay more than this, so the financial projections are conservative. It's worth noting that home businesses, including farms usually buy residential products for both broadband and telephone service.

Cable TV Products

Offering competitive cable TV in a new market is a challenge. If a small ISP offers cable at rates comparable to the incumbent, like Comcast, the product will lose a lot of money. Alternatively, an ISP in Falmouth could offer cable at a breakeven, which would likely mean rates $10 per

month, or more, higher than Comcast rates. I've elected to not put cable revenues in the financial projections for this reason.

This is not to say that an ISP might not decide to offer cable for competitive purposes in Falmouth. They might decide that it's needed to get customers. But if they offer cable at breakeven rates, doing so would not change the cash flows in the projections made for this study.

I would point out that most new ISPs do not offer cable. This goes from the largest overbuilders like Google and Ting down to new municipal broadband systems. Most smaller ISPs these days are instead helping customers find online streaming products that provide the programming that's important.

Broadband Products

The studies do not specify data speeds, but we assume that broadband over fiber will be far faster than any broadband available today in the rural areas. We have shown data speeds by 3 tiers. A typical mix of products in three tiers on fiber might be something like 100 Mbps, 250 Mbps, and 1 Gbps. The following rates match the 'Rate 2' pricing tiers discussed a few pages ago.

	Price	Percentage
Residential Fiber Broadband		
Tier 1	$ 60.00	80%
Tier 2	$ 75.00	17%
Tier 3	$ 90.00	3%
Business Fiber Broadband		
Tier 1	$ 75.00	75%
Tier 2	$ 90.00	15%
Tier 3	$105.00	10%

Most ISPs charge more to businesses for broadband, and the studies assume a $15 additive to business rates.

These would all be shared data products, meaning that the overall bandwidth to provide them is shared among multiple customers. This is not to say that the data path to a given customer is not secure, because the transmission to any specific customer is encrypted for privacy purposes. Still, there might be some business customers that will want a dedicated data product that is not shared with anyone else. The fiber network can accommodate this by providing such customers with an active ethernet connection. Prices for these services would cost a lot more than shared data services.

The financial models assume that the data products don't have data caps and provide unlimited broadband usage to customers. If there were data caps, then customers that exceeded those caps would be charged more than the basic prices. The only provider in the county today with a data

cap is CenturyLink DSL, but it's been widely reported that the company often doesn't bill for data overages.

Managed WiFi

This is a relatively new product that's been around for a few years. ISPs have found that one of the biggest problems with home broadband is due to obsolete or poorly placed WiFi routers in the home. A poor WiFi router translates to a poor broadband experience.

Many ISPs are now offering managed WiFi. This product places carrier-class WiFi routers in the home that are placed and operated by the ISP. High quality routers, and the placement of multiple routers for larger homes usually means better broadband coverage throughout a home. ISPs often assist customers when adding a new device to the wireless network. The managed WiFi routers provide a secondary benefit to an ISP because they provide a network monitoring location inside the home, meaning that the ISP is more easily able to pinpoint problems.

The studies assume a monthly rate for managed WiFi of $5.00 per customer per month for residences and $7.00 for businesses. It's further assumed that 70% of residents would buy this product and 80% of businesses.

Large Broadband Products

There are potential customers in the town that might buy larger bandwidth products. However, OpenCape is already serving many such customers. The studies are conservative and don't predict extra revenues from these kinds of opportunities. However, if fiber is built everywhere then it's likely over time that at least some such opportunities will arise.

One of the more interesting opportunities are small cell sites for wireless carriers. If there was fiber everywhere the carriers might elect to lease fiber from a new network – but there is an equal chance that they would instead build fiber instead to avoid long-term lease costs.

Network Capital Costs

The telecom industry uses the term capital costs to describe is the industry term for the cost of assets required to operate the business. The capital expenditures predicted in these models reflect the results of the engineering studies referenced in Section II.B of the report.

Below is a summary of the specific capital assets needed for each base scenario. The amount of capital investment required varies by the technology used as well as by the number of customers covered by a given scenario.

Capital for broadband networks include several broad categories of equipment including fiber cable, electronics for FTTP, huts and wireless towers, wireless electronics, and customer devices like cable settop boxes and WiFi modems. In addition to capital needed for the network, there are operational capital costs predicted in the projections for assets like furniture, buildings, computers, vehicles, tools, inventory, and capitalized software.

We have tried to be realistic, but a little conservative in our estimates, so that hopefully the actual cost of construction will be something lower than our projections. One way we were conservative was by adding a 5% construction contingency to the cost of the fiber.

However, it is important to remember that the engineering used to make these estimates is high level. The detailed engineering needed to be more precise is expensive and would involve having an engineer examine all places in the potential network to look at local construction conditions. That kind of engineering is generally not done until a project is ready for construction. Instead, the engineering was done using some field examination of the county, along with maps and other tools. We have made many such estimates over the years and we know that this level of engineering is generally good enough to assess if a project is worth further consideration.

The studies all assume that the provider of service will not build a new cable TV headend or buy a new voice switch for the provision of cable TV or telephone service. If the new provider is an ISP that already offers those products elsewhere, the assumption is that they would transport in the products over the fiber backbone. These services are widely available today on a wholesale basis.

Following is the capital required for the base case for each of the three primary scenarios. These represent the capital expended during the first 5 years, which for most projects are covered by borrowing before the business becomes cash positive.

The scenarios assumed different customer penetration rates. The base scenario assumes a 50% customer penetration rate. The capital costs would be higher or lower if there were greater or fewer customers than the penetration rates used to calculate these figures.

Fiber	$41,260,625
Fiber Drops	$ 3,722,685
Electronics	$ 7,735,306
Operational Assets	$ 1,877,055
Total	$54,595,670
Cost per Passing	$ 2,272

Customer Costs

Residential Fiber Electronics Costs: The model assumes that the hardware electronics for an ONT cost $441, including the cost of the labor for installation at the home. We've assumed the average electronics and installation for a business is $540, with the difference being higher labor costs. In the projections it was assumed that the installation would be done by external contractors. It might be less expensive to do installations using existing company personnel or local contractors who can install at a lower cost.

We've assumed that the service provider will supply a WiFi router for customers that want one. We've assumed these routers cost $110.

Fiber Drops: Fiber drops are the fiber that connects from the street to the customer premises. In this study the cost of fiber drops is significant. The assumption has been made that with the volume of drops

needed plus the anticipated speed of network deployment the drops during the first four years of the project would be installed by external contractors.

Drop costs vary according to the length of the drop. The fiber drops in the town are mostly relatively short with a significant number of homes close to the street. We sampled the average lengths of drops by sampling neighborhoods using Google Earth. The cost for an aerial drop for residences is estimated to cost $275 while buried drops are estimated to cost $378. The cost for an aerial drop for businesses is estimated to cost $380 while buried drops are estimated to cost $586. Most of the cost of providing drops is labor. These represent our best estimate of costs using external contractors for the labor.

The drops are the one portion of the fiber network where an ISP might be able to save some cost compared to our study. For example, an ISP might be able to assemble their own construction team to build drops for less our estimate. An ISP might also be able to find a local contractor that will build the drops for less.

Customer Penetration Rates

One of the most important variables in the study is the customer penetration rate, or the percentage of the homes and businesses in the community that will buy broadband service.

The analysis looks at customer penetration rates in several different ways. The base scenario begins with what we call expected rates. We started the analysis using a conservative customer penetration rate of 50%. The residential survey predicted that the long-term residential penetration rate might be as high as 61%, but we always want to start our analysis at something more conservative.

We also looked at higher and lower penetration rates to understand the impact of the penetration rate on cash flow. Finally, as will be discussed below, we calculated a “breakeven” penetration rate which represents the smallest number of the customers the business would have to win in order to maintain a business that would have a positive cash flow.

Expense Assumptions

As a reminder, unless otherwise noted, all scenarios are created from the perspective of a small ISP offering the services. There is one scenario that compares small ISPs to a municipal ISP. The assumptions listed below are for the small ISP scenarios.

The following assumptions also assume that the same ISP owns the network and operates the business – be that the town or a commercial ISP.

Expense Assumptions

Expenses are the recurring costs of operating the business once it’s built. We strive when building financial projections to be conservatively high with expense estimates. It’s often less costly for an existing service provider to add a new market than what is shown in these projections.

As mentioned earlier, expenses are estimated on an incremental basis, meaning that the models only consider new expenses that would be needed to open the new market for an ISP. In an incremental

analysis it's assumed, for example, that the existing ISP is already paying for positions like a general manager, an accountant, etc. and that the ISP only needs to hire employees needed to open a new market and add additional customers. The incremental expenses for a newly formed ISP would be higher than for an existing ISP coming to the new market.

The primary expense assumptions are as follows:

Employees: Labor is generally one of the largest expenses of operating a broadband network. The models assume that an ISP will need to hire additional staff to take care of the new customers. We have assumed salaries at market rates with an annual 2.5% inflation increase for all positions.

There is a difference in the cost of supporting employees depending upon if the employees are hired by the town or hired by a commercial ISP. Employees of a town generally incur higher costs for employee benefits since government employees typically are earning a pension. We express this in financial analysis by developing a loading factor that covers payroll taxes and other taxes like workers' compensation, as well as employee benefits.

Theoretically, government employees ought to be paid less to make up for the difference in salaries, but for broadband technical positions we don't generally see much salary difference between the two types of employers. We've assumed that the salary loading factor for a municipal employee is 60% while the loading factor for employees of a commercial ISP is 38%on top of the basic annual salary. Some ISPs pay union wages, and if we knew for certain that we were studying an ISP, then the salary loading is generally a little less than the municipal loading factor.

As stated earlier, these models are incremental and only consider the new employees that would need to be hired. An existing ISP that is already selling in other markets would likely add the following employees:

Customer Service Representative. Takes new orders, answers customer questions about billing, services, etc. Often serves as the first level technical support.

At a 50% customer penetration the business grows to a little over 12,000 customers. We've assumed that the business would need about 9 customer service representatives by the time the business reaches maturity.

Install/Repair Technician. These technicians maintain the network and respond to customer trouble calls. The technicians also maintain network electronics and facilities as well as customer electronics. We've assumed that by the time the business reaches maturity that the business would have 9 Install/Repair Technicians.

Inside Technician. This technician maintains the core network electronics, oversees the connection to the Internet, and monitors customer installations. In a new market of this size we're assuming that an ISP would add one new inside technicians.

Salesperson. A market of this size would require at least one full time salesperson. Selling to businesses can only be accomplished with door-to-door consultative sales. Some ISPs would put additional salespeople in the market initially to jumpstart sales.

If the town started an ISP or a new commercial or non-profit ISP was created to serve the town then other new positions would be created. An existing ISP would likely cover these functions using existing staff. The additional positions include:

General Manager. This would be the person in charge of executing the business plan. Most existing ISPs would not hire a new ISP just for a market the size of Falmouth, but a new ISP has no choice but to hire a GM.

Marketing Analyst. This person would be in charge of developing a local marketing strategy and overseeing residential sales.

Billing Specialist. This position oversees the billing and cash collection process.

There are additional positions that an ISP might staff. For example, somebody needs to keep the books. If the local government was to become an ISP, then it would likely handle accounting, payroll, human resources and other similar backoffice functions.

The studies assume that construction contractors will build the fiber network. We've also assumed that customer installations will be outsourced during the construction process and for the first few years thereafter. Once the bulk of customers has been added the forecasts assume that future installations will be done by company technicians.

Start-Up Costs: To be conservative, the analysis includes start-up costs. There are expenses associated with launching a new business or new market and rather than list them all specifically we have included them as start-up costs. There are start-up costs even for an existing ISP when entering a new market. We've assumed the start-up costs are $210,000.

Sales and Marketing Expenses: Every scenario requires a significantly high customer penetration rate to be successful. We used the assumption that there would be a marketing effort to sign customers (instead of the word-of-mouth that often happens in rural markets). It would be too risky to spend the money to build a network without knowing for sure that there are enough interested customers to allow the business to pay for itself. We've assumed over $700,000 in marketing expenses during the first four years. It's possible that marketing money could be spent earlier than what we're showing in the forecasts.

Delivery of Products: The projections assume that the new business will not construct a headend to provide the services. It's likely that any ISP tackling the town is likely already buying and providing these products to customers.

The studies assume that a wholesale basic telephone line can be purchased wholesale at $6.00 per month. A line with unlimited long distance is assumed to be $9.00. These are conservatively high costs and lower-cost alternatives are available.

Maintenance Expenses: There are a number of routine maintenance expenses that the new business would incur on an incremental basis. These include:

- Vehicle expenses to maintain the vehicles required for the field technicians.
- Computer expenses to support the computers used by employees.
- Tools and equipment expenses.
- Power expenses to provide power to the network.
- General maintenance and repair of the outside plant network and the electronics to repair damaged or nonfunctional electronics.
- Internet Backbone. This is the cost to communicate with the Internet. The expense consists of transport (leasing fiber to connect the town to an Internet POP), and bandwidth.
- ISP Function / Help Desk. We've assumed that the ISP will outsource these functions – most small ISPs do. This fee covers a wide array of services. The fee covers network monitoring where technicians are ready 24/7 to respond to troubles or network outages. The fee includes security features such as protecting the network against spam and denial-of-service attacks. The fee covers basic ISP functions such as routing data traffic to and from the Internet (called the DNS function). The fee includes the help desk function, which is the function of assisting customers with broadband and network issues. The models assume a monthly cost of $4 per customer. This function could be provided by ISP employees, in which case this cost would cover new employees, or this function could be outsourced. This fee does not provide company voice mail, and most small ISPs do not offer white labeled voice mail.

Software Maintenance: Triple-play providers maintain a complex software system called BSS/OSS (billing and operational support systems). This software provides a wide range of functions: order taking, provisioning new customers, tracking of customer equipment, tracking of inventory, creation of customer bills, tracking of customer payments (or nonpayment). Since most such software is billed to providers on a per-customer basis we have assumed an expense for this maintenance.

Billing: Billing costs are shown as the incremental cost used to bill customers. We assumed that there would be some mix of mailing paper bills, of charging bills to credit cards, and of charging bills directly as debits to bank accounts.

Taxes: The model assumes that a commercial ISP that operates the business will pay state and federal income taxes. These taxes would not apply if this was operated as a municipal business or as a nonprofit.

We have assumed no property taxes on assets, but it's possible that some amount of this might apply. There are a few places in the country that charge property taxes on fiber networks, but most of the country doesn't. The issue of charging or not charging is usually county specific.

The forecasts do not include any taxes that are assessed to customers. For example, this business would be expected to charge and collect various telephone taxes. These kinds of fees are normally added to the customer bill, and thus customers directly pay these taxes. The models don't show these taxes and the assumption is that the taxes would be collected and sent to the tax

authorities on the customers' behalf. They are not shown as revenue or expense to the forecasts, but rather are just a pass-through.

Overhead Expenses: The forecasts include various overhead expenses. These include new expenses like legal, accounting audit expenses, consulting expenses, business insurance, and other similar expenses that are directly related to entering a new market. Since we are looking at incremental expenses, we have not shown an allocation of expenses from existing corporate or overhead employees.

Depreciation and Amortization Expense: The forecasts include both depreciation and amortization expense. These are the expenses recognized by writing off assets over their expected accounting lives. For example, the depreciation rate for a vehicle is 20% per year (is written off over 5 years). The cost of a new vehicle is then depreciated monthly to write off the asset over the 5 years, or 60 months. All hard assets are depreciated except land. Depreciation rates are set according to the expected life of the assets—something that is usually determined to comply with IRS rules and also accounting standard practices. Soft assets like software are instead amortized, using the same process as depreciation.

D. Financial Model Results

It is never easy to summarize the results of complicated business plans to make them understandable to the non-financial layperson. In the following summary are some key results of each study scenario that we think best allows a comparison of the numbers between scenarios. These summaries look at the amount of cash generated over the life of the plan.

The way to measure profitability in a new business is going to differ according to the structure of the business. A municipal business, for example, generally measures success by the ability of the business to generate enough cash to operate without any external subsidy. While for-profit business would generally use something like net income to measure profits.

It is important that a business always has cash in the bank to meet its obligations. In this particular business plan the ideal situation would be to always have at least $300,000 in the bank to have a cushion against nonlinear monthly expenditures. Not all expenditures are spent evenly throughout the year and a business must maintain a cash cushion to allow for those times of the year when the expenses are higher than normal or when the revenues are lower than normal.

Following are the results of the various scenarios. Note that a table of all of the financial results is included in Exhibit II. That Exhibit makes it easier to compare different scenarios.

Why the Projections Are Conservative

We always try to make our business plans conservative. By conservative, we mean that an actual business plan ought to perform a little better than we are projecting. Following are some of the conservative assumptions used in the business plan:

- The models contain no "home run" revenues. These would be sales of larger broadband products such as selling bandwidth to the local schools. We know that every fiber business gets some of

this kind of revenue, but we took the conservative approach of not showing it because we can't guess how much and when such opportunities might occur. We try to avoid predicting such revenues since it's possible they will never materialize.

- The engineering estimates include an 8% contingency on the fiber everywhere scenario and 5% contingency on the other two scenarios. We think the estimates of construction costs are solid and this contingency might not be needed.
- If the network is constructed by "edging out" from existing telcos, there could be some savings for ISPs in the cost of building fiber.
- In the model, we show an increase in the cost of wholesale bandwidth over time. However, industry costs for raw data might be less than we are projecting and might even drop over time.
- Our model assumes a regular replacement of electronics. However, it is possible that upgrades will be needed less often than we have shown. Further, our assumption is that the cost of electronics at the time of each upgrade would cost as much as the equipment that is being retired. The experience of the electronics industry is that electronics get cheaper and more efficient over time, so the cost of upgrades is probably going to be less than is shown in the model. The vendors in the industry have also gotten better at having phased upgrades that allow for keeping older equipment in place and not having to replace everything at once, making upgrades less expensive than we have projected.
- There are steps that the new business could take to improve upon these projections.
    - Preselling: We've seen service providers that are able to get earlier revenues when they presell to customers. This gives them the opportunity to begin connecting the network to the homes of presold customers while the network is being built. This would allow customers to be turned on in "nodes" or neighborhood-by-neighborhood as construction to specific parts of the county was completed.
    - More Concentrated Build Schedule: It's always possible to build faster than shown in these forecasts if the ISP is able to execute on a faster construction schedule. The amount of network that can be built in a given time period increases by adding more construction crews.
    - Get Temporary Help: There are often other bottlenecks at small companies that can slow down customer installations. This could mean the need for more sales and marketing staff, additional customer service reps, or inside technicians needed to provision new customers. Service providers should strongly consider using temporary employees during the roll-out of a major new market.

One Retail Operator

As a reminder from above, here are the basic assumptions included in the following scenarios:

- All of the above assumptions for revenues and costs are used in the models.
- Fiber is built to pass every home and business in the town.

A summary of all financial results is included in Exhibit II. The following is a summary of financial results for the four primary options studied. The first two columns look at the town (or some other local entity like the EDIC) being the ISP and consider general obligation (GO) bonds and revenue bonds. The final two column looks instead at a commercial ISP serving the community – the third column is a new ISP formed to serve in Falmouth and the last column shows an existing ISP adding Falmouth as a new market.

	Town as the ISP			
	GO Bond	Revenue Bond	New ISP	Existing ISP
Asset Costs	$54.64 M	$54.64 M	$54.64 M	$54.60 M
Equity	$ 0.00 M	$ 0.00 M	$ 7.85 M	$ 7.59 M
Debt	$62.90 M	$69.40 M	$52.35 M	$50.63 M
Total Financing	$62.90 M	$69.40 M	$60.20 M	$58.22 M
Cash after 20 Years	$13.20 M	$ 5.91 M	$10.65 M	$16.31 M

The above results show how different ISP models and different types of financing affect the financial performance. Here are important things to understand about each financing option.

- Bond financing borrows all of the money at the start of a project. That means the project starts accruing significant interest expense from the first day of borrowing. Since fiber project projects are not likely to reach a cash breakeven position for 3 to 5 years, using bond funding for a fiber project requires pre-borrowing the interest payments for at least the first three years. This is the primary reason why the amount of borrowing for bonds is greater than for a bank loan for the identical project.
- Revenue bonds generally have additional fees referred to generically as surety. In the studies we have included a Debt Service Reserve Fund (DSRF) in the revenue bond scenario that borrows an extra amount equal to a year of debt payment that serves as a safety net for the bondholders in case the project is ever unable to meet debt obligations.
- In today's market, bond interest rates are generally less expensive than bank interest rates, but that historically has not always been the case. In the studies we've assumed that general obligation bonds would be for 25 years with an interest rate of 3.5%. General obligation bonds have been assumed for 25 years at 3.25%. Bank loans are assumed at 20 years at a 4.5% interest rate. All these rates can vary widely depending upon who is doing the borrowing, and the assumed rates are current market rates for borrowers with a good credit rating.
- The last two columns above show the same project funded by bank loans. One of the biggest issues with using ban loans is that banks are not as likely to give a long repayment term like 25 years. Many banks are leery about lending for more than 12 to 15 years – which doesn't align well with fiber projects.
- Bank financing also almost always requires cash equity – meaning the borrower must bring some cash to a project. The above examples assume that the bank requires that 15% of the cost of the project is funded with borrower cash. In the examples above, a borrower would need more than $7 million in equity, and there are not many small or regional ISPs that could provide that much cash. The requirement for equity is the number one issue that makes it hard for commercial ISPs to grow quickly or to tackle projects the size of Falmouth.

Here is what can be learned by the number table above:

- It looks feasible for a fiber business to be financially successful in Falmouth – assuming it can achieve the 50% market penetration assumed in the above numbers.
- The extra borrowing required for revenue bonds make for a bigger challenge, from a financial basis, than general obligation bonds. There are often political challenges using general obligation bonds – but from a dollar perspective GO bonds make it easier for a fiber project to succeed.
- As mentioned above, the biggest drawback for bank financing is bringing the needed equity to the project. Note that grant money can act as equity, but it seems highly unlikely that a project in Falmouth could attract over $7 million in grants in the current environment.

- While commercial bank financing means smaller loans, the loans are likely to incur higher interest rates and shorter loan terms, which together can equalize the impact of bank versus bond financing.

Sensitivity Analysis with Revenue Bond Financing

The study then considered what we call a sensitivity analysis. We looked at the impact of changing the key variables and assumptions that have the biggest impact on the bottom line of a fiber project. The following describes the impact of changing key variables for the scenario of financing with revenue bonds (the second column in the table above). We could create a similar description of the impact of changing the variables for each of the options in the table above – but the impact of most of these changes is similar regardless of the specific business model. For example, the impact of changing prices is the same regardless of the way a project is funded.

Changing Customer Penetration Rate

The base analysis considered a penetration rate of 50%. We also looked at increasing the penetration to 55% and 60%. The impact of changing penetration rates high or lower by 5% was a change in cash over 20 years of $13.45 million. This means that the impact to the business of a 1% change in penetration rate (from 50% to 51%) is almost $2.7 million. We would describe the fiber business plan in Falmouth as being extremely sensitive to the customer penetration rate. This means that it will be vital to understand customer demand before launching the business. This also means that it would be prudent to pre-sell to as many customers as possible before launching the business.

Changing Broadband Prices

We looked at a scenario that changed broadband prices. Increasing broadband prices by $5 per month (changing a rate from $60 to $65) changed cash flow over 20 years by $11.2 million. Decreasing rates by $5 lowered cash over 20 years by $10.9 million. This means that a $1 change in broadband prices changes 20-year cash flow by approximately $2.2 million. This is also a high sensitivity. The cautionary tale about this finding is that an ISP must be careful after launch to stick to target prices. If a future decision is made to cut rates to be more competitive, the impact on the bottom line could be huge.

We also looked at the impact of increasing rates over time. The base study assumes there is never an increase in broadband rates. That is a conservative assumption, and we know markets where there are multiple providers where the rates have never been increased – no competitor wants to be the first to raise rates. However, the big cable companies like Comcast are under a lot of pressure from Wall Street to keep raising rates. Comcast has gotten guidance from analysts that they ought to have a target base broadband rate of $90. That doesn't mean the company will raise rates that much, but we've now seen rate increases for several years in a row and having annual broadband rate increases might become the norm

We assumed a very conservative rate increase. We raised rates by 5% every fifth year. This means the effective rate increase is less than 1% per year – far below the likely rate of inflation. This rate increase means that the starting broadband price of $60 today would still be less than $70 in twenty years.

The impact of raising the rates is large and increases cash flow over 20 years by $12.9 million. While it might seem like a no-brainer to assume the rate increase in a business model, there is no way to know today that competition might lead to a long period in the market where rates might not increase. Alternatively, Comcast could decide to raise the rates in the market the same as everywhere else, and a local ISP might be able to mimic rate increases and generate a lot more than the extra $12.9 million.

Changing Financing Terms

We looked at the impact of changing the various financing parameters.

Interest Rate. We looked at a scenario that changed the interest rate by 50 basis points, or 0.5 % (such as changing the interest rate from 3.5% to 4.0%). This changed cash flow by $6.1 million over 20 years.

This equates to a warning that anybody planning a new fiber network during a time of financial uncertainty must keep a close eye on interest rates and be ready to not proceed with financing if interest rates move too high. We've been lucky for the last decade that interest rates have held steady for years at a time, but over history it's more normal for interest rates to fluctuate.

Loan Term. We looked at the impact of increasing the loan term from 25 years to 30 years. This had a dramatic impact and increased cash over 20 years by almost $14.7 million. This provides a great incentive to consider the longest loan maturity that can be achieved. Longer loans mean lower annual debt payments (just like with a home mortgage). Bonds can always be repaid earlier if that becomes a goal, but the longer the loan term, the smaller the annual required debt payments.

We looked at the feasibility of shortening the loan to 20 years and we couldn't find a way to make this work. The payments on a 20-year revenue bond are higher than can be supported by the cash flow of the business.

Adding 5% to the Construction Contingency

We examined the impact of changing the cost of the network. In this case, we chose to change the cost of fiber by 5%, or more than $1.6 million This changed cash over 20 years by $2.4 million. To put that into perspective, changing the cost of the network by $1 million changes cash flow over 20 years by over $1.4 million.

The Additive Nature of the Variables

The impacts citied for the various variables are somewhat additive. For example, the above discussion describes an improvement to cash generated by the business from finding a lower interest rate on debt than shown in the models and for spending less on the network. These improvements are roughly additive, meaning that you can add the results above together and will come close to the impact of making both changes to the models.

It's impossible at this early stage of considering the feasibility of building fiber to know the exact market conditions that might be in place should the town move forward and build this network. Interest rates a few years from now might be higher or lower than we've assumed. The town might decide that you can charge a higher rate than is assumed in the models. You might go out for construction bids and find that you can build the network for less than assumed in these models. If all of those positive changes occur, then the business could do significantly better than any of the scenarios shown in the summary in Exhibit II. But these changes might just as easily go the other way. The biggest unknown is probably interest rates, and there have been a number of times during my career when interest rates were far higher than what we see today and what are in these models.

Public-Private Partnership (PPP)

There are numerous ways to structure a public-private partnership where the town and a commercial ISP work together to fund and bring broadband to the market.

A town that wants a fiber network only has a few choices:

- The town can fund the network and become the ISP. We've shown above how these scenarios work.
- The town can try to attract an ISP to invest in and operate a fiber network. We've also shown this scenario above. There are only a handful of examples of ISPs coming to larger cities using their own funding. Google Fiber invested in fiber in Kansas City, Austin, Texas, and parts of the research triangle in North Carolina. However, it appears that Google Fiber has abandoned this model as too expensive and is no longer funding the construction of networks in cities. This study shows that the cost of the network needed to bring fiber to Falmouth costs over $54 million. There are few, and perhaps no ISPs who are willing and able to make an investment of that magnitude to build fiber in the town. Nationwide, we don't see few ISPs making that level of investment in a single community.
- The third option is for a town to invest in a fiber network and invite a quality ISP to operate the network. In this sort of PPP, a municipality has to make a major investment in fiber. Most municipalities don't want to be an ISP, and so they often look for an operating partner. There are a handful of partnerships that have been formed where the municipal partner brought most of the financing. Google Fiber has entered into this type of partnership in West Des Moines, Iowa and Huntsville, Alabama. Ting has entered this type of arrangement in Charlottesville, Virginia, and other markets.

Following is an example of this kind of partnership in Falmouth. There are numerous other ways that the partnerships could be structured, but all other scenarios would be a different version of the numbers below. The partnership below assumes a penetration rate of 55%. That illustrates one of the biggest downsides of partnerships – the fiber business must perform well enough to be financially attractive to both partners (and good enough to feel safe to the municipal partner).

	ISP Partner	Falmouth
Customer Revenues	192,738,492	
Cost of Goods Sold	(7,461,975)	
Operating Expenses	(66,135,267)	
Interest Expense	(3,827,740)	(24,547,664)

Income Taxes	(8,214,770)	0
Margin	107,098,741	(24,547,664)
Equity	1,305,000	
Assets	(22,362,989)	(46,647,794)
Loans	8,700,000	52,000,000
Loan Repayment	(8,700,000)	(37,243,935)
Net Change in A/R & A/P	(304,843)	(250,802)
Cash Generated	85,735,905	(56,690,195)
Lease of the Network	(61,352,598)	61,352,598
Cash Return	24,383,310	4,662,403

Here are the specific assumptions behind the above partnership:

- This partnership builds the same fiber network as other scenarios we studied and brings fiber to every home and business.
- These numbers represent the cumulate cost for each line item over 20 years.
- The town would finance, build, and own the fiber network and the fiber drops and would finance the project with general obligation bonds.
- The ISP partner pays for all electronics and installation costs.
- The ISP partner operates the business including maintaining the fiber network. All employees work for the ISP and the town has no fiber employees.
- All revenues go to the ISP.
- The ISP covers all operating expenses.
- The ISP needs a loan to cover the cost of assets.
- The ISP pays a sizable lease to the town. This lease covers all financing costs for the town needed to cover debt payments and in the above example the lease also returns a small profit to the town over time.

There are numerous variations on this partnership, but none are drastically different than the table above. Changing the partnership assumptions would move dollars between the two columns above. Following are some of the ways that the partnership could differ:

- The town might pay for the core electronics, which would increase the investment for the town and decrease the borrowing for the ISP partner.
- The town could hire a few technicians and maintain the fiber network instead of letting the ISP maintain the network.
- The town could pay for all of the assets.
- The ISP could finance the fiber drops.
- There could be more or less profit sharing with the town.

None of these changes would make a drastic change to the table above. In all likely partnership scenarios, the town is likely going to have to fund the fiber network, which is the big dollar item. All scenarios would still require a large lease payment between the two parties to cover the cost of the network.

There are a few issues to consider in creating this kind of partnership:

- Negotiating the lease between the two parties is the hardest part of the arrangement. No town wants to get lease payments lower than their annual debt payments. No ISP wants to have an arrangement that would make them pay a lease payment that is higher than the cash generated by the business. One of the two parties generally has to compromise to make a PPP work, because the business generally doesn't generate enough cash in the first five years to make both parties whole. There is also always that chance that the business will underperform – and in that case cash shortages could be permanent for both partners.
- To get a bank loan a partner is likely still going to need to provide equity. In this expel we assumed equity of $1.3 million.
- One of the biggest hurdles in finding a partner is finding one that want to remain in the partnership for the length of the financing – in this case 25 year. A lot of ISPs today have a goal to sell and realize the accumulated value of their businesses, and so the challenge of finding a commercial partner is increased if you only want partners that are likely to still be operating the business decades from the start. It's not hard to envision a partnership where an ISP sells, and the purchasing partner doesn't want to maintain the partnership relationship. If a town owns that network and not the customers, this could be a problem. It's also not hard envisioning a partner selling to an ISP the town doesn't like.

Open Access

The open access operating model is discussed in Section III.A. of the report. In this model, the town would build, own, and operate a fiber network and would sell wholesale connections to multiple ISPs which would sell retail services to customers.

There are a lot of difference in the open access model versus the partnership model above. Following are the primary assumptions for the open access network:

- The town would finance, build, own, and operate the fiber network and the fiber drops and would finance the project with general obligation bonds. This means the town would need to have several technicians to take care of the fiber network.
- The town would pay for core electronics. In the scenario shown below, the ISPs would pay for the customer electronics, although in some open access networks that is also the responsibility of the network owner.
- The various ISPs compete against each other for sales to customers. The ISPs each cover their own cost of sales and operations.
- All retail revenues go to the ISPs.
- The ISP buy "fiber loops." In the example below, this rate is set at $30 per month, meaning an ISP would pay that rate for each customer they connect to the fiber network. The example below also assumes that connections to apartment buildings would be set at a lower rate. This differs significantly from a lease in that ISPs only pay for customers that are connected to the network. This means revenues to the town are low for the first few years until a customer base is built up.
- There are a few dozen open access networks around the country, and each of these shares a few common characteristics:

- The retail prices charged by the ISPs are higher than what would likely be charged if the town owned and operated the business. In the example below, broadband rates are set $65 for the lowest-price option. Rates might be even higher than this.
- Open access networks almost never get as many customers as a single ISP would get which owned and operated the network. In the example below, we assumed the overall penetration rate for all of the ISPs is 45%. Penetration rates are lower for several reasons.
  - The ISPs are not liable for the debt on the network and are not driven to push for enough customers to make the business work. ISPs really aren't bothered in the town that owns the network loses money.
  - The small ISPs that get onto open access network generally are not well funded and tend to not be able to afford a robust marketing program.
  - To some degree, every customer on an open access network returns a positive margin to the ISPs, and so a given ISP might be happy with some lower number of customers.
  - ISPs on an open access network always "cherry-pick." They rarely will sell to customers that buy only the lowest-price fiber product and nothing else. That alone might eliminate 5% to 10% of the market as potential customers.

Following is an example of an open access network. For convenience, all of the ISPs are lumped together.

	ISPs	Falmouth
Customer Revenues	168,055,264	
Cost of Goods Sold	(6,132,567)	
Operating Expenses	(52,377,217)	(11,325,610)
Interest Expense	(2,429,829)	(24,736,492)
Income Taxes	(7,367,927)	0
Margin	99,747,723	(36,062,102)
Equity	828,750	
Assets	(18,332,647)	(49,293,226)
Loans	5,525,000	52,400,000
Loan Repayment	(5,525,000)	(37,530,427)
Net Change in A/R & A/P	(249,044)	(193,406)
Cash Generated	81,994,782	(70,679,161)
ISP Loop Fees	(61,396,088)	61,396,088
Cash Return	20,598,693	(9,283,072)

This scenario shows the ISPs collectively making money and the town / owner losing money. This example is pretty typical for the open access networks in place around the country today. Many of these businesses generate enough cash to cover operating expenses, as does the example above. But the open access model still loses money every year, and a town that builds an open access network will likely have to somehow subsidize the debt payments each year. We don't know of any open access network that covers the full cost of the business including covering debt. A number of the open access networks

in the country have been built by municipalities that also operate municipal electric companies. Some of these cities knew the business would need to be subsidized but decided that broadband was needed badly enough to build the network anyway. Many such networks are located in rural counties.

There is no way that I know of to turn the above analysis positive. If the town raises the ISP loop fee, the ISP passes this on in the form of higher rates to customers – and that generally results in fewer customers on the network. If the town lowers the loop rate to get more customers, there is not enough revenues generated due to the lower loop rate. This is a market model that doesn't seem solvable.

What Conclusions Can We Draw from the Financial Results?

There are a number of conclusions we can draw from the results of the business plan analysis:

It is Feasible to Operate a Profitable ISP in the Town. We undertook our analysis starting at a 50% market penetration to be conservative. The residential survey suggest that the long-term penetration rate might be as high as 61%, and at the number of customers the business looks to be profitable. There are profitable scenarios even at a 50% penetration rate, although you might hesitate to get into the business if that is the expectation of long-term performance.

It is possible for a business with a 50% penetration rate to lose money if the some of the key parameters work against you. For example, if interest rates are higher at the time of financing the project the cash flows would be a lot tighter. It might feel necessary to cut rates if the ISP business encountered a competitor that wanted to compete with lower rates. The best news there is that the big ISPs don't seem to do that anywhere, so it's not likely, for example, that Comcast would undercut your rates. They are more likely to match your rates.

Perhaps the key finding associated with profitability is the breakeven penetration rate. This represents the number of customers needed to create a business that should always remain cash positive. With bond funding the breakeven was calculated at a 48% penetration rate. With bank financing the breakeven drops to a 42% penetration rate.

The Method of Financing Matters. It's easier to make the fiber work if a new network is financed with general obligation bonds instead of revenue bonds – but very few towns want to take on new debt that is backed by taxes.

Hard for a Private ISP to Fund. There are few private ISPs that would be able to raise the cash needed to build a fiber network in the town. The cost of the needed assets is over $54 million and there are almost no fiber overbuilders in the country that are making this kind of investment anywhere in a single market. If an ISP had that kind of funding, there are other cities that would have a lower cost of network than Falmouth. Falmouth covers a large geographic footprint, and while there are parts of the town with sufficient housing density, there are plenty of places within the town with lower densities.

The biggest problem for most commercial ISPs is that they'd have to bring significant equity to get this project financed. If an ISP had to bring the somewhat standard 15% equity to raise funding, that means an ISP would need to have over $7 million in free cash – there are few ISPs that carry free cash since most constantly reinvest in existing networks.

The Business is Sensitive to a Few Key Variables. All of the scenarios are sensitive to changes in a few key variables:

- Penetration Rate. The most important variable is customer penetration rate. Our starting analysis was at a 50% penetration rate to be conservative. Our analysis shows that changing the penetration rate by 1% will change cash flow over 20 years by $1.8 million. While this demonstrates improved cash flow from doing better than expected, this means a significant risk from underperforming on the planned customer penetration rate. Not getting enough customers is probably the number one problem for new ISPs.
- Broadband Prices, The financial results are also highly sensitive to broadband prices. The studies all used an assumed starting price of $60 for the basic broadband product. Changing broadband prices higher or lower by $1 changes long-term cash flow over 20 years by 1.5 million.
- Rate Increases. The base models assume no rate increases to be conservative. It's possible in a competitive market that rate increases could be slim or even not happen. However, if competitors like Comcast continue to raise rates, then there is a huge upside in cash flow if this fiber business can raise rates. Raising rates by less than 1% per year increases cash flow over 20 years by $8.9 million. Unfortunately, there is no way to safely build those increases into projections.
- Interest Rate. The business plan scenarios are sensitive to changes in interest rates. A change of 50 basis points (changing interest rate from 3.5% to 4%) will change the cash flow in a bond-financed project by $6.1 million over 20 years. The impact on a bank-financed project is smaller, but still significant at $2.26 million over 20 years. While we've had a long period of over a decade where interest rates have remained steady, in a time of economic uncertainty it will be vital to keep an eye on interest rates.
- Loan Term. Increasing the length of loans by five years would provide a major benefit to financing fiber. With bond financing, changing from 25-year bonds to 30-year bonds would improve cash flow over 20 years by $10.9 million. With bank financing, changing from 20 years to 25 years improves cash flow by $10.4 million over 20 years.
- Changing Capital Costs. The impact of changing the amount of capital needed for a project has a much smaller impact than other variables. With bond financing, changing capital costs by $1 million changes cash flow over 20 years by $1.4 billion. With bank financing the impact of changing capital costs by $1 million is a little less than $1 million.

It is essential before deciding to get into the business to pin down these key variables. Changes in any of these variables will affect the long-term earnings potential for a given scenario. The impacts of changes of the variables are also largely additive. For example, the improvements that might be achieved through raising the rates or lowering the interest rate on debt can be added together if both variables change in a real business plan.

Public Private Partnerships Can Work. Since there are scenarios that would be profitable for a single service provider, then there are scenarios that will support public-private partnerships. The most likely partnerships are still going to require the town to make a significant investment in a fiber network.

Open Access Does Not Look Feasible. We could not find an open access scenario that was profitable for the town. This scenario does look to be profitable for ISPs that would operate on the network.

IV. Other Issues

A. Funding for Broadband Networks

For a large percentage of broadband projects, the biggest challenge is finding the funding. This section of the report looks at the various ways that other communities have been able to fund broadband networks. If a community wants fiber badly enough, there probably is a way to pay for it.

There are a number of different financing option to consider. Below we look at the following:

- Private Financing (loans)
- Private Funders of Fiber Networks
- Federal Loans
- Public Financing
- Grants
  - Federal Programs
  - State Programs
- Loan Guarantees
- Opportunity Zones and New Market Tax Credits
- Customer Financed
- Public Private Partnerships
- Other Sources of Financing

Private Financing Options

When commercial ISPS build networks, they have to rely on traditional private financing, meaning loans. Following are the key elements that determine the cost of bank financing:

> **Equity**: Most forms of private financing require some equity. Equity means that the borrower brings some sort of cash or cash equivalent to the business as part of the financing package. The amount of equity required will vary according to the perceived risk of the venture by the lender. The higher the risk, the more equity required.
>
> Equity can take a number of different forms:
>
> - Cash: Cash is the preferred kind of equity and lenders like to see cash infused into a new business that can't be taken back out or that doesn't earn interest.
> - Preferred Equity: For a stock organization (like an LLC or other type of corporation) the business can issue some form of preferred stock that then acts as equity. Preferred equity usually gets some sort of interest rate return, but the payments are not usually guaranteed like they are for bank loans. If the business gets into a cash crunch, they must pay bank loans and other forms of debt before they pay preferred equity interest.
> - Assets: It's possible to contribute assets as equity. For example, a new fiber venture might be seeded by having one of the partners contribute an existing fiber route or other valuable asset to the business. In such a case the contributed asset often has to be assigned a market value by an independent appraiser.

- Non-recourse Cash: Non-recourse cash means accepting a contribution to the business that is not guaranteed to be paid back. To give an example, in Sibley and Renville counties, a fiber business was launched in the form of a cooperative. The local government provided an economic development bond to the business as a non-recourse loan. This means that the new fiber business will make their best effort to make the bond payments, but if they are short of cash then the government entities that issued the bonds would have to make the bond payments. The banks involved in that project looked at the contributions from the bonds to be the same as equity.

Bank Loans: The banking industry as a whole does not like to finance long-term infrastructure projects. This is the primary reason why the country has such an infrastructure deficit. Fifty or more years ago, banks would fund things like power plants, electric and water systems, telephone networks, and other long-term revenue-generating assets. But various changes in banking laws have required banks to maintain larger cash reserves which makes them less willing to make long-term loans. Banks have also increased their expectations over time to want to earn higher interest rates. Many attribute this to the fact that giant publicly traded banks have captured most of the banking market. Banks don't like long-term loans since the interest rates get locked in for many years, possibly depriving the banks from earning more on their own equity.

Most banks prefer not to make loans with a term much longer than 12–15 years, and many telecom projects can't generate enough cash in that time period to repay the loans.

There are exceptions. A few of the large banks like Key Bank and Bank of America have divisions that will make bank loans to municipal ventures that look a lot like bonds. These loans will have long payment terms of 20 years or more and reasonable interest rates. However, most of these loans go for things like power generation plants and other projects that have a strong guaranteed revenue stream. These banks have done a tiny handful of telecom projects, but they view most broadband projects to be too risky.

Banks are also averse to start-ups and prefer to make loans to existing businesses that already have a proven revenue stream. It's extremely hard for a first-time borrower to be able to borrow the kind of money needed to build a telecom project.

There is one unique banking resource available to companies who want to build fiber projects. This is CoBank, a boutique bank and a cooperative. This bank has financed hundreds of telecom projects, mostly for independent telephone companies and for electric cooperatives. CoBank is a relatively small bank and has strict requirements for financing a project. They are leery of start-ups and we can't think of a start-up they have financed recently. They also expect significant equity to be infused into a new venture. They tend to have somewhat high interest rates and somewhat short loan terms of 10–12 years.

Cooperatives also have another bank that lends only to cooperatives. This is RTFC (Rural Telephone Financing Cooperative) that is owned by cooperatives.

One interesting source of bank financing is local banks. Historically local banks were the source in many communities for car and home loans. But over the last few decades those loan portfolios have migrated to other lenders and local banks have been struggling for a decade to find

worthwhile projects in their regions. We know of many commercial projects for small telcos that have been financed by local banks.

The biggest challenge of borrowing from a local bank is that they typically have a relatively small lending limit. Most local banks won't make an individual loan for more than a few million dollars. That obviously doesn't go far in a fiber project. However, local banks have become adept at working in consortiums of multiple banks to make larger loans. This spreads the risk of any one loan across many banks. A banking consortium usually begins with a local bank in the area of the project, with the local bank taking the role of finding other banking partners and of servicing the loan. This approach requires a lot of extra effort from a local bank, but the approach has been used to finance good telecom projects.

Collateral. The biggest issue that banks have in lending to broadband projects is the lack of collateral, which is the assets they inherit if the project should fail. Banks like hard collateral like buildings, vehicles, shared of stock, and things they know they can readily sell for a reasonable price. Banks don't like broadband networks as collateral, because even a little bit of web searching shows them that networks are sometimes sold for pennies on the dollar.

It is important understand the importance of collateral. Communities often ask an ISP operating nearby to come build fiber in their town. What they generally fail to realize is that the ISP likely had to pledge their entire business as collateral in order to secure the loan to finance a new market – meaning that if the new venture fails they can lose the whole business.

Return on Bank Equity. Banks don't only consider the interest rate when making loans. A bank concentrates on its return on equity and will consider a combination of factors like interest rates, up front and monthly loan fees, the likelihood that a borrower will pay a loan off early or default on a loan, etc. A bank will look at a dozen financial parameters before making an offer of interest rate and term – all based up their analysis of return on bank equity. There is a misperception that interest rates are negotiable, but the same project offered to multiple banks is likely to get a nearly identical financing package offered by all of the banks.

Private Funders of Fiber Networks

There are a few fiber projects around the country that have been funded by private equity. This is still a relatively new phenomenon. Here are a few examples:

SiFi Networks.[19] This venture is headquartered in Morristown, NJ. SiFi has financed and built a fiber optic network in Fullerton, CA. This is a city with 54,000 passings. This is an open access network, meaning there will be multiple ISPs. For now, the two ISPs are Ting (an ISP headquartered in Canada) and GigabitNow (an ISP from Seattle). SiFi networks is currently working on funding projects in Salem MA, East Harford CT, and Saratoga Springs NY.

[19] https://sifinetworks.com/corporate/fibercity/

Netly.[20] Netly is located in Solano Beach, CA, and has built a fiber network in that city. The company is now considering additional cities. They want to fund, build, and operate open access networks, allowing multiple ISPs to use the network.

Federal Loans

The only federal loan program for broadband is operated by the Rural Utility Service (RUS), which is part of the Department of Agriculture. Unfortunately, this agency only makes loans, grants or loan guarantees for communities smaller than 20,000 people. Even was that limitation changed, there are numerous restrictions on RUS loans and we've never seen a loan given to a municipality.

Public Financing Options

The two primary mechanisms used for public financing are revenue bonds and general obligation bonds. There are some major benefits of using bond financing. First, the term of the bond can match the expected life of the assets and it is not unusual to find bonds for fiber projects that stretch out for 25 or 30 years. It's also possible to finance a project completely with bonds, meaning that no cash or equity is needed. The primary historic source of public money used to finance telecom projects is through the issuance of municipal tax-exempt bonds, meaning the buyers of the bonds don't have to pay federal and/or state income taxes on the revenue from the bonds.

Revenue Bonds: Most of the municipal fiber networks that have been built have been financed through revenue bonds. Revenue bonds are backed by the revenues and the assets of the fiber network and the associated business. With a pure revenue bond, a local government would not have to repay the bonds if the project fails. With that said, having a bond default is a financial black eye that might make it hard for a community to finance future projects. So, to some degree, most governments feel obligated to pay back revenue bonds, since there is a big cost for not doing so.

It has gotten harder to finance broadband projects with pure revenue bonds due to some failures on the part of other municipal networks. Among these are Monticello, MN; Crawfordsville, IN; and Alameda, CA. These kinds of failures have made investors leery about buying bonds that are only backed by the business. This reluctance has made financing with revenue bonds more expensive.

The cost of a bond issue cannot be judged only by the interest paid. In fact, the other financing costs of bonds can outweigh the interest rate in the effect on the bottom-line cost of repaying a bond issue. Because of market reluctance to buy revenue bonds, they often have higher interest rates than general obligation bonds, but they also can incur the following costs:

Debt Service Reserve Fund (DSRF): Many revenue bonds require borrowing additional funds to be kept in escrow as a hedge against missing future payments. The DSRF is often set to equal a year's worth of principle and interest payments. This money is put into escrow and is not available to operate the business.

[20] https://www.netlyfiber.com/

Capitalized Interest: Bonds begin accruing interest from the day the money is borrowed. Since fiber businesses take a number of years to generate enough cash to make bond payments, the bondholders require capitalized interest that is used to make the interest payments for up to the first five years of the project. Basically, the project must borrow the amounts needed to make debt payments which can add a significant amount to the size of the bond issue.

Bond Insurance: Bond insurance is an up-front fee paid to an insurance company that will then pay one year of bond payments to bond holders in case of a default. We've seen bonds issued that have required both a debt service reserve fund and bond insurance.

For a number of years now the interest rates charged to bonds have been lower than the interest rate on commercial loans. But that has not always historically been the case. The difference between bond interest rates and commercial interest rates both change over time; that difference is referred to in the industry as the "spread." Sometimes the spread favors bonds and at other times it favors commercial borrowing. In our financial analysis we assumed that the interest rates are lower on bonds. Interest rates are also not the same for all kinds of bonds. For instance, the interest rate for revenue bonds can be considerably higher than general obligation bonds due to the perceived higher risk.

General Obligation Bonds (GO Bonds): If revenue bonds aren't an option, then the next typical alternative is general obligation bonds. General obligation bonds are backed by the tax revenues of the entity issuing the bonds. This backing can be in the form of various government revenues such as sales taxes, property taxes, or the general coffers of a government doing the borrowing.

What these pledges mean is that if the broadband project fails and can't make the bond payments, then the backing, the pledge revenue source such as property or sales tax, would have to be used to make the bond payments.

Many states require a referendum to approve general obligation bonds. Most states have a few exceptions for things like economic development bonds that don't require a referendum, but local government sometimes hold a referendum anyway just to make sure the public supports the initiative being financed.

There are other financing mechanisms that have been used by other municipalities to fund revenue-generating projects. These include:

Variable Rate Demand Obligations (VRDOs): VRDOs are a bond where the principal is paid in a lump sum at maturity. However, the borrower has the right to repay the bonds in whole or in part at any time (upon an agreed-upon notice). VRDOs are effective in circumstances when the borrower wants to match the repayment of the bonds to a revenue stream that varies year to year or a revenue stream that can vary from initial estimates and changes over time. In the case of the new telecommunications system, this type of financing provides the flexibility to make bond payments that match the actual revenues received. If revenues are slower than anticipated, principal payments do not need to be made. If revenues come in faster than anticipated, repayment of the bonds can be accelerated without penalty. We can recall having only ever seen

this used once for a municipal telecom system by the city of Alameda, California. This kind of financing is used fairly routinely for other kinds of municipal needs.

VRDOs are most commonly structured as 7-day floating rate bonds. Interest rates are reset each week, and this adds a lot of risk to this type of financing. Unlike fixed-rate bonds, the borrower doesn't know what the interest rate will be on the VRDOs over the life of the issue. Interest rates on VRDOs are on the short end of the yield curve and have therefore historically been lower than interest rates on fixed-rate bonds even with the additional ongoing costs for a liquidity provider and a remarketing agent. There is typically a maximum rate stated which the VRDOs cannot exceed. But in a market where there is a significant increase in overall interest rates this kind of financing could end up being significantly more expensive.

Capital Appreciation (Zero Coupon) Bonds (CABs): CABs are bonds that are issued at a deep discount and which do not bear any stated interest rate. Like a Series E savings bond, CABs are bought at a price that implies a stated return calculated on a basis of the bond being payable at par at maturity. With no stated interest rate there is no interest paid until maturity, at which time all of the compounded accreted interest is paid. With no interest payments required in the beginning years of the bonds, this would enhance the cash flow in the beginning years of the business.

CABs do, however, have several drawbacks over other types of available financing. First, the interest rates on CABs are typically higher than both the fixed-rate and VRDOs. Second, investors prefer not to have a prepayment option on CABs, which limits the flexibility of the government to call the bonds early if revenue collections are better than anticipated or if a restructuring of the debt is needed. This structure is used frequently for various government borrowings, but we've not ever heard of this being used for telecom—although there is no reason why it could not be used.

Grants

It's hard imagining the construction of fiber networks in rural areas without some grant support. This is particular true in these counties, which have rougher terrain and other issues that add to the cost of building fiber compared to many other parts of the country.

Federal Broadband Grants: The current federal broadband grant initiatives all fund fiber in places with little or no broadband connectivity. Unfortunately, we don't see any of the current round of grants applying to Falmouth (or to any other cities that are already served by a large cable company). The current grants include:

Rural Digital Opportunity Fund Grant (RDOF). The FCC has created a massive $20 billion grant program that will be awarded in 2020 and 2021 for rural locations with little or no existing broadband.

ReConnect Grants.[21] In the 2017 Farm Bill, Congress created a grant program called ReConnect. The program awarded $200 million in grants, $200 million in loans, and $200 million in a

[21] https://www.usda.gov/reconnect

combination of grants and loans in 2019. Congress reauthorized an additional $600 million to be awarded in 2020. These grants are administered and awarded by the US Department of Agriculture.

Community Connect Grants.[22] This program specifically targets the poorest parts of the country and ones with little or no existing broadband. This program awarded $34 million in 2018 and $30 million in 2019. Grant awards for the program are generally between $100,000 and $3 million and require at least a 15% matching from the grant recipient.

BroadbandUSA Program.[23] This program is part of the Department of Commerce's National Telecommunications and Information Administration (NTIA). The agency provides an annual database of grants that can sometimes be used for broadband (and are often used for other purposes). Examples include the Appalachian Regional Commission and the Community Development Block Grant (CDBG) Program. We've seen communities be creative in using such grants to fund at least some small portion of a broadband initiative. Every mile of fiber funded through one of these alternative initiatives is one less mile of fiber needed for a whole-city build. For example, we've seen grants provided for things like:

- Building fiber to schools and libraries to replaced expensive leased fiber.
- We've seen a fiber component in smart energy initiatives like smart-grid and smart lighting.
- We've seen public safety grants used to fund fiber to critical public safety locations like sheriff stations, 911 centers, public safety radio towers, firehouses and other first responders, etc.
- We've seen grants awarded for extending broadband to public housing.
- We're starting to see the placement of conduit for fiber included in state and federal grant funding for federal and state highways.

State Grant Programs

The State of Massachusetts has a broadband program operated by the Massachusetts Broadband Institute. (MBI)[24] The Commonwealth created MBI in 2008 as a division within the Massachusetts Technology Collaborative to coordinate state efforts to expand broadband in unserved and underserved parts of the state. MBI works closely with the Executive Office of Housing and Economic Development (EOHED)[25] to coordinate funding ventures, and the Public Safety Broadband Office[26] to coordinate public safety efforts. MBI maintains a document, the Last Mile Program Policy, which acts as the State's broadband policy.

MBI administers two grant programs.

[22] https://www.rd.usda.gov/programs-services/community-connect-grants
[23] https://www.broadbandusa.ntia.doc.gov/new-fund-search
[24] https://broadband.masstech.org/
[25] https://www.mass.gov/orgs/executive-office-of-housing-and-economic-development
[26] https://www.mass.gov/orgs/massachusetts-public-safety-broadband-office

Last Mile Grants[27] This grant program is aimed at 44 specific communities in Western Massachusetts to build broadband infrastructure. These grants can also find additional grant money for engineering and related services through the Last Mile Infrastructure Grant program administered by the EOHED.

Broadband Extension Grant Program.[28] For now this program is only available to communities in Western and North Central Massachusetts. It provides grants to municipalities to expand broadband networks when the coverage of a cable provider is less than 96% of the community.

For now, these grant programs do not provide benefits to Cape Cod. However, it's still worth investigating these efforts and lobbying local politicians to extend the programs to your area.

Loan Guarantees.

Another way to help finance broadband projects is through federal loan guarantees. A loan guarantee is just what it sounds like. Some state or federal agency will provide a loan guarantee, which is very much like getting a co-signer on a personal loan. These programs guarantee to make the payments in the case of a default and thus greatly lower the risk for a lending bank. In return for the lower risk, a bank is required to offer a significantly lower interest rate.

These guarantees are not free. There is an application process to get a loan guarantee in much the same manner as applying for a bank loan or a grant, meaning lots of paperwork. And then the agency making the guarantee will generally want a fee equal to several interest "points" up front. To some extent, this process works like insurance and the agency keeps these fees to cover some of the cost of defaults. If they issue enough loan guarantees, then the up-front fees can cover eventual losses if the default rates are low. These points are a payment to the agency for issuing the guarantee and are not refundable.

There are several federal agencies that might be willing to make loan guarantees for telecom projects. The following agencies are worth considering:

HUD 108 Program: The Department of Housing and Urban Development has a loan and loan guarantee program that is allotted for economic development. There is both federal money under this program as well as money from this program given to the state to administer. While these loans and loan guarantees generally are housing related, the agency has made loan guarantees for other economic development projects that can be shown to benefit low- or moderate-income households. If enough of a fiber project can be said to benefit low-income residents, then these loans can theoretically be used for some portion of a fiber project.

Small Business Administration 504 Loan Program: This program by the SBA provides loans or loan guarantees to small start-up businesses. These loans or loan guarantees must be made in conjunction with a bank, with the bank providing some loan funds directly and with the SBA loaning or guaranteeing up to 50% of the total loan. This program would only be possibly

[27] https://broadband.masstech.org/last-mile-programs/program-unserved-towns

[28] https://broadband.masstech.org/last-mile-programs/program-partially-served-cable-towns

available if a small business (an ISP) ended up funding the network. There are dollar limits on the size of these loans and this funding would not be nearly enough to fund a fiber network – but it could be one source of funding for a start-up community-based ISP that could be used to fund during the start-up phase of launching a fiber business.

There are other federal loan guarantees that benefit only rural areas or only a specific region of the country like Appalachia, and such programs would not be available in Falmouth.

Opportunity Zones

Congress created a new tax opportunity as part of the 2017 Tax Cuts and Jobs Act. The Act created Opportunity Zones in which investors can get special capital gains treatment and other tax breaks for investing in qualified infrastructure within an opportunity zone. Each state governor then designated specific opportunity zones.

Qualified investments made inside that area can get special tax treatment. The first benefit is that taxes can be deferred from past investments if the gains are invested inside of an opportunity zone. For example, if an investor had a capital gain from the sale of a property, they could invest those gains and not pay taxes on the gains now, but have those gains deferred until as long as 2047. Investors have until 2026 to make such investments.

An investor also gets tax forgiveness on new investments made inside the opportunity zones if that investment is held for at least 10 years. Most of the opportunity zones include sizable areas of low-income residents and a qualified investment must meet a test of benefitting that community in some significant way. A fiber optic network that will bring broadband to all of the homes in an opportunity zone should meet that test – there are lot of demonstrable benefits of fiber.

Most opportunity zone investments are being made from special funds created for that purpose, although a high-wealth individual could also make an investment.

Opportunity zone financing is most attractive when combined across multiple projects. For example, somebody might be interested in making an opportunity zone investment in a fiber network is that was coupled with some other opportunity investment in the same neighborhoods. This might be low-income housing, green energy production, or some other project that has a clear benefit to the local community.

The town has an opportunity zone in the east end of town, defined by Census tract 25001014500.[29] This Census tract covers a population of about 5,650. There is a fuller description of how an opportunity zone investment might be used in a fiber project at the end of this section of the report.

New Market Tax Credits

The New Markets Tax Credit (NMTC) Program was established in 2000 as part of the Community Tax Relief Act of 2000. The goal of the program is to spur revitalization efforts of low-income and impoverished communities across the United States and Territories. New market tax credits are normally used to fund only a small portion of a project.

[29] Map at: https://esrimedia.maps.arcgis.com/apps/View/index.html?appid=77f3cad12b6c4bffb816332544f04542

Eligibility of the town to use these funds would depend upon meeting an earnings test, and it's likely that the town would not be eligible for these investments. However, this would be worth checking with a specialist working with NMTC.

The NMTC Program works by giving big tax credits to investors that are willing to invest in infrastructure projects in qualifying communities. The tax credits are so lucrative that often the other terms for accepting the funding are modest. The tax credit equals 39% of the investment paid out—5% in each of the first 3 years, then 6% in the final 4 years, for a total of 39%.

The Community Development Financial Institutions (CDFI) Fund and the Department of the Treasury administer the program. The process of how the Treasury allots credits is a complicated one and we won't cover it, but in essence, there are entities around the country each year that are awarded tax credits and these entities work as brokers to allot the credits to specific project. The credits are often purchased by the large national banks or other firms that invest in infrastructure.

Generally, in practice, these funds act like a mix of loans and credits to the recipient. For instance, a community that received these funds might have to pay some modest amount of interest during the 7 years of the tax credit, and at the end would have a balloon payment for the principal. However, in some cases even some or all of the principal will be excused, making this look almost like a grant.

Because the entities that get the tax credits change each year, and because applications are made to the entities that hold the credits, the process for applying for this money is somewhat fluid and changes from year to year. However, there are entities and consultants who help find New Market Tax Credits and who can help you through the maze of requirements.

Customer Financing

When neither an ISP nor municipality can finance a project, we've seen citizens to step up and agree to somehow fund directly some or all of a broadband project. There are several examples of places where this has been done in the country:

Property (or Other Kind of Tax) Revenues. It is possible to obtain some or all of the cost of a broadband network through a pledge of future tax revenues. That pledge can then support a bond. This is different than most bonds for a broadband network where the network would be secured by revenues of the broadband venture. But a pledge of some other kind of tax revenue is one of the easiest ways to get a bond. There are some real examples of this kind of financing:

- Lyndon Township, Michigan: This is a township of about 1,000 homes that voted to raise property taxes to fund to build a fiber network. The township then partnered with a local broadband cooperative to provide services. The project is a win/win for citizens. Property taxes increased about $25 per month per household. The township provides free access to the network to the cooperative which is charging about $25 for broadband – making the total cost of getting broadband about $50 per month. This is an area that had no broadband before the project.
- UTOPIA, Utah: UTOPIA is a consortium of a number of small towns in Utah that banded together to get fiber. Each town has pledged property tax revenues to fund part of the cost of the network.

- Cook County, Minnesota: Cook County funded about half of their fiber network using a federal grant awarded from the Stimulus funding program in 2008. The county held a referendum and used a sales tax increase to pay for the matching funds needed to build the project.

Direct Customer Contributions: It's also possible to pay for some of a broadband project through direct contribution of possible customers. This has never been done on a large scale because it would be exceedingly difficult to get a lot of residents to agree to write a check to fund a network. But there are some examples to consider:

- Contribution to Aid in Construction: Most utilities have a program where they will agree to extend their network to customers if those customers agree to pay the cost of the connection. We are aware in the broadband area of numerous cases where small pockets of rural home raised the needed money to get connected to a nearby broadband network.
- Ammon, Idaho: This is the only municipal attempt at funding a network in this way. The City of Ammon will connect customers to a fiber network if they will contribute $3,500 up-front to cover the cost of construction.

Public Private Partnerships

A public private partnership (PPP) is formed when a government entity and commercial entity fund a project together. There is no one model for a PPP and such an arrangement can be structured in many different ways. The main benefit of a PPP is that the commercial operator of a project benefits by getting some bond financing from the municipal partner. This allows the business to blend the benefits of bond and commercial financing and is one of the ways that makes it easier to get through the first few years of the project.

The general benefits of bond financing are what makes public money attractive to a commercial partner—low interest rates, long repayment term, and small or no payments for the first few years. But the downside is that there are more overall financing costs and in the long run a bond makes a project cost more in terms of cash. The safety of a bond in the first few years, though, can be very attractive.

Combining Public and Private Financing. There are benefits to combining the two kinds of financing:

- Banks will often consider the financing that comes with bonds as the equivalent of equity, meaning that the commercial partner will not require as much, or even no, cash equity.
- In terms of the amount borrowed, the two methods work well together if construction loans are used to cover the construction and bond financing is used for the longer-term financing costs.
- Combining the two methods works to produce a payment term that is longer than a traditional commercial loan.
- Combining the two methods also usually means lower debt payment during the first few critical years while the network is being built.
- One banking issue must be resolved when combining public and private financing. When there are multiple lenders to a project, one of the lenders must be given the "first lien position," meaning that payments to them take priority over other loans. It would not be unusual for a bank loan and a bond issue to both want the first lien position. In our experience this dilemma is most often solved by having the municipal bonds take a second lien position, meaning that the municipal bond payments must be secured by something other than the revenues of the project.

- There is also likely to be wrangling between the parties for collateral. As mentioned elsewhere, a physical fiber network makes for poor collateral, but each lender is still going to want to latch on to whatever collateral they can grab. The most covered collateral is customer revenues, which almost always would go to the lender with the first lien position.

Following are two examples of this type of PPP, both from Minnesota:

- RS Fiber: RS Fiber is a new broadband cooperative that was formed in Renville and Sibley counties. The project was funded from various sources including a loan for 25% of the project supplied by a bond backed by the cities and counties involved in the project. The Cooperative raised the other money with a combination of bank loans and grants.
- Swift County: The county government there contributed a significant percentage of the cost needed to construct a broadband network in the county. The bond proceeds were loaned to Federated Telephone Cooperative and are expected to be paid back over time. However, the county loans took second lien position behind commercial loans.

Other Sources of Financing

Vendor Financing. Vendor financing for electronics was huge during the telecom boom in the late 1990s. Several vendors would finance the purchase and installation costs for electronics for fiber networks. The primary benefit of vendor financing is no payments for a few years while the network is being constructed and customers are being added. Such financing worked best when combined with other kinds of commercial financing. We've heard of several cases of vendor financing in the past year, mostly from some of the lesser-known vendors in the industry.

Loans from Individuals: We've seen broadband projects where 5% - 10% of a project has been funded through loans from individuals in the community. This is a well-known method when constructing fiber networks in a farming community where farmers kick-in a part of the cost of building the network. Such loans usually take last place in payment priority behind any commercial lenders. Banks love such loans because they are direct evidence of community buy-in of the network. Such loans would generally have a simplified loan contract with simple loan covenants. Money borrowed in this manner generally avoids the fees associated with commercial or municipal financing.

Loans / Grants from Non-Profits. We know of several communities that have gotten substantial loans and grants from major non-profits or trusts. These have typically been non-profits located in the communities that see the public benefits of broadband.

Comparing Financing Options

Comparing Bond and Bank Financing

Benefits of Bond Financing: There are several major benefits for using bond financing:

- The term of the bond can match the expected life of the assets and it is not unusual to find bonds for fiber projects that stretch out for 25 to 30 years. It's difficult to finance a commercial loan longer than 15 years and most loans are shorter. The longer the length of the loan, the lower the annual bond payments.

- Bonds can be used to 100% finance a project, meaning there is no need for cash or equity to fund the new business. Lack of cash equity is generally the requirement that creates a challenge for traditional commercial financing.
- Bonds often, but not always, have lower interest rates than commercial debt. The interest rate is dependent upon several factors including the credit worthiness (bond rating) of the borrower as well as the perceived risk of the project.
- It's generally easier to sell bonds than to raise commercial money from banks. Sometimes bonds require a referendum, but once bonds are approved there is generally a ready market for buying the bonds and raising the needed funds.

Benefits of Commercial Financing: There are also a few benefits for commercial financing.

- Generally, the amount that must be borrowed from commercial financing is lower, sometimes significantly lower. This is due to several issues associated with bond financing. Bond financing often contains the following extra costs that are not included with commercial loans:
  - Surety: Bonds often require a pledge of surety to protect against default of the bonds. The two most common kinds of surety are the use of a debt service reserve fund and bond insurance. A debt service reserve fund (DSRF) borrows some amount of money, perhaps the equivalent of one year of bond payments and puts it into escrow for the term of the bond. They money just sits there to be used to help make bond payments should the project have trouble making the payments. Bond insurance works the same way, and a borrower will pre-pay and insurance policy at the beginning of the bond that will cover some defined amount of payments in case of a default.
  - Capitalized Interest: Bonds typically borrow the interest payments to cover bond payments for some period of time, up to five years.
- Construction Loans: Another reason that commercial financing results in smaller debt is through the use of construction financing. A commercial loan will forward the cash needed each month as construction is done, and interest is not paid on funds until those funds have been used. However, bonds borrow all of the money on day one and begin accruing interest expense on the full amount borrowed on day one. Construction loans also means that a borrower will only draw loans they need while bond financing is often padded with a construction contingency in case the project costs more than expected.
- Deferred Payment: Commercial financing can be structured so that there are no debt payments due for the first year or two. This contrasts with bonds that generally expect interest payments to be paid immediately after borrowing. Since fiber projects can take several years to reach a cash breakeven, it's typical for a bond to pre-borrow the interest payments for the first few years (known as capitalized interest).
- Retirement of Debt: It's generally easy to retire commercial debt, which might be done in order to pay a project off early or to refinance the debt. This contrasts to bonds that often require that the original borrowing be held for a fixed number of years before it can be retired or refinanced.

Funding Strategy for This Project

The RFP asks us to discuss a funding strategy based upon the following questions:

- Stakeholder or potential third-party contributors.

- Grant funding options.
- Millage funding options (municipal bonds).
- Establishing a public-private partnership if viable.
- Capital, revenue bond, and municipal self-funding options.
- Provide suggestions on funding sources for the infrastructure buildout.
- Based on estimated user fees, describe a sustainable debt repayment method.

The town has three possible options for funding a broadband solution:

- Attracting an ISP to Invest in the town.
- Public-private partnerships
- Locally financed network.

Attracting an ISP. This study quantified the cost of building a fiber network everywhere in Falmouth. There are not many ISPs in the country that are able to make an investment of the size needed to build fiber everywhere. Most of the ISPs in the region do not have the financial wherewithal to make an investment of that size. This is not to say that it is impossible to attract and ISP and there are other cities that have attracted ISPs to make the needed investments.

The best way we know of to find a potential ISP partner is by issuing an RFI looking for a partner. That RFI could contain a summary of the key findings of this study including the cost of building fiber in the cities and a discussion of the potential returns for an ISP. We have seen well over one hundred such RFPs in recent years and most RFIs have gotten no serious responses from ISPs – but some do, and some cities have found ISP partners in this manner. The more typical response you'll get will be from ISPs offering to operate the network if the town builds the network.

Public-Private Partnerships (PPP). A public-private partnership is going to require a significant local financial commitment since you'll still have to pay for most of the cost of building a network. The three most common forms of PPP are:

- The town builds everything and you find a partner to operate the ISP business.
- The town builds the fiber network to the point of reaching customers and an ISP partner covers costs inside the home. The ISP partner in this situation would typically operate the business.
- The town builds the fiber network and an ISP partner builds the drops and provides the electronics needed to provide service.

Each of these options still requires a significant local investment since building the fiber network is the biggest cost for bringing fiber to the communities. The options for funding a fiber network are the same as described in the next option below.

Municipality Builds and Operates the Network. In this option the municipality has to cover all of the costs of the business. That includes the cost of building the network, the operating costs for launching and running the ISP, and the debt costs incurred to finance the network.

Cities which have built fiber networks have mostly funded the networks with municipal bonds – and there are good reasons for doing so:

- Municipal bonds are the only form of financing that allows for borrowing 100% of the costs of building a network, including borrowing to make the interest payments, at the beginning of a project.
- While cities are allowed to borrow from banks, most cities are not willing or able to meet the terms required by banks. Banks also have little experience in lending to cities since most such lending is done through municipal bonds.
- Banks are somewhat put off by the public nature of everything to do with financing a municipal project. Banks require non-disclosures from most borrowers and are not comfortable with public disclosure laws.
- Perhaps the biggest reason is that banks rarely make loans for the long payment terms needed to support a broadband business. Most banks loans are under ten years in duration. We've seen bank infrastructure loans with terms as long as twenty years, but that's relatively rare.

This is not to say that bank loans are impossible, but it would be a highly challenging process to tackle for the size of the borrowing needed to this project. This makes the most likely path for financing a fiber project to be municipal bonds.

The biggest decision to make when using bond is the surety. This means the revenue stream that is used to guarantee the bonds. There are a number of ways that other communities have guaranteed bond payments:

- General Tax Revenues. The most common kind of surety for bonds is general tax revenues. Should a bond backed by tax revenues ever get into trouble, a town would be obligated to raise taxes to cover the shortfall. This would normally be negotiated up-front with the sale of the bonds and the pledge revenues could be property taxes, sales taxes, or any other kind of tax revenue that is under the town's control and that could be increased to cover bond payments.
- Revenue Bonds. A revenue bond would pledge the revenues from the fiber project to cover bond payments. Should the business underperform, the bondholders have to accept the lower payments. Many such bonds would let the bondholders seize the property in the case of a default, which would mean they would take over the fiber network and business. However, since most bonds are sold to "coupon-pinchers," meaning small private investors, it's exceedingly hard for a group of bondholders to agree on that sort of takeover. Every town funding fiber hopes to get revenue bonds, but there we don't think that a pure revenue bond is an option for cities any longer, due to several defaults on revenue bonds for broadband networks. Some of the failures include Alameda, California, Crawfordsville, Indiana, and Monticello, Minnesota.
- Quasi-Revenue Bonds. Most municipal fiber networks have been funding with bonds that straddle both revenue and general obligation bonds. Such projects first pledge all of the revenues from the fiber business to the bondholders. But bondholders don't feel safe with just the fiber business revenue pledge and ask for more surety. This primary form of extra surety used is the creation of a debt service reserve fund (DSRF). This generally means that the municipality borrows (or puts into escrow from general funds) a deposit equal to one-year of debt payments. Should the project ever get into trouble, the bondholders can take bond payments from the DSRF. The municipal borrower is then required to replenish the DSRF.

  Municipalities like this process a lot more than a pure revenue bond. For example, if a revenue bond pledges property tax revenues, then the town is obligated to raise property taxes, with zero recourse. However, a town generally has total flexibility in deciding how to replenish the DSRF. They could do so from cash reserves, or they could find the needed revenue from any other

source including raising taxes. Just as a footnote to keep in mind, it would be an extraordinary circumstance if the fiber business can't cover most of the debt payments in a year, so normally a call on a DSRF fund would be some amount smaller than the whole balance of the DSRF.

There are other ways that cities have raised the funds needed to build fiber:

- Homeowner Pledge of Property Taxes. There have been some small communities where homeowners agreed to an increase in property taxes directly used to pay for a fiber network. One example is Lyndon Township in Michigan where homeowners voted to raise property taxes for twenty years to finance the network. The benefit to citizens is that the township was then able to drastically lower the cost of broadband, which is sold for $25 per month. The township still had to issue a municipal bond, but those payments are made from the increased property taxes and none of the revenues from the fiber business are used to pay for debt. There have been a number of communities that have tried to duplicate this concept but that have failed to pass a referendum approving the increased property taxes.
- Pledges of Sales Tax. Cook County, Minnesota paid for about one-fourth of their fiber network through an increase in sales taxes. The sales taxes were increased by a penny, and that revenue goes directly towards covering a portion of the bond payments.
- Homeowner House Equity. Utopia is a network in Utah that covers more than a dozen smaller communities. The business got started by asking homeowners in a community to allow for a lien against each home in the community. These liens provided the surety for the municipal bonds. The fiber business revenues were still expected to cover debt payments. But if the project were ever unable to cover debt payments then the bondholders could have called the homeowner liens and gotten payments from each homeowner in the community. This was a cumbersome process and took a long time to organize. In more recent years as the business has grown, Utopia has refinanced to a more normal debt structure.
- Homeowner Contributions. The City of Ammon, Idaho requires any homeowner that wants to be connected to the network to pay $3,500. The city is willing to accept the payments over time. These payments significantly reduce the amount of network that needs to be financed in some more traditional manner.

  There are some drawbacks to the financing method. Neighborhoods only get fiber when enough homeowners have made the contribution. Some neighborhoods are not meeting the needed funding threshold. Of more significance, homes that can't afford the payment are locked out from buying fiber. It seems somewhat odd for a municipality to be supporting a financing mechanism that discriminates against the poorest people in the community – most cities have the opposite goal, which is to make fiber available to everybody.
- Municipal Self-Funding. The only municipal network we can think of that was totally self-funded is North Kansas City, Kansas. This small town, surrounded by Kansas City, was able to fund a fiber network by using revenues from two riverboat casinos moored in the city. Those revenues, by law, could only be used by the city for making infrastructure investments.

  However, many cities that build fiber networks contribute some cash towards the project. This is particularly common for cities that operate an electric utility that might be sitting on cash reserves. Cities generally 'lend' the cash internally to the fiber project and expect the money to eventually be paid back to reserves. Such loans can be set at a low interest rate to match whatever the funds might have been earnings from investments. Any cash that can reduce bond

payments is generally a major benefit to a fiber project since it lowers annual debt payments and reduces the risk of failure.

Thinking Outside the Box. We're seeing today that some of the communities getting fiber networks are only doing so by thinking outside the box. Following are a few ideas that are worth considering as non-standard ways to finance a fiber network.

- Direct Tax Funding. One of the more interesting ways to pay for a fiber network is by directly paying for some of all of the network directly with taxes. There are a few examples of this for existing municipal fiber initiatives. Cook County Minnesota funded about 25% of a countywide fiber project through an increase in sales taxes.

  Another example is with Lyndon Township in Michigan. The township passed a referendum to pay for the entire fiber network through an increase in property taxes. This means that the fiber business does not have to contribute to debt.

  The concept behind this kind of financing is that everybody in the community contributes to a fiber network, which is a benefit to the community even for households that don't buy broadband. There are a number of benefits from the fiber network not having to cover all debt costs:
  - Broadband prices could be reduced, which makes broadband affordable to more homes. In the extreme case, if tax revenues fund the whole network then broadband prices could be set far below market rates – it might be possible to have something like a $30 gigabit product.
  - Broadband prices could be set at market, and a fiber business could turn into a new source of revenue for the community from the profits derived from selling broadband.
  - In a town like Falmouth, having a fiber network might distinguish you from other tourist towns. This could drive up property values (and property tax revenues) that would help to pay for a network. A new fiber network could also draw more people to visit Falmouth.
  - Fiber broadband might entice more people to live permanently in Falmouth. It seems likely that a lot more professionals will be working from home even after the end of the pandemic.

  This kind of funding can be made to work if voters can see a broadband benefit that equals or exceeds the increased tax burden.

- Raising Local Start-up Funding. Mansfield Community Fiber is a new fiber initiative that is currently in the process of building networks in over 20 rural towns in Vermont. The company got initial funding by soliciting funds from the community. They sold membership "shares" in increments of $2,500. Some wealthy people purchased multiple shares and some households went in together to buy shares. The company eventually sold over $7 million in shares which provided enough seed money to begin borrowing the rest of the money to build the network.

  The shares are not equity but are notes that carry a reasonable interest rate. The advantage for the startup business is that they can accrue interest for many years on the shares, giving them time to build the business to be a cash success.

This kind of start-up capital could be used along with any other kind of financing. For example, if a similar amount of $7 million could be raised in Falmouth, it would significantly lower the size of the bond needed to fund the rest of the project.

Falmouth might be the ideal kind of community to consider this kind of financing. We got the sense in doing this study that there are a lot of people in the community who care about the success of the town and might be open to investing in a fiber business. Raising some of any needed funding locally makes a strong statement that the community is behind a broadband effort.

- Partnering with an Incumbent. Chesterfield and other villages in New Hampshire that have partnered with Consolidated Communications, the incumbent telephone company. Consolidated is a large telco operating in almost thirty states. The village raised bond money to help pay for a fiber network to reach every home and business. Consolidated agreed to serve the business and is going to charge a small premium on broadband for twenty years to recover its costs for entering the partnership.

  It's not inconceivable that Verizon would consider such a partnership if the town were bringing significant funding to a partnership. Verizon has never done a partnership with a community, but you can't write off this idea without giving it consideration. Verizon would benefit by gaining major market share in a town the size of Falmouth and the town would benefit by having gigabit broadband.

- Consider Opportunity Zone Financing. Congress created a new tax opportunity as part of the 2017 Tax Cuts and Jobs Act. The Act created Opportunity Zones in which investors can get special capital gains treatment and other tax breaks for investing in qualified infrastructure within an opportunity zone. Each state governor then designated specific opportunity zones. The town has an opportunity zone in the east end of town that covers a population of about 5,650. Here's how an opportunity zone investment might be part of a larger financial funding effort:
  - An investor looking to take advantage of opportunity zone benefits would invest equity to help finance a broadband network in the town. The benefits would be limited to the portion of the network built within the opportunity zone.
  - Opportunity zone investors are looking for tax-free capital gains. A typical structure might be that the town (or whoever is building the network) would gain a low-interest or even no-interest loan from the investor. At some pre-determined future date (at least 10 years in the future) the town would "buy-out" the investor at some multiple, say twice as much as way invested. That multiple would equal the interest that might have been earned over the 10-years but would be expressed as capital gains for the investor.
  - Such an investment would have a great benefit for a broadband project. One of the biggest hurdles in financing a fiber network is covering the interest and principal payments on debt. Getting even a portion of the funding with an opportunity zone investment would reduce principal and interest payments for 10 years. The remaining loan would likely have to be refinanced at the time of the repayment, but by then the business might have accumulated enough cash to pay to loan balance outright, or likely is in a good position to take on a new debt.
  - An opportunity zone loan is still a loan and all of the normal issues like collateral and priority of payments would still need to be established. We are not aware of anywhere

that opportunity zone financing has been paired with municipal bond funding, so these issues would have to be resolved.

B. Choosing an Operating Model / Partnering Potential

How does the EDIC and the town take this report and decide what operating model to choose? This involves a decision-making process that commercial ISPs are used to but that might be alien to a government entity. Choosing an operating model means undergoing a three-step process:

- The first is to look internally. Specify your goals. Know your existing strengths and weaknesses in terms of what you might bring as an ISP or as a partner. Understand your willingness to accept risk and the willingness for the community to accept losses.
- The second step is to then take your attributes and compare them to the pros and cons of the various operating models.
- Finally requires looking externally to see if the option you chose is reasonably feasible. If a municipality want to become the ISP, can it borrow the needed funds to build the network. If a municipality wants to join a partnership, are there partners available?

Internal Assessment

Choosing an operating model means undertaking an honest assessment of the local government's ability to participate in one of more of the operating models. Sometimes this assessment is easy. For instance, if the government is not willing to borrow money, then any options that require the government to help fund the network are off the table. But for a government that is open to the range of possibilities, the internal assessment is a needed part of the process of choosing an operating model.

Goals. This process should always start off with a set of goals of what you want to achieve with better broadband. The goals are important, because the goals alone sometimes dictate the operating models that you must consider. For example, if a goal is to make sure that broadband is affordable for even the lowest-income homes, then inviting in a commercial ISP might be off the table – most commercial ISPs are unwilling to serve everybody in a community or to subsidize service for low-income homes. If the goal is to promote competition over everything else, then the only good choice might be to pursue open access.

Strengths and Weaknesses. One of the hardest things any organization to do is to make a fair assessment of your own strengths and weaknesses. Government entities, almost by definition, don't share the same attributes as a competitive corporation. Before any community contemplates being an ISP, we always recommend that a government entity rate themselves in terms of the attributes that would be desired by a competitive ISP. These include things like:

- Competitive nature
- Quick decision-making
- Comfortable in selling to the public
- Technology savvy and willingness to remain cutting edge
- Willingness to accept the risk of losses and poor performance
- Willingness to hire and fire staff based upon performance
- Willingness to empower employees at all levels to make needed decisions

There are a number of ways to assess strengths and weaknesses. Perhaps the most common is to undertake a SWOT analysis that provides a framework for assessing the strengths, weaknesses, opportunities, and threats posed by a new challenge. If you've never done this there are consultants that can help you through this process. What's most important in this analysis is the willingness to be brutally honest in the assessment.

That is not easy for a local government to honestly assess its weaknesses because that invites criticism of the local government. However, for a town that doesn't already operate an electric utility, it would be vital to fully assess the ability of the town successfully operate or partner in a broadband business before undertaking such a major project.

Is a Municipal Electric Utility Necessary to Succeed with Fiber?

There is an extra step of consideration for any government entity that is not already operating an electric utility. Most of the municipalities that have decided to build and operate their own broadband utility already had an existing electric utility. There are some significant advantages to already being an electric utility:

- The biggest advantage that an existing electric utility has is a billing relationship with every customer in the community. Assuming that the public likes the municipal utility (not always the case, but usually so) then the utility has instant name recognition and public trust when they open an ISP. This gives them a leg up on a new ISP entering the same market.
- The municipality likely owns most or all of the utility poles, making it a lot easier to build fiber. A pole-owner has a lot more options on how to string fiber on poles. For example, they can place some or all of the fiber in the power space (near to the electric lines) which is something that is rarely available to fiber overbuilders.
- An electric utility already engages in many of the activities needed to operate a fiber network. The company will have technical staff who can easily learn fiber technology. The utility will already have cherry-pickers and technicians used to working on aerial wires.
- An electric utility will already have management staff that doesn't necessarily need to be duplicated. For instance, the general manager of the utility can also be the general manager of the broadband business, which reduces the need to hire a whole new staff to operate as an ISP. This sharing or resources can happen across a lot of middle management.
- An electric utility will already have the needed backoffice functions like accounting, human resources, billing systems, cash collection processes, a public business office, etc. that all must be established for a new ISP.
- An electric utility will already have a customer service group that interfaces with customers. Depending on the size of the community, a lot of residents will be on a first-name basis with long-term customer care employees.
- An electric utility should already have outage plans in place to allow it to quickly respond to electric outages. This is one of the hardest things for a new ISP to develop. Electric utilities also often have emergency plans in place that will bring technicians from out of market in the case of major storm damage.
- A municipality with an electric utility often has an easier time raising bond funding. If the electric utility is successful enough, bonds can be issued that are backed by electric rates rather than backed by tax revenues. We've seen cases where this meant that bonds could be issued without needing a referendum.

- One of the less obvious benefits of adding a broadband utility to an existing electric utility is that the electric utility can pick up a significant piece of the cost of building the network. This can be done by having the electric utility pay for a portion of the fiber build for fibers to connect to substations, or this can be done by having the electric utility lease this capacity over time, making them a large customer of the fiber utility. Cities that tackle smart grid have even more opportunities to generate revenues for a fiber utility.
- Another hidden benefit for an electric utility that opens a fiber business is that the operating costs for the electric utility drop. As costs for things like a portion of the general manager, for a business office, and all of the other shared functions are allocated to broadband, the allocations to electric are reduced. This can take pressure off of electric rates, or even reduce rates over the long haul.
- It's been the experience at CCG that an electric utility can launch a broadband business faster than a new ISP can be established in a market.

These advantages all result in a significant cost advantage for a municipality with an electric utility. Most municipalities that don't have any existing electric utility are intimidated by launching a new broadband ISP. These municipalities look at all of the aspects of creating a new ISP and generally realize quickly that they are not prepared to tackle the huge number of steps it takes to create an ISP from scratch.

Partner Instead? An ISP partner can bring many of the same advantages that come with an electric utility. They are already in the business and have the staff that understand the business. An ISP already has the upper and middle management that likely wouldn't have to be duplicated to open a new market. An ISP will have all of the backoffice functions such as billing systems already covered.

An ISP partner brings some things that an electric utility does not. They are already experts in the broadband business. They already sell bandwidth and likely other triple-play products to customers. They already understand all of the nuances of the industry such as regulations, taxation, the construction process, the industry vendors, etc.

ISPs also bring one big advantage that doesn't come from an electric utility. An ISP knows how to sell in a competitive environment – the one aspect of being an ISP that often intimidates a monopoly electric utility.

One of the other big advantages of working with an existing ISP is that they can significantly shorten the time to market. It wouldn't be a surprise for a commercial ISP to get the first paying customer 6 – 9 months earlier than the same ISP business launched by the electric utility.

However, partnering is not without a cost. An ISP partner is going to want to make a profit, and that adds cost back onto the process that likely wipes out the cost advantages just mentioned above. Being in a partnership can cost more than launching a standalone ISP.

The many reasons discussed above are why almost every municipality that doesn't have its own electric utility generally has chosen to have an ISP partner or partners. Starting from scratch to build an ISP is extremely challenging. It means having to simultaneously master the following types of tasks. This is an abbreviated list and in a new market launch we've seen Gantt charts that list several thousand steps needed to open a new ISP market. That list is even longer if it's being done by a newly created ISP.

- The Technology. This includes the technology of building, maintaining, repairing, and installing fiber. It involves choosing a last mile electronics technology. It means choosing for a variety of different network designs for the network topology including issues like using huts versus centralizing electronics. It involves mastering the process of installing fiber at a wide variety of different homes and businesses. It means deciding how to tackle apartments and other more complex deployment situations. It means deciding how to deploy alarms to notify of network problems, how to monitor the network, how to respond to network problems. It means deciding the ancillary issues such as how to best map the network to most useful in the future or the best way to establish a spares inventory.
- The Construction Process. This involves selecting an engineering firm to design the network. It means selecting a construction company to build the network. It means finding a vendor and buying the electronics. It means directly buying many of the components of the network. Even if the construction company or engineer purchases the major components of the network there will be long list of things that have to bought directly – and this often overtaxes the government purchasing process. Somebody has to then monitor the construction process to make sure they stay on specification. A municipality often gets involved in the process by issuing construction permits, locating existing underground utilities, inspecting construction work sites, etc.
- Creating the ISP Organization. An organization chart has to be created including detailed job descriptions that often must be integrated into the civil service job structure. Employees must be interviewed and hired. With a new company there has to be a plan for training and integrating employees into a team. This also means defining how the new ISP fits in with the rest of the existing organization. It means defining who in the organization gets to make specific types of decisions.
- Creating the Products. Products and prices need to be selected, down to the smallest detail. For each product, the ISP must decide how it will function – done internally or outsourced, and then the appropriate purchasing processes must be used to acquire and activate all the components of the products. Processes must be established to implementing products for customers. As a small example, if telephone service will be offered, customers will want to keep existing phone numbers and will expect the ISP to "port" the number from the old ISP to the new one.
- Developing Backoffice Practices. This starts with implementing the accounting process and deciding how to account for the cost of the network and the operating expenses of the business. That means developing a chart of accounts. It might mean creating work orders in order to capitalize labor, interest expense and other overheads into the cost of the network. It means defining how cash will work from the business from financing the network through the final process of collecting cash from customers. Bond financing generally layers on a lot of specific processes. The biggest decision to make for the backoffice is the software to use to operate the ISP. This is called BSS/OSS software in the industry, which means a billing and operating software system. It can take 6 – 9 months to implement a new BSS/OSS, so the process of selecting software should start early.
- Develop Provisioning Process. Provisioning in the industry means all of the processes that must be put into place from the time that a salesperson closes a sale until the customer has received their first bill for service. For an ISP to work smoothly processes must be well-defined so that paperwork (hopefully all computerized with BSS/OSS software). It means deciding the steps that must be taken during the process and defining exactly who does each step. Creating an efficient provisioning processes is often one of the most challenging steps for a new ISP. There are a few dozen steps at minimum in the provisioning process such as taking and verifying orders, making sure each customers gets the right products at the time of installation, qualifying customers and

doing credit checks or taking deposits as needed, getting each customer properly entered into the billing system so that all products are billed, coordinating with customers during the process up through scheduling the installation visit, etc.

- Develop Operational Processes. This means defining daily workflow. For example, what exactly does an installer do from the beginning to the end of the day. What software systems do they need to do their job right. What records do they need to keep during the day in terms of a time sheet, a vehicle log, a list of materials used, etc. How does the business decide which field technicians goes to which field task? This means keeping track of a time calendar and trying to meet pre-scheduled meetings with customers (something the competition does poorly). How does the business cope with holidays, vacation days, sick days, training days?
- Developing a Sales and Marketing Plan. This starts with developing a brand for the business which includes a logo, web page, social media presence, etc. It means deciding how to communicate with the public during the construction process and then deciding when it's time to take orders. The sales process must be specifically designed. If you're going to advertise it means developing advertising content and figuring out how to get it in front of the public. If you're going to deploy a sales staff it means defining sales quotas, sales compensation. This also means being ready to modify the sales and marketing process quickly as you find out what works and doesn't work in the market.
- Implementing Business Process. This might mean setting up a business office for customers to visit and pay bills. It might mean establishing the processes of getting bills out the door. It means establishing the process of notifying and disconnecting customers that don't pay. It means buying trucks, furniture, computers, etc. for employees. It means getting the needed training for new employees. It means deciding how to take trouble calls and how to react to them. It means developing an escalation process where issues go up the chain as needed to be resolved.
- Deciding on Policies. An ISP will have dozens of policies. Are deposits or credit checks required? What are the options for paying for service (credit cards, bank debits, paper bills, email bills? It means deciding when customers get notified about non-payment and when they get disconnected and then reconnected. It means determining how and if you're willing to give discounts to customers. It means deciding which employees have the authority to make decisions that directly affect customers.
- Develop Customer Installation Processes. These are the processes at the home or business. Will you use contractors or employees for various tasks? What paperwork does a customer need to sign (contract, terms of service, rights-of-way to cross a yard)? What exactly is included in an installation for free and what incurs extra charges. What are the policies for where you're willing to bring a wire inside a home or business? Can and should an installer upsell customers during the sale process, and how does the rest of the business change an order quickly?
- Meeting Legal / Regulatory Obligations. What federal, state, and local regulations affect the business and how do you make sure you are following regulations? What taxes must be collected from customers and how do you remit taxes to taxing authorities. What contract must be in place with the many vendors for construction and buying the products? Is there insurance you want to buy, or will the municipality self-insure?

While this is an intimidating list, it can be done. Tackling becoming an ISP means hiring a few people who have done this successfully before and can help to navigate the many tasks described above. It means finding engineers and consultants to help through the launch process to step the business from making big costly mistakes and from having unnecessary delays in the business launch.

Some of the cities that have decided to be an ISP start with what they call a pilot project. For a pilot project to be useful, most of the above steps must be implemented, and the concept of a pilot project is to observe and modify the processes to meet your company's skill set. The downside of a pilot project is that it drives only a tiny amount of revenue to cover a business with at last a decent core of staff on board.

Understanding the Risks of Operating an ISP

Regardless of operating choice you make (partner or going it alone), a municipality should take some time to consider the market risks of forming a competitive broadband business. It's far too easy to have a profitable looking financial business plan and assume that you end up with a profitable ISP that spins off cash to the municipality. The reality of the marketplace is that there are a number of risks that experienced ISPs recognize when entering a new market. Following is a list of some of the more likely market risks:

Competitive Risks. There is always the risk of a significant response from existing service providers. For example, it hasn't happened many times, but there are a few examples where incumbent service providers engaged in a serious price war with a new ISP. In a price war, prices can go so low that all service providers in the market lose money. Large incumbents can ride out the operating losses in a price war, while a new operator can't.

There is also the risk that a competitor could overbuild a new fiber network. It doesn't happen often, but it has happened. For example, in Monticello Minnesota, the incumbent telephone company TDS reacted to a municipal fiber network by building a second fiber network. In parts of the North Carolina research triangle and in Austin, Texas, both the incumbent telephone company and the cable company built some fiber-to-the-home as a reaction to fiber built by Google Fiber. That means a few lucky households are served by three gigabit fiber networks.

Existing cable companies often pull out all of the stops to make it hard for a new competitor to thrive. For example, they might offer low rates in a special and lock up customer in 2- to 3-year contracts before a new ISP is open for business. They often saturate the market with advertising and have been known to use negative advertising against new market entrants.

Financial Risks. The need to pass referendums to get public funding of broadband money can be a major barrier to entry, particularly for projects that use property or sales taxes to guarantee a broadband project.

Finding satisfactory collateral for loans is always a challenge when financing broadband projects.

No business plan is foolproof and there is always a risk of a project failing. Fear of failure often stops municipalities or commercial ISPs from taking the chance and making the needed investment.

Operational Market Risks. Above is a description of the many steps required to successfully launch a new ISP or a new market. The operational risks come from doing any of the tasks on that list poorly. For example, a new ISP might build a world class network but then stumble badly in the sales and marketing process.

The danger of botching the launch is in tarnishing the reputation of the new ISP business before it really gets going. An example of this was the FTTH network in Lafayette, Louisiana which suffered from huge problems with their video product. This was due to their vendor Alcatel not delivering the product that was promised in their response to the original RFP. The TV was so bad that many customers dropped the city ISP and word-of-mouth stopped a lot more customers from trying the new network. It took over a year to fix the video problems and during that time period the business fell significantly short of their business plan projections. Over time the city regained a reputation as a quality service provider and today is financially successful and is expanding into the surround suburbs. But that one mistake really hurt the business.

Risks of Operating Losses. One issue that new ISPs don't like to think about is what happens if the new ISP loses more money than anticipated. A new ISP needs to have a contingency financing plan to cover unexpected losses. A municipal ISP needs to be prepared to dip into municipal funds to cover shortfalls. Cities with electric utilities sometimes cover these losses by using electric cash reserves or even by raising electric rates. Commercial ventures that are part of a larger company can be covered for a while by the parent company.

However, standalone fiber ventures, either municipal or commercial, run a much greater risk. A standalone commercial venture that runs out of cash generally folds. In a municipal venture the only recourse might be to somehow cover losses from tax revenues or municipal cash reserves.

The Cost of Success. In the telecom world there is a phenomenon I call the cost of success. It's costly to add a new customer to a fiber network and if a new venture does better than expected, then a new ISP can find themselves without the capital funds needed to add new customers. The alternatives are to somehow borrow more money to fund the growth, or else make customers wait until the project generates enough cash to cover customers in a queue. It's often not practical for a municipality to borrow more money.

Local Rules and Regulations. It's important to realize that there are different rules governing fiber construction along county, state, and federal roads that might differ significantly from rules for city streets. We know of one that ran into a huge problem when the discovered after they had been funded with a bond that the county government wouldn't let them bury fiber in the ditches along the side of the road as had been planned. It turns out that the original public rights-of-way for these roads was a dozen feet off the edge of the road and over the last fifty years almost the entire service area had been overgrown with trees and woods along the roads. The municipal ISP had to bury fiber through the trees at significant extra cost when the county government refused to relax the rules.

In another case we know of an ISP that encountered a process along a county road where permits were required for each pole rather than filing a permit for a batch of poles. The extra paperwork slowed the permitting process to a grinding halt and delayed the construction process. The moral

of these stories is to do the needed homework with all jurisdictions early before raising money and committing resources.

Municipal Purchasing Rules. We've seen that municipal purchasing rules can add to the cost of building a government network. While these rules have the goal of making sure that a municipality doesn't overpay for good and services, the rules can add significant time and costs when buying all of the needed components and service vendors involved in a broadband network launch.

We've also seen the municipal purchasing process add cost to purchased goods and materials. Most of the vendors in the telecom world are not used to dealing with the municipal purchasing process, so many of them pad their prices when bidding – fully expecting to negotiate the prices lower later, only to sometimes find that their bid price was accepted without negotiation. We also find that there are quality vendors that refuse to participate in the municipal purchasing process.

A Few Municipal ISPs Have Failed. It's worth noting that there is a much longer list of commercial ISPs that have failed. There is no guarantee of being a success in a business where a lot of money is needed to fund a network and a business must win a lot of customers to break even. Following is a short description of a few of the municipal failures that the town will likely hear about if you decide to move forward:

- Monticello, Minnesota. The city was sued by the incumbent telephone company, TDS, within a few days after closing on bond funding. In hindsight the city should have returned the bond money to investors until the lawsuit was solved – but it didn't and the accumulated interest costs put the company far behind the business plan after it won the lawsuit. Additionally, the telco built fiber to some parts of the city to complete against the municipal fiber network.
- Crawfordsville, IN. The city built a fiber network, and for some inexplicable reason did almost no marketing. This might be the ultimate example of the 'build it and they will come' philosophy – and without marketing customers do not automatically show up.
- Alameda, California. The utility operated an ISP that never made money mostly due to the extremely high salaries in California (Alameda is an island across the bay from San Francisco). The city ultimately sold the business to Comcast.
- Bristol, Virginia. The city was one of the first to build a fiber network to reach everybody and from a financial perspective was a success. Years after the network was built some employees defrauded the company of money as part of a grant-funded project. Ultimately, several employees went to prison, but the city was able to sell the network and recovered the money that had been invested in the network. This is a warning that failure doesn't always have to be financial.
- Burlington, Vermont. The business lost money annually after the city decided to raid bond proceeds from the fiber project when the city had an economic downturn. The city eventually sold the business to a commercial ISP.

Looking Externally

Before finally deciding on an operating model we recommend that a potential ISP look externally to validate that what they have in mind is possible.

If everything above was considered in the first two steps, then there are usually only a few external issues to consider. Every situation is different, but the biggest external issues are things like the following:

Finding Qualified Staff. This isn't generally an issue in urban areas, but it can be a major issue in smaller markets. We've seen small-market ISPs struggle and sometimes fail to find needed experienced staff. For example, I helped a client find a CFO for a sizable rural ISP and it took nearly two years to finally attract a qualified person. Any new ISP needs at least a few seasoned veterans and finding them and attracting them can be a challenge. There is also often a significant wage differential between public and private jobs that has to be considered.

Verify the Availability of Funding. If you're going to use municipal bonds this would be the point in the process to have a detailed discussion with your bond advisors. Interest rates have been somewhat steady for many years in the United States, but there is a chance due to the unsettled nature of the economy that this could change. Any government that raised bond money back in times when interest rate fluctuated recalls delaying bond issue to try to find that "perfect" day to sell the bonds in order to get an acceptable interest rate.

If a project is going to require commercial funding, this is the time to get bankers talking to bond advisors to identify any issues that might become impediments.

Finding a Partner. We find that most municipalities tend towards liking partnerships. This means they can bring in somebody that already knows how to operate an ISP. It also might mean mitigating the risk by bringing in commercial funding to help offset some municipal funding. Finding a partner is such an integral step for many municipalities that we're going to discuss the partnership process in detail and answer the question of how to identify a good partner. Following are the best characteristics of an ISP operating partner:

> Experience. We know of several investor-driven ISPs looking to invest and operate broadband networks, but that have never built or operated a network. This isn't to say that such a group can't be a good partner, but it's a higher risk to work with an ISP that doesn't already have customers and that hasn't worked in a partnership before.
>
> There are a few horror stories in the industry of public/private partnerships that went awry because of lack of experience by the ISP partner. In the following two examples the ISP management team was made up of folks with industry experience but who had never worked together as a team before.
>
> - The first example is Utopia in Utah. This is a collaboration of small towns that are working together through the Utopia organization to create economy of scale for the business. State law in Utah doesn't allow municipalities to be an ISP, so Utopia works as an open access network where the consortium of cities built the network and various ISPs compete for customers.
>
> Utopia started by hiring an external management team that had not worked in the open access environment before. A number of things went wrong – the networks were late in getting constructed and came in over budget. The ISPs did not sell as aggressively as the business plan had supposed. Utopia ran out of cash before construction was complete and

almost folded, but the business was eventually saved through several rounds of refinancing and is now large enough to be financially stable. It took almost a decade of the business being in financial duress to get to that point.

- Another example is Lake County, Minnesota. The county decided to borrow money to build a county-wide fiber network. This is one of the northernmost counties in the state and quite remote. There are 11,000 residents in 2,100 square miles. They hired an outside firm to construct the network and run the ISP. The project went way over budget and the project ran out of money with a backlog of almost 1,000 customers they couldn't connect to the network.

  The project was funded through a combination of a $10 million federal grant and a low interest government loan for $56 million. The county also bonded over $7 million locally for the project plus floated loans to keep the project afloat. The project went completely underwater financially and didn't make enough money to cover debt payments. In 2019 the county sold the network to an ISP for $8.4 million. The federal government had to write off about $40 million in debt and the county still must cover the original bonds plus the internal loans made to the project.

Experience Working with Municipalities. It's somewhat important to work with an ISP that has worked with local governments before. CCG has witnessed a number of public private partnerships with the recurring theme that the two parties get frustrated with each other over time. This is due to two factors – frustration with the decision-making process and a difference in goals and expectations.

Commercial ISPs become quickly frustrated with the municipal decision-making process. Most local governments have a specified legal process that must be followed to make certain kinds of decisions. This might mean listing the topic for a public meeting, waiting for a period of time, and allowing public comment on the issue. Commercial ISPs are used to making decisions quickly and they don't like the drawn-out processes that government requires. Government entities get frustrated as well since their commercial partners push them to make decisions quickly when they can't.

A more fundamental issue in public private partnerships is a fundamental difference in goals. The issue commonly arises when the two parties didn't thoroughly discuss their long-term goals for broadband before a partnership began. Commercial ISPs are often most worried about cash flow and profit margins. If they've invested equity in a broadband network, they become unhappy if the business doesn't meet their earnings goals. Governments often have a different set of goals – serving every household, offering low-priced broadband to low-income houses, providing subsidized broadband to non-profits and anchor institutions. In many cases, these kinds of fundamental differences can't be overcome and eventually result in a dissolution of the partnership.

The differences between the two kinds of entities often surface when there is a discussion of rates. Local governments often push back against rate increases – particularly in election years. Cities push partners for low rates in general, and often want an ISP to give low rates for low-income households and even free rates to groups like non-profits.

These kinds of issues are less likely to be a huge problem if the ISP has worked successfully with other municipalities before. A government entity that is working with an ISP that has not partnered in this manner before should have an in-depth discussion up front about expectations. It's a lot easier if the two parties decide up front that they aren't compatible instead of getting a divorce after the partnership has been launched.

Financial Strength. Municipal entities often have a hard time judging the financial strength of partners. Unfortunately, most public/private partnerships are not with big well-financed ISPs. The more typical partnerships are with telephone companies, electric cooperatives, or fiber overbuilders. It's typical for commercial ISPs of this type to overstate their financial security – and they may even believe what they say in doing so. But there are a few fundamental things about ISPs that a municipality should understand:

- Every ISP has a natural borrowing limit. There is only so much debt that bankers and other lenders will allow them to carry. By definition, when an ISP nears that lending limit it means that bankers think the company is pushing its financial limitations. Any ISP that has borrowed to its limit can't afford to make financial mistakes, and that means the partnership and all their other ventures need to perform as expected. It's not unusual to see budding partnership be dependent upon obtaining financing, and it's not uncommon for the ISP to not get the hoped-for funding.
- The biggest issue with ISPs and borrowing is collateral. Banks don't look at fiber networks as good collateral for loans because there is very little value from repossessing a fiber network. This means the only good collateral that most ISPs have is the value of their existing company. Even surprisingly large ISPs might have to pledge their entire company in order to borrow a sizable amount of money to build an expensive network. It's often necessary for owners of ISPs to make personal guarantees on loans, meaning that both their business and their personal assets are on the line with a new fiber project. ISPs are highly unlikely to disclose to a government partner the details of how they raise money – among other reasons they are scared of public disclosure laws and don't want their personal financial position discoverable as a public record.

Capacity to Grow. One of the hardest things to judge is the ability of an ISP to grow quickly. A traditional ISP like a telephone company may have a lot of customers – but they acquired them slowly over decades. ISPs (and all other types of businesses) often get stressed to the breaking point when they try to grow too fast. It's not unusual for an ISP to somehow assume that existing middle and upper management can handle a growth scenario while still somehow handling the existing responsibilities they've always had.

Just because a company is a great ISP doesn't mean that the company is capable of growing quickly. Unfortunately, there is no way to judge this unless the ISP has already been growing prior to the creation of the partnership.

Fair Recognition of Value. One of the important attributes of a good partnership is the full and fair recognition of the value that each party brings to the partnership. Municipalities should be wary of a partner that overvalues what they bring to and undervalues what you bring. A government can create value for a public/private partnership in a number of ways:

- Funding. Any amounts paid towards funding a broadband network are valuable. Governments often don't know how to set a value for cash contributions – something that

commercial partners routinely figure out. It's been my experience that ISPs don't value government funding as much as they do other funding sources. I think this is because government funding doesn't come with the same stringent strings and responsibilities. A local government is not likely (or even able) to require things that a bank might require such as collateral or a lien on a partner's assets. If an ISP gets into financial trouble, the first entity they will try not to pay is a government partner. This can be dealt with in creating a partnership agreement, but to some degree that requires a government to think like a bank.

- Anchor Tenant. Government entities often make good anchor tenants – which is pledging to be an early customer of a network and guaranteeing to buy services with a long-term contract. It's not untypical for a government to be one of the largest broadband and telecom customers on a network. This might be a challenge in Falmouth since local government already largely uses OpenCape.
- Other Assets. Governments often have other assets that can benefit a partnership. This could be land for placing equipment; It could be a building to create a central office or a storefront. It might mean towers, empty conduit, or spare existing fiber that can be used to defray the cost of constructing a broadband solution. The value of such assets should be set according to what the partnership would pay to get the same thing from a third party.
- Easier Construction Processes. Local governments often take a significant role during the construction process. They might have to approve permits for rights-of-way. They might be the entity that locates existing utilities. They might require inspection of construction work sites, during and after construction. They might require things life traffic management during construction. Before tackling a major fiber construction project with a partner, a government might review these various requirements to see if they can be streamlined to make it easier to build fiber. Note in doing so that this likely means making any relaxed rules available to any other entity that wants to build fiber.
- Contributed Labor. A government can contribute labor. Using the last example above, a government could agree to conduct permits, locating, or some other service for free as a way to contribute to launching a partnership project.
- Tax Abatements. Tax abatements have always been a tool for economic development. Governments often have it within their power to excuse certain taxes to entities that bring something of economic value to the community. For example, it's common to not charge a large new business any property taxes for some period of time as a way to lure them to locate in the community. There are numerous taxes and fees that might impact a new broadband network such as property taxes, sales taxes, right-of-way fees, etc. that a government might be willing to waive to help a new network get established.

The bottom line to this discussion is that a government can bring significant value to a partnership, and that contribution should be fairly valued. Even when a government brings tangible value, such as contributing funding, it's not unusual for an ISP to undervalue that contribution. It's even more prevalent for an ISP to not assign a realistic value to the more intangible contributions.

How do You Find a Potential Partner? We've seen almost every partnership we know of come through three different processes:

Request for Information (RFI). It's fairly typical for communities that want broadband to issue an RFI aimed specifically at soliciting potential ISP partners. These RFIs typically describe the situation in the community, typically describe whatever work has already been accomplished (such as this feasibility study) and describe the role the municipality wants to take in a partnership.

The RFI then asks ISPs to describe themselves and their capabilities. The RFI generally doesn't go so far as to request a specific solution, but rather asks the ISPs to discuss how they might tackle broadband issues in the community.

An RFI is generally a first step to determine which ISPs might be interested in partnering. After the RFI the process typically moves to one of the two processes described below.

Request for Proposal (RFP). An RFP is typically a lot more in depth. In addition to asking ISPs to introduce themselves, an RFP might ask for specific proposed solutions. It might go further in detail asking about the financial strength of the ISP business and details of how they operate in other market.

Direct Negotiation. In some states, governments can interact directly with potential ISP partners rather than go through an RFI or RFP – all depending on state purchasing and contract rules for government entities.

Comparing the Three Options. It's first worth considering the issue from the perspective of an ISP. ISPs are leery of public records laws. ISPs are often highly reluctant to provide financial information, customer lists, or other information that they feel is confidential. They don't trust that local governments will fight to keep such information confidential. ISPs are even more leery of spelling out specific details of their business plan and how they approach a broadband market – they don't want that information to be available to their competitors.

Many ISPs are not willing or able to respond to an RFI or an RFP that asks for lengthy written responses to a long list of questions. Businesses that sell equipment and services are used to the idea of making proposals and usually have a pile of pre-prepared canned responses to the typical questions they are asked by a prospective customer. However, an ISP may never have been asked to make a proposal in writing in the specific and detailed way that might be needed to respond to an RFI or an RFP. There are ISPs that refuse to participate in an RFI or RFP for this and related issues. We know there are ISPs that eliminate cities from consideration if they insist on going through the formal RFP process.

ISPs prefer direct discussions where nothing is put into writing during the negotiation stage. That's the same process that ISPs typically use when they partner with other ISPs – they sit and talk out the pros and cons and mutually decide if there is a potential for a partnership. As often as not, such discussions end up with the realization that a partnership is not a good idea, and the parties amicably go their separate ways and nothing they discussed is in writing.

Here is the process that I like best, having been through a lot of discussions between governments and ISPs:

For most local governments, the best first step is to invite known ISPs for a high-level discussion about whether a partnership makes sense. This process might involve several meetings where an ISP might come back with ideas, and where the local government reacts.

A lot of cities like the RFI process when it makes sense. For example, CCG was working with a geographically isolated community where there was no local ISP candidate within fifty miles. An RFI made sense since the community didn't have a wish list of local ISPs to consider. An RFI also might make sense for larger communities. In this case I define larger to mean that the cost of the project is large – perhaps more than $25 million. I've known communities that found an ISP partner through an RFI that they would never have otherwise found.

If a community issues an RFI it should ask for basic information only. That might include asking an ISP to provide their history, telling about the products they normally sell, and talking about the management team. While cities might have a hundred questions for a prospective partner, the ISP is going to be a lot happier if the details of their business are not put into writing at the early stage of meeting and negotiating.

RFPs only make sense for larger cities – probably those with network costs over $100 million. It's not likely that a small ISP will respond to such an RFP. Even in an RFP, I recommend not asking for sensitive financial information about the ISP – that can always be provided if the likelihood of a partnership develops.

Establishing Compatible Goals. At some point during the early stages of the process it's vital for both sides to thoroughly discuss their goals for the project. Misalignment of goals is the number one issue that plagues any partnership eventually. Both parties need to fully hear and understand, and be completely comfortable with the goals of the other partner.

Goals generally can be stated simply and don't have to be complicated. Goals for a municipality might be things like serving the entire community, not needing to subsidize the project, keeping rates low, etc. Goals for an ISP might be to generate s specific target of cash flows / profits. It wouldn't be unusual for an ISP partner to eventually want the option to buy the business. An ISP also might want just the opposite and might want to capitalize on the success of the business by selling out after some period of time.

It's important to not only see each other's goals, but it's vital for a municipality to understand the ISP's goals. This is one situation where a municipality might want to discuss these goals with a consultant or somebody with broad industry experience. It's not unusual for two partners to be talking a different language when discussing financial issues and it's vital to fully comprehend what a partner is telling you about their goals.

Alignment of goals is a make-or-break point in a potential partnership. Many of the differences that a municipality and an ISP might have can be negotiated, but you can't negotiate a difference in philosophy. If an ISP has a goal that a municipality can't live with, such as selling out in ten years, then our advice is to not pursue the partnership. When an ISP tells you a goal of that nature, they mean it.

How to Rank Potential Partners? There are hundreds of questions that a local government might ask an ISP that might range from big important questions like, "Can you bring funding to this project?" to questions that are important but have lesser impact on creating a partnership such as, "What's your process of disconnecting customers who don't pay?"

I advise prospective partners (government or otherwise) to place their questions into three categories, 1) make or break questions, 2) questions that might disqualify a potential partner, and 3) all other questions.

Every community will have its own list of make or break questions based upon their own priorities for what a partner should bring to the table. Make or break questions might be things like 1) "How much funding can you bring to the project?" or 2) "Are you willing to serve everybody in the community?"

Questions that might disqualify a potential partner might be similar questions, again based on the specific priority and goals of a given community. Keep in mind that some of the items in this category might be subject to negotiation – something that should be asked.

The first two categories of questions are the important ones that should be used to qualify and rank potential partners. Other less critical questions are important, but probably don't get considered unless it's close between two candidates. You choose a partner based upon the most important aspects of the relationship.

There are several techniques that are used to compile rankings. Most rankings of this sort are done by compiling the rankings by a team of reviewers. The most important questions might get weighted somehow to have the biggest impact on the composite answer. At the end of this process is a numerical answer that reflects the composite opinion of those doing the ranking. It's likely that such rankings are not even the final answer and often the ranking process will send a government back to ask more questions. Since this is not a purchase of service, but a partnership, it's also highly unlikely that it would be mandatory to take the ISP that ranked the best.

Defining the Role of Each Partner. It's vital to define the specific roles and responsibilities of each partner. Ideally, this should be done before formalizing the partnership arrangement. CCG has often used a technique that seems to work ideally in defining a partnership. It starts with a list of all of the tasks needed for launching and operating the upcoming broadband business. The level of detail usually become readily apparent. For example, if it's clear that the ISP is going to have 100% of the interactions with customers, then having a task called "Interface with customers" would be sufficient rather than listing all of the various ways that somebody might interface with customers.

The items on the list would include financial and other contributions as discussed earlier, issues having to do with construction the new network, issues having to do with governance, issues having to do with operating the business.

A responsibility must be assigned for each task on the list. The choices for each task are 1) the task is the responsibility of the government, 2) the task is the responsibility of the ISP, 3) the task

is a joint responsibility of both parties (in which case that needs to be fully described), or 4) the task is the responsibility of some third party (like an outsourced arrangement). This kind of process quickly shows if the two parties are aligned and agree on all of the responsibilities and if there are tasks where the two sides have a different view. The example used earlier involved setting of rates – this is a good way to get it in writing from both parties about the roles in setting rates.

Making this list serves two purposes. It's a great tool for getting both parties to acknowledge the specific roles of each partner. It also then serves as a great template for developing a contract between the partners.

Maintaining Local Control. One of the hardest things to approach is having a partnership yet retaining local control. The following issues all have bearing on the level of control a municipality might have for an ongoing broadband business.

Before answering the question, I would challenge a municipality to make a list of items they would like to have some control over. It's likely that a list will include major aspects of operating the business such as rates, installation intervals, business hours, priorities of repairing customers after an outage, etc. I then ask the municipality to change hats and look at these same issues from the perspective of the ISP, who is trying to run a profitable business. This exercise often highlights requests for control that are unreasonable.

One of the stories I tell about politics and the broadband business concerns Bristol Virginia Utilities, which was one of the first cities to enter the broadband business. The business was operated by the electric utility, which was a branch of the local government, but which had a full standalone operating authority. The bonds were fully backed by the electric utility, but since the city had to approve any bond issue, the city reserved the right to set and approve rates. A few years after launching the business, and during an election year, the city council voted to slash all of the rates by 15%. The utility warned them this would put the business underwater, and sure enough they were unable to meet a bond payment due six months later. The city got the message and ended up raising the rates to a higher level than the original rates to correct the shortfall, and the city also changed their ordinances so that no future city council could change rates.

There are numerous other examples of negative ways that local governments have meddled in a broadband business. Politicians might make promises to constituents on behalf of the ISP. Politicians often press to give special rates to friends or to forgive bad debts for a constituent. It's not unusual for politicians to go further and interfere in things like personnel decisions. It's incredibly important to have clearly defined boundaries and lines so that an ISP is able to say no to meddling.

ISPs are highly wary of ceding any control to a government entity. ISPs fully comprehend that a partnership with a municipality is always tentative and can change drastically after an election. There are plenty of examples of a council or board that changed from pro-broadband utility to anti after an election. Political changes can put a huge strain on the business relationship even if there are no control issues. ISPs know that the municipality they partner with today may not be the same in the future.

This is not to say that a municipality shouldn't have any control over the business. One of the more obvious aspects to maintaining control depends upon who funds the network. A municipality is going to get little or no say in how to operate a network that includes significant funding from a commercial ISP. If an ISP brings money to a project, they generally will not take the risk of letting a municipality tell them how to operate the business – since the ISP's primary goal will be in getting a good return on their investment.

But even funding doesn't always determine control. Many ISPs will only partner if they get to make all of the business decisions – even if the government funded the network. This is why potential partners need to ask all of these questions before they create the partnership.

The only sure-fire way for a municipality to have control is to fund and operate the network. It's going to be difficult to find an ISP partner that will want a local government to influence business decisions once the business is operating. This is a case where a little authority is a bad thing. If a municipality has any authority to control the business, then eventually somebody at municipality will go too far, either today or in the future as the government changes.

The conclusion of this long discussion is that some parts of everything discussed in here should be on the table for a government that doesn't know the operating model they want to use. If there is interest in either going it alone as a standalone ISP or else partnering with an ISP, then most of the things discussed above should be considered. The decision to get into the broadband business is a consequential one for a government entity. You don't want to rush the decision and you want to kick the tires on all aspects of the different operating models.

C. Getting Local Buy-In

This section of the report will discuss a community engagement strategy – how to bring the public into the decision-making and implementation of broadband. Government entities have always known how difficult it is to activate the public to get engaged on any issue. It takes an enormous amount of effort to do this right. This section will describe techniques used successfully by other communities.

A community engagement strategy generally has two phases:

- The first phase is exploratory and has the goal of understanding the level of community interest in broadband.
- A second phase would be activated at the point that the community decides to move forward with a broadband solution. The goal of a second phase is to identify residents and businesses who will support a broadband network when built.

Staffing for Community Engagement

Both phases of community engagement require some level of staffing to be successful. Both phases require a focused and persistent effort, so it's important to identify staffing needed to be successful. We've seen many efforts to get community buy-in fizzle when nobody was dedicated to the community engagement tasks. We've seen the following ways that communities have staffed the effort.

- Dedicated Government Staff. The most expensive option, but one of the most effective, is to dedicate government staff to concentrate on community engagement. That requires a

commitment by elected officials to fund the effort. This would typically not be a permanent position, but rather somebody dedicated to the effort for some fixed period of time. This is also not a 9 to 5 job since interfacing with residents often means evening meetings.

A county in Minnesota found a broadband solution because the mayor of one of the smallest towns in the county told his economic development director that getting broadband was his top priority. This economic development leader spearheaded the first phase of the process – educating the public on the issue of broadband. This particular area had towns with okay broadband from a cable company and rural areas with little or no broadband. The economic development director met with everybody imaginable in the area including other city governments, county governments, state representatives, and every civic and social group imaginable. After two years of tireless work by this one staff person the communities in parts of two counties agreed on a broadband solution. This would never have happened without this one dedicated staff position.

- Volunteers. Volunteers are also an important part of this effort. Every community seems to have some people who really hate the state of the existing broadband and who are willing to volunteer time to hunting for a solution. In the example given above, the economic development director assembled a group of active volunteers to help with the effort to engage with and educate the public. These folks created email lists, went canvassing door-to-door talking about the need for broadband, and showed up at every government meeting to stress that they wanted a broadband solution. It's important that any volunteer effort have some structure and working with a staff person can make sure such a group stays focused. If a community decides to engage volunteers there should still be a commitment to providing some funding. In the case of the Minnesota effort, local governments funded the effort required to engage in a canvass of the communities to understand the interest in broadband. This included several rounds of mailing postcards asking homeowners to pledge support for broadband.

- Broadband Task Force. Another approach is to create a formal committee of citizens who are willing to work together to explore the issues around community broadband. Such a Broadband Task Force generally is composed of citizen volunteers and perhaps a few elected officials. The group would meet regularly and work towards exploring the need for a broadband solution. It's normal that such a group would report back regularly to the government about their progress. Such a group can collectively take on some of the needed community engagement tasks, and we've seen effective committees do this well. It's not unusual for a Broadband Task Force to solicit help from additional volunteers.

  Such groups are usually given a budget, but also restrained by needing to have expenditures pre-approved. We could write pages on the dos and don'ts of operating a successful citizen's advisory group. It's likely the town has done this before for other issues. The main key for success is to make sure that the group has a specific agenda, a specified budget, and the specified authority to meet their goals. Citizen groups can accomplish great things if they are properly directed to do so – but can stray if not given good direction.

Consumer Education

One important aspect during both phases of community engagement is to provide useful information to help the public better understand broadband issues. We've seen communities tackle public education in some of the following ways.

- Publish This Feasibility Report. While not many people will wade the whole way through a report of this size, it's been written for anyone in the community to read.
- Hold Public Meetings. Public meetings can be held to explain the results of this study, or meetings could be more generic and be aimed at explaining the broadband issues. It's worthwhile to have elected officials at public meeting so they can directly hear the kinds of issues that households and businesses have with existing broadband. It's vital to advertise heavily to drive attendance at meetings. CCG has been to a community meeting where only one resident showed up, and to others that were standing room only in a large room.
- Broadband Web Site / Social Media. Many communities create a broadband web page or accomplish the same thing using social media. Such a page can be used to educate as well as inform. For example, a common educational feature is to have a lengthy section with responses to "Frequently Asked Questions." Such a website can also inform the public about upcoming events or other things the government wants to advertise.
- Gather List of Broadband Proponents. One important resource is to create a database of local broadband proponents – citizens who say they support broadband. Having list of emails, home addresses, and phone numbers will be useful when it's time to gather support for public actions.
- Broadband Newsletter. Communities often create a newsletter dedicated to broadband. These newsletters are aimed at educating the public on topics related to broadband and also to keep the public informed on the progress of the effort to get better broadband.
- Outreach Meetings. One of the most successful ways to reach the public is what CCG calls outreach. This means sending a spokesperson to meetings of the local organizations to talk about broadband issues and to answer questions. This can be any sorts of groups – PTAs, church groups, service organizations, youth groups, etc. Most organizations will allow time for a short presentation. It's vital to have a prepared presentation to get across whatever message you want the public to know. These outreach meetings are best done by those who are strong broadband proponents or who have specific knowledge about broadband.

Pre-marketing Efforts

If the broadband effort reaches the second phase, one of the most important steps is to identify potential customers for a broadband network. The biggest concern that every ISP has about a new market is knowing if they can get enough customers to be successful. We already have an inkling of the support in Falmouth from the residential survey. The pre-marketing efforts go a layer deeper and ask residents and business to pledge support for a new network. There are several techniques that communities have used to understand market demand.

Statistically Valid Surveys. Falmouth has already undertaken a residential survey. The goal for doing a residential survey is to be able to predict the most likely range of customer broadband penetration should somebody build a broadband network. We've found over the years that if a survey is conducted in a way to be statistically valid that the results provide a good prediction of the likely customer penetration rates.

Canvass. A canvass is similar to a survey but has the goal of reaching out to everybody in the

community. Communities often undertake a canvass at the point where there is a decision to move forward to implement a broadband solution. A canvass can have several goals. The simplest goal would be to create a list of broadband supporters. A canvass could also be used to get homes and businesses to pledge to buy broadband if a network is built. Such pledges are typically non-binding but can provide good support when the community is looking for funding

Canvasses can be done in several ways. A canvass often starts with an online invitation to support a broadband initiative. Canvassing can also be done by mail. We've seen communities engage groups like the PTA or service organization to get people to participate in the canvass. We've seen communities that send volunteers door-to-door to ask citizens to participate in a canvass.

Other Areas of Broadband Concern

Often when communities are looking at attracting a broadband solution, this raises a few issues related to but separate from getting a broadband network. Communities often embark in research and community outreach on these issues in addition to the broadband issue.

Better Broadband for Schools. Communities that don't already have gigabit connections in schools usually make it a priority to beef up school broadband as one of the first priorities of getting a broadband network.

Computers for Students. One of the reasons that communities often build broadband networks is to solve the homework gap, where students don't have computers or broadband at home to do homework. Even if a community solves the broadband issue, they still need to find a solution for the computer issue. Sometimes this is accomplished by having the schools give a computer or tablet to every student. Other communities have undertaken a program to get a computer into each household that needs one.

Focus on the Digital Divide. Communities also often undertake programs to make sure that everybody can take advantage of the new broadband network. This can manifest in numerous ways. That might mean getting computers and WiFi into public housing. It might mean beefing up computers and broadband in libraries. It might mean establishing numerous outdoor WiFi hotspots around the community. It might mean starting basic computer literacy classes. It might mean looking for a solution to bring affordable products to qualifying low-income homes.

D. Other Issues

Falmouth Community Television

One of the questions asked by the RFP is how having a community network could impact Falmouth Community Television which is funded largely from cable franchise fees. Since franchise fees are collected based upon traditional cable TV revenues in a community, it's worth looking at the regulatory and market trends that are already affecting cable revenues and franchise taxes.

The Downward Trajectory of the Cable Industry. The traditional cable TV industry had a miserable 2019. Collectively the biggest cable TV providers lost over 5.9 million subscribers during the year,

almost 7% of the total customer base. The impacts of the coronavirus, along with the already existing trends in the industry spell bad news for the industry in 2020.

The coronavirus pandemic has had a big impact on the cable industry in 2020. The largest traditional cable providers collectively lost over 1.5 million customers in the second quarter of 2020 – an overall loss of 2.0% of customers. This is the smaller than the loss in the first quarter of 1.7 million net customers. To put the quarter's loss into perspective, the big cable providers lost 16,700 cable customers per day throughout the quarter.

The majority of subscribers leaving traditional cable cite cost as the primary reason, and as millions of people have lost jobs due to the pandemic, one of the first things they are going to do is to ditch traditional cable for something less expensive. For years, nationwide surveys of subscriber sentiment have shown that as many as 20% of households each year contemplate dropping traditional cable TV, but for a variety of reasons they don't get around to doing so. This year a lot of these homes are finally going to make the change.

A Recent Roku Survey. Roku undertook a survey in March 2020 that took a deep dive into cord cutting and interviewed over 7,000 homes. The overall conclusion of the survey is that cord cutting is accelerating in 2020. The survey was done at the beginning of the pandemic, and overall industry statistics for the second quarter make it sound like cord cutting exploded in the second quarter of this year.

The Roku survey segregates the television market as follows: 43% of homes still have traditional cable TV. Another 25% still have traditional cable TV but have reduced to a lower-cost video package, making them cord shavers. 25% of the market are now cord cutters and 7% of the market never have had traditional cable TV.

Probably the most interesting statistic is that one-fourth of the market consists of cord-shavers who have reduced their traditional programming packages. It's been clear that cord-shaving has been happening, but I've never seen it quantified before. The big cable companies never mention cord shaving when reporting cable TV subscribers. The magnitude of the households that have trimmed back to lower-cost programming packages explains why the paid subscriptions to cable networks is dropping far faster than the drop in cable customers.

Lack of sports is driving some cord cutting during the pandemic, and 28% of cord cutters said that lack of sports was their number one reason for cutting the cord. 17% of cord cutters (or 4% of the whole video market) say they will consider returning to traditional TV when sports returns to the air fulltime. 31% of cord cutters say they will pursue a sports streaming service when sports returns.

The number one reason cited for cutting the cord was cost savings, and many of those surveyed said they were driven to this decision due to change in household income due to the pandemic. The average Roku user said that they are saving $75 per month with cord cutting. Cord cutters are watching more free ad-supported content as a way to cut costs. 42% of cord-cutting households said that free content or extended free subscriptions to streaming services helped to convince them to cut the cord.

45% of the households in the cord shaver category say they are likely to cancel traditional TV in the next six months. Almost every survey about cable TV I've seen for the last five years has included

substantial numbers of homes that say they are going to drop cable TV – but then don't. But this statistic does indicate that there are a lot of households thinking about cutting the cord. It's often a complicated decision for a home with multiple family members to finally cut the cord.

The pandemic makes it harder to discern long-term trends in the cable industry. This survey supports what we're seeing in the market, that a lot of homes continue to drop traditional TV packages. But the pandemic provides several good reasons to drop a cable subscription that won't be permanent. Sports will eventually come back to TV and sports fans are going to find a way to watch sports. As the economy rebounds, people will get back to work – it's an easier decision to cut a $100 per month cable subscription when one or more people in a home are unemployed. The pandemic has also ended the creation of new content, and many cable subscribers are willing to pay for an expensive cable TV subscription in order to see the latest versions of their favorite shows. I've read that it might take more than a year after the pandemic ends to see a fresh supply of new content again.

It will take time to see if an improved economy reverses any of the cord cutting trends. For now, any company offering cable TV is in for a rough ride. It's hard to see any positive news from the results of this survey for programmers other than ESPN.

Franchise fees are plummeting in the same trajectory as cable TV revenues. The franchise fees collected are lowered when somebody drops cable in favor of online programming or downsizes to a less expensive cable package.

Regulations and Franchise Fees. In September 2018, the FCC issued a Report and Further Notice of Proposed Rulemaking (NPRM) concerning cable franchise fees and related issues. This docket was prompted by a court decision in July 2017 by the US Court of Appeals for the Sixth Circuit concerning earlier efforts by the FCC to clarify and restrict franchise fees. In that case, Montgomery County Maryland v. FCC the courts had remanded several FCC rulings as being unclear.

The original FCC order that was challenged in court clarified a few rules concerning franchise fees. First, the agency clarified that the maximum franchise fee that can be levied against a cable provider is 5%, and that the 5% fee had to include any in-kind payments expected from a cable company under a franchise agreement. Further, the FCC clarified that franchise fees are only supposed to be levied against cable TV revenues and not against other products and services offered by a cable company.

Cities have expanded franchise agreements over the years to include other kinds of compensation. For instance, many cities require cable companies to provide free cable TV service to government offices and schools. Some franchise agreements require cable companies to provide free or reduced bandwidth to schools or low-income housing. The FCC even citied franchise agreements that required unusual activities such as cable companies having to plant flowers in parks.

The 2017 lawsuit was aimed at clarifying the original FCC order, particularly the requirement that cities are allowed to extract payments in-kind, but that any such costs to cable companies count against the 5% cap on total franchise fees. The court decided that the FCC had not been clear on the definition of in-kind payments. For example, the court said the FCC wasn't clear if the costs of providing PEG channels was considered as an in-kind payment. If the act of providing the channels is considered as an in-kind cost, then the amount of franchise fees paid to Falmouth and to Falmouth Community Television would be reduced.

The 2018 order is an attempt by the FCC to clarify the questions raised by the court. Specifically, the FCC NPRM asks comments on the following issues:

- The FCC proposes to treat incumbent and new competitive cable operators identically in order to not impose any restrictions that might hurt the expansion of broadband deployment.
- The FCC seeks to clarify the definition of in-kind payments and reiterates that any such payments are to be included in the 5% cap on franchise fees.
- The FCC is reaffirming that there should be no franchise fees imposed on other services like broadband, telephone, or smart-home services.
- The further clarify that there can be no other provisions included in a franchise agreement that would act to regulate any service other than cable TV. For example, some LFAs have been trying to use franchise agreements to dictate things like the coverage, speeds, or prices of broadband services.
- The FCC also asks if these same rules should apply to statewide franchise rules that have been created by state legislators as an alternative to local franchise authority.

The FCC still has not reacted to the comments it gathered on this docket in 2018 and 2019. The FCC has no mandatory timetable for such decisions and the agency has given no clue about when it might react. Until the FCC reacts, some of the rules in its first order are on hold until the FCC clarifies. The risk to Falmouth Community Television is that the FCC will affirm that in-kind contributions can reduce franchise payments. Comcast could claim a significant cost for providing the PEG channels used by Falmouth Community Television and could reduce franchise fee payments accordingly.

Regulations on Traditional versus Online Programming. Traditional cable TV is heavily regulated at the federal, state, and local levels. The FCC website has a nice summary of the history of cable regulation.[30] The industry is less heavily regulated today than it was forty years ago, but there are still a lot of federal regulations that apply to cable TV.

The FCC website includes a definition of cable television as follows: "***Cable television*** *is a video delivery service provided by a cable operator to subscribers via a coaxial cable or fiber optics. Programming delivered without a wire via satellite or other facilities is not "cable television" under the Commission's definitions."*

All of the federal cable regulations are aimed at cable TV that enters the home via a coaxial or fiber wire. Satellite or wireless delivery of television signal is not considered to be traditional cable TV, although the FCC regulates satellite TV under a different set of rules.

Today there are surrogates to cable TV that are not regulated. There are online cable alternatives like Sling TV and YouTube TV that have grown over time to look a lot like traditional cable TV. The service included a channel guide. From a functional perspective it's hard to see the difference between the online programming and traditional cable. Online video enters most homes using coaxial or fiber cables. Both offer a line-up of local channels and a similar mix of national programming. Both kinds of services offer options like DVR service to record programming to watch later. If you were to show both services to somebody who never watched TV before, they'd probably not see any difference in the two services.

[30] https://www.fcc.gov/media/engineering/cable-television

The huge difference at the local level is that there are no franchise fees levied against Sling TV or YouTube TV. Cable companies are arguing that this difference alone gives online programming a competitive edge – and it's hard to disagree with them. From a regulatory perspective, this is closely analogous to the difference between traditional telephone service and voice over IP (VoIP). ISPs successful fought to define VoIP as a non-regulated service, although there is no functional difference between the two products at the customer level. It's likely just a matter of time until we see a legal challenge by a large cable company trying to avoid collecting franchise fees. They'll argue that they are not different than Sling TV, and the courts might side with them.

The City of Creve Coeur, Missouri, filed a lawsuit in 2019 against Netflix and Hulu claiming that the companies should be paying the same local franchise fees as Charter Communication, which is the incumbent video provider in the community. The city claims that it is losing franchise tax revenues as people cut the cord and go from Charter to the online content. The city wants to tax the companies that are taking that business away from Charter. They argue that Netflix and Charter ride the same wires and rights-of-way to deliver content and both should be taxed the same.

Just before this report went to print a similar lawsuit was filed by four cities in Indiana - Indianapolis, Evansville, Valparaiso, and Fishers. They sued Netflix, Hulu, DirecTV, and Dish Networks on almost identical grounds as Creve Coeur.

If the court sees this as a regulatory battle the case will likely get remanded to the FCC. But there's no way to predict what might happen if a court looks at this as a tax dispute. There is at least some tiny chance that a court could rule that Netflix can be taxed.

It's not clear if Creve Coeur wants Netflix and Hulu to sign a franchise agreement, but if they do the city might not like the result. Current FCC regulations require that a municipality can't demand concessions from one franchise holder that doesn't apply to all franchise holders. I can picture a stripped-down franchise agreement for Netflix that Charter would leverage to get out of obligations such as having to provide a PEG channel.

The FCC does not want this issue handed to them because it opens the door to defining who is a cable company. The agency opened an investigation into this issue a few years ago and quietly let it drop, because it's not a decision they want to make. The FCC is constrained on many issues related to cable by laws passed by Congress. I think the FCC decided early in the investigation that they did not want to tackle the sticky issues of declaring online programmers to be cable companies. Had the FCC done so this suit might have good traction.

What's the Future for Falmouth Community Television? There are a few impacts that are definite and a few impacts that hang as possible threats. Franchise revenues that fund Falmouth Community Television are going to continue to plummet. In the past we saw landline telephones drop from a nationwide penetration rate of 98% down to under 40% today, and still dropping. Cable subscriptions are being dropped at a much faster rate than were landline, and the peak penetration of traditional cable in the country was around 82%. It's impossible to predict where the bottom of the industry will land, but it's going to be a lot lower than just a few years ago. Franchise revenues are also going to continue to drop from cord shaving, where homes downgrade to a less expensive cable package.

The FCC will eventually react to the NPRM involving franchise fees. If the FCC affirms its original order, then Comcast is going to lower the amount of franchise fees paid in Falmouth to account for any in-kind value provided that is not cash.

The RFP asked for our opinion of what happens if somebody builds a competitive fiber network in the community. CCG Consulting has worked with both commercial and government builders of fiber networks and we foresee the following as the likely outcome of having a new fiber provider:

We've seen with dozens of clients that over half of customers who move to a new network use that change as the opportunity to cut the cord and drop traditional cable TV. This happens even if the new network provider offers a cable TV alternative. The Roku survey citied above showed that over 40% of homes are at least think about cutting the cord, and going through the process of changing providers is an easy way to do so without that long call from the cable company trying to talk them into staying.

A lot of new fiber providers aren't offering traditional cable. It's nearly impossible for a small ISP to even break even with a cable product, and most ISPs are not willing to go through the hard work of offering cable that loses money.

The bottom line is that a new fiber network in the community is going to push down cable subscription rates faster than they would otherwise drop. In the long run, the people who drop cable when moving to fiber would likely have eventually dropped cable anyway – but the new network will accelerate the drop.

Falmouth Community Television has the same future options as many other community cable TV organizations:

- As revenues plummet, they can cut expenses accordingly and reduce the programming and functions they provide in the community.
- They can look for alternate sources of revenue to offset some of the losses. This might include selling local advertising, getting local sponsors, creating content for other community systems for pay.
- A harder path is to replace funding with some other source of tax revenues. We haven't heard anybody doing this yet, but we know communities that are considering providing some funding for community television from other revenue sources like sales tax or property taxes.
- We know of small cities and rural counties that have abandoned PEG channels and put the same content directly on the web. That has the downside of making the content unavailable to homes without broadband.
- Another option being discussed around the country is consolidation of community television operations. There can be a significant economy of scale for neighboring communities to share technicians, administration, studio space, electronics, and all of the costs of operating a community television station. The upside to consolidation is a reduction in costs; the downside is losing at least some local control.

Working with Other Utilities

The RFP asks us to discuss the possibility of working with the local electric utility (Eversource) and gas utility (National Grid) if you built a fiber network. There is the additional benefit to also incorporate fiber more into the town's water utility.

There are several distinct ways that utilities can benefit from a communications network like fiber. The first is in monitoring existing networks. The second is in interfacing directly with customers.

Utility Network Monitoring. Network monitoring generally involves connecting a communications network to sensors that are used to provide feedback on the operations of various parts of the network, often back to a centralized monitoring center. The various utilities have had used sensors of various types for decades. Before that, staff had to periodically visit the various parts of the network to physically make sure things were operating properly.

Electric Utility Monitoring. Electric utilities refer to their monitoring network as SCADA (supervisory control architecture and data acquisition). A SCADA system connects to sensors or electronics at various points in the network that report back on power usage and other information that tells the utility how a remote electrical component is working. For example, the utility can gather data from a remote electric substation so that an operator at the hub can see how that unit is performing. A modern SCADA system also provides the capability to provide feedback to the substation to correct any settings that can be directed from the core.

SCADA monitoring has been around for many years and the connections were originally made using telephone copper connections and small bandwidth applications like ISDN. The low bandwidth connections were more conducive to monitoring than in remotely controlling a location. Over time, electric utilities required more bandwidth to allow for greater interaction and control between the hub monitoring location and remote devices. Electric companies have also greatly expanded the reach of SCADA systems. Originally this was used only for remote electric substations, but today an electric company might monitor a number of other devices such as backup generators, power interfaces at key industrial customers, and even transformers in key locations that have had repeated problems.

There is an entirely different set of monitoring and controls used to interface with power generation. Electric companies that generate power within their own grid need to closely monitor the quantify and quality of electricity being generated in order to incorporate local power with purchased power. The scope of electric generation has expanded significantly in the last decade. Originally power generation mean coal-fired power plants, hydroelectric power generation, or nuclear power plants. But today that also means solar power generation, like the new generation plan built in Falmouth. At the extreme, electric companies want to monitor home and business solar generation if those power sources are fed into the grid. Power generation today might also include wind power generation locations.

Electric companies have expanded SCADA capabilities in two ways. Many electric companies have built private fiber networks to connect to their large installations like substations. However, even utilities with their own fiber networks still often lease commercial broadband connections to reach to locations where it's not cost justified to build a new fiber route. There are many electric utilities that rely entirely upon purchased broadband connections. Some electric utilities are making the internal connection using microwave radios rather than fibers.

Water Company Monitoring. Water utilities have the same needs to monitor key locations in their network. They want to be able to communicate with pumps, water towers, waste treatment

plants, and any other key locations where the utility wants to track water flow, wants to monitor the performance of facilities, or want to control devices like pumps.

Many water utilities are greatly expanding their monitoring capabilities in recent years. It has become apparent that underground water leaks can cost a utility huge amounts of money, and so water companies have been expanding the use of flow meters to be able to pinpoint the location of new water leaks.

Gas Company Monitoring. Gas company monitoring is similar to what's done with water systems, except that there is a host of additional sensors in the system checking to identify gas leaks. Gas utilities not only measure gas pressure and flows, but they generally have sensors that can 'sniff' leaked gas at key locations.

For all of these utilities, the amount of broadband needed to monitor a single location is relatively small. This means that the extra broadband that is available with fiber is not needed. The primary reason that utilities consider building their own fiber networks is because of private control of the network. No utility wants to have major problems that occur during times when the telephone company or cable company connection are out of service – something is somewhat routine in most local broadband networks. Electric utilities want to quickly respond to issues that issues that might cause power outages. They want to take remedial action to stop power outages.

Electric companies learned a valuable lesson twenty years ago when the country suffered several significant and widespread power outages – some that affected as much as half of the country. They learned that outages were made worse because the utilities were not closely monitoring grid locations and didn't have in place any systems that could react quickly enough to pinch off rolling blackouts and brownouts. In many cases the remedial actions needed must happen within seconds or minutes – and electric utilities realized that meant having their own networks so they didn't have to trust in communications from somebody else.

Smart Grid – Interfacing with Customers. A smart grid is an electrical grid which communicates with a wide variety of devices like smart meters and smart appliances. Smart grid technology started over 25 years ago when utilities asked customers for the ability to turn off power-consuming devices like air conditioners during days when the electric grid was under stress. The first-generation technology was basically not much more than an on/off switch for the air conditioners or heat pumps that could be activated remotely by the electric company. This was one of the innovations that was put into place to control the big rolling brownouts.

Over time smart grid has grown to be a lot more sophisticated. For example, electric companies now offer smart thermostats where the electric company will help customers save money while also providing for the original function of acting as a safety valve for turning off devices during network stress. The smart thermostat is not really smart and the brains that control the device are in the cloud and controlled by the electric utility. A smart meter can perform a range of cost-saving activities. For instance, the technology can automatically turn the temperature down when residents go to work or are sleeping and turning it back up when people are active in the home.

The newest technology deployed by electric companies is being called smart grid. Electric grids most typically differ significantly during the day in the cost of producing electricity. When electric usage for

the whole grid is low the utility might be generating all of the power itself. When power usage for the whole grid gets higher the utility might have to buy power from a neighboring utility at a higher cost than internally generated electricity. It can also work the other way. For example, a utility might have access to low cost solar power on sunny days but have to rely on other power sources at night and on cloudy days. Utility costs also vary in towns where there are large industrial users of electricity, like large manufacturing plants, that use a lot of electricity at only certain times of the day or night.

A smart utility has technology in place that tries to minimize the use of the most expensive power. One of the tools used to do this is smart meters. This can help consumers use electricity at the times when power is the cheapest. For example, charging electric cars uses a lot of electricity at a home. A consumer can save a lot of money if they are willing to let the electric utility only charge the vehicle at the times when the grid is using the lowest-cost electricity. The utility can pass that savings on to the consumer. Smart meters allow for time-of-day billing where power is charged at different rates throughout the day. Customers and the utility together can use the smart meter to minimize the use of home electricity when usage on the grid is getting too high. Rather than just turn off an air conditioner, the technology can be connected to other appliances and systems like basement freezers, sump pumps, dehumidifiers, and any device that uses a substantial amount of power. When the utility can apply the technology to large number of homes, they can influence the amount of power used by the grid and save them (and consumers) money.

Electric utilities are introducing new technologies to control their costs even further. Some are selling battery storage for homes and businesses that can store power from solar panels or even from the grid. The utility can dip into the stored power when needed rather than buy power externally and can save a lot of money. The utility can also use excess power at times when power costs are at the lowest to charge the storage devices.

Fiber and Smart Grid. Just like with SCADA connections, the amount of bandwidth needed for a single smart grid customer is relatively small. The smart grid system passes data between a customer and the utility about electric usage, but this is a relatively small amount of data.

When the smart grid technology was new there were those who thought that fiber networks would be the ultimate tool for controlling a smart grid. However, since there were so few fiber networks in the country, and only a tiny few owned by electric utilities, the industry took a different path. Today most electric utilities communicated with smart grid customers using wireless technology. The utilities build wireless transmitters around the community that communicate with external smart electric meters or with devices that are mounted on the side of the home to connect to indoor meters.

The electric companies generally own the wireless system, and this provides the 100% control feature they are seeking when it comes to controlling devices that affect the overall grid performance. Many electric utilities have eliminated meter readers because they can read the meters through the radio systems. But these same connections can also be used to communicate with a smart meter and the other smart devices that customer might choose to use.

Water Companies and Fiber. Water companies can also benefit by having a fully connected monitoring system. Placing monitors throughout the system can solve a few problems that water systems typically have:

- Some percentage of water meters on most systems are inaccurate and are underbilling for water. Monitoring and comparing the amount of water billed versus what is delivered to various parts of town can help to identify where meters might be faulty.
- All water systems lose water through leaks into the ground. A monitoring system can be used to more quickly identify fast water leaks. Cities tend to find leaks that result in above-ground flows, but often don't know about underground leaks. More insidious or slow steady leaks, and it's not unusual for older water systems to lose 20% or more of water per year to slow leaks. A well-designed monitoring system that compares flows per route can identify routes with these problems.
- Most water systems already have some sort of communication to connect to pumps and other water infrastructure throughout a system.

There are few water companies that have upgraded to the latest monitoring technologies. Instead, most water companies communicate with field units like pumps through wireless connections or low-price broadband connections like DSL. The bandwidth needed for communicating and for monitors do not require the big broadband provided by fiber. However, if a city had a fiber network, it could eliminate any external communications costs by making all such connections on fiber.

Summary. What does all of this mean in terms of the opportunity for a fiber network owner and these other utilities to work together? There are some opportunities, but it's not nearly as large as might be suspected:

- All of the utilities have connections that are used for monitoring. To the extent that those connections are not on radio systems owned by the utility, then there is a possibility for a fiber network provider to sell broadband connections to the utility. However, utilities are often looking for the lowest-cost broadband available. They might want to stick with DSL connections, for example, of those cost less than fiber connections.
- Almost all electric companies are using wireless technology to make smart grid connections to customers. There is an opportunity to sell fiber connectivity to reach utility radio towers, but most utilities prefer to own these fiber connections themselves – it goes back to the idea of not wanting to rely on anybody else's network. Even many municipalities that own fiber networks and electric utilities still provide these connections using wireless technology – because the industry has not developed affordable interfaces between smart meters and fiber connections. The mass-produced wireless devices are much cheaper.
- The final consideration is that larger utilities that serve multiple communities generally want to have the identical solution everywhere in the network. For example, if Eversource uses Verizon throughout its network to make connections, it is likely unwilling to do something different in one town like Falmouth, even if you have a fiber connection. A utility does not want to have to work with multiple ISPs or have to troubleshoot if there is a problem to find out which ISP is causing problems. We know of many sizable municipal fiber networks that have not sold any connections to the local utilities due to this concern. However, the town should definitely talk to Eversource about being a partner – it's possible they would be interested.

Collaborating with Neighboring Communities

One thing we learned in doing this study is that the entire Cape has nearly the identical broadband situation. Verizon has not built any FiOS on the Cape and all of the communities are served by a combination of Comcast along with Verizon DSL.

It also seems that Falmouth is the first community on the Cape to undertake a formal broadband study like this one. Other communities have considered this, but not have gone so far as quantifying the cost of building a fiber network or examined the opportunity for a fiber ISP to succeed in a community.

The idea of regional collaboration is relatively common in the broadband and utility world. There are numerous examples of collaborations that have been created to save on costs and to achieve economy of scale. For example, there are dozens of regional collaborations that have been created for rural electric companies. These businesses benefit tremendously by having one administrative staff operate multiple small utilities. There is a smaller set of similar collaborations in the broadband world, but there are around a dozen collaborations that we know of that have combined the backoffice functions for multiple small telephone companies and cooperatives. There are another dozen collaborations where telephone companies in a state have joined forces to fund and build a middle-mile fiber network to provide connectivity into rural areas.

All of these collaborations are based upon taking advantage of economy of scale. That is an economics term that describes how companies can be more efficient with size. It's easy to understand economy of scale when contemplating multiple cities building fiber broadband networks in the Cape. The analysis that we did for this study of the cost of bringing fiber broadband to Falmouth. In that study we supposed that a new ISP created to serve the town would need to hire backoffice staff like a general manger and accountants. The business would need to buy software systems and develop processes for communicating with customers.

All of these functions would be far more cost effective when spread across a greater number of customers. A general manager that was hired to operate an ISP in Falmouth could equally manage the same function in nearby towns. The same is true for most of the administrative and backoffice costs of operating a broadband business – big is better in terms of the cost required to serve a single customer.

Creating Collaborations. Almost all of the existing collaborations that we know of are the result of existing ISPs coming together to save money. For example, there is a collaboration of telephone cooperatives in Tennessee that provides the backoffice functions and management for a business that served hundreds of thousands of customers. The joint holding company created to provide those functions is far more cost effective than the costs that were experienced before the collaboration collectively of each of the member cooperatives.

From what we've seen, collaborations often grow around one existing hub ISP. For example, the City of Windom in Minnesota has operated a municipal cable network since the 1970s. The city upgraded the network to provide broadband over a decade ago, and eventually decided to upgrade to fiber and changed the business name to Windom.net. A half dozen small communities around Windom decided to finance fiber and allow Windom to operate the ISP. These small towns would not have been able to afford to create an ISP on their own saw the economic sense in the collaboration. There are similar stories associated with most existing collaborations.

There are very few examples of collaborations that were created for the purpose of building broadband that did not start with an existing ISP at the core of the collaboration. We can only think of two such collaborations, and both happen to be in Minnesota.

Southwest Minnesota Broadband Systems (SMBS) is a collaboration among ten small communities that built a new broadband network and business together. These are tiny communities which combined only had 3,600 residents. The communities all had no broadband alternatives and started meeting in 2007 to see if they could attract an ISP to serve the communities. The consortium was not formally created until the opportunity arose to win a large grant. The newly formed consortium was awarded a big grant in 2009 from the American Recovery and Reinvestment Act (ARRA). This was a one-time grant program that was created as part of the stimulus funding bills created to pull the country out of the 2008 economic recession.

The grant funding still required the communities to raise additional matching funds, but the grants provided enough cash to enable the cities to borrow the remaining funds and to create a business that could succeed. The newly created consortium hired a management team that built the fiber network and launched the ISP. The network brought gigabit broadband to an area that had no broadband faster than rural DSL before the fiber network.

RS Fiber Cooperative is a consortium ISP that was created to serve a number of small cities and the surrounding rural areas in two rural counties in Minnesota. The consortium was formed when the mayor of one of the small towns decided that his town needed fiber and sent his economic development manager off to find a solution. It took years, but eventually all of the small towns in the region decided that broadband was something the area needed, and they formally banded together to create a Joint Board, which is a formal government organization in Minnesota that can be created by multiple government entities to solve a common problem.

The Joint Board tried to raise the money to fully finance a fiber-based ISP. However, after almost two years of trying it became evident that this wasn't going to work as a municipal venture. A few of the cities were unable to make the needed financial pledge to support a municipal bond issue. Even more aggravating, the city and county attorneys from the various cities, townships, and counties were unable to agree on much of anything. The whole effort fell apart.

But the Joint Board didn't give up and CCG suggested a few alternative business ideas, which included creating a new broadband cooperative. RS Fiber Cooperative was formed by some of the remaining cities (a few dropped out from the original consortium). The plan was to raise 25% of the financing from the cities and the rest from banks. This passed muster with the remaining cities because their pledge for the bonds was much smaller, and the type of bonds changed from general obligation bonds to an economic development bond. The legal squabbling was also greatly reduced due to the change in the form of the bonds.

The RS Fiber story is perhaps the best demonstration of the huge amount of work required to create a broadband consortium from scratch, without an existing ISP involved. There were hundreds of meetings and hearings on the issue at the various cities and the process took years and a huge amount of perseverance. There are not many groups of cities or towns that would have made it through the challenge.

A collaboration of communities on the Cape is always a possibility – but creating a collaboration where there is no existing ISP presents the following challenges:

- As this study shows, the amount of money needed to build fiber on the Cape is going to be enormous. The different towns on the Cape are going to differ in their ability to raise the needed money to build fiber.
- It's extremely challenging to combine forces to coordinate to raise large amounts of municipal financing on the same schedule. The coordination required for each community to raise money at the same time is an extremely daunting challenge. It would likely require one or more full time people to coordinate the effort – and the chances of communities dropping out of the process are high. In the RS Fiber example, a number of cities dropped from the consortium when they were unable to meet the expectations and timetable to make the effort happen.
- Perhaps the hardest challenge of this kind of consortium is governance. When there is no existing ISP, every town is going to have differing ideas on how the new broadband business ought to work. Getting everybody on the same page for the dozens of important decisions that have to be made is hard. The RS Fiber effort spent over a year of wrestling in choosing which of the cities would house the newly formed business and staff – everybody wanted the new jobs in their community. Other issues like broadband prices or the obligation of the newly formed ISP to serve low income homes can also be contentious.

This is not to say that a collaboration isn't possible, just that it's extremely challenging. There is a risk of pursuing a collaboration and the process bogging down and nobody ever getting to the point of building a fiber network. We're aware of numerous collaborations that have never gotten past the discussion and planning stage.

However, if Falmouth or some other town on the Cape was to launch a fiber broadband business, there is a high likelihood that over time that other communities would want to join in. That means the first community to decide to build fiber would likely take all of the risks and that following communities get to see an operating ISP before deciding to tackle the venture. The initial ISP will see financial benefits if other communities join them since there will be cost savings from the economy of scale of the business growing larger.

Other Communities with Fiber

The RFP asks us to identify other municipalities with fiber-to-the-home networks that are similar to Falmouth. Following are examples in three categories, 1) municipalities with population seasonality, 2) municipalities with no existing electric utility, and 3) municipalities of about the same size as Falmouth. The last category is a little tricky since Falmouth varies from 30,000 residents in the winter to 100,000 people in town in the summer. Since our conclusion of this study is that the network must be self-sufficient based only upon the fulltime residents, we looked at cities with approximately 30,000 residents.

Municipal Networks with Seasonality

Cook County, Minnesota[31]

The city with the closest seasonality issue is Cook County, Minnesota. This county is an hour north of Duluth, MN, and sits on Lake Superior and on the Canadian border. The county seat

[31] https://truenorthbroadband.com/

Grand Marais is a beautiful lakefront tourist location. A large portion of the county is covered by the Superior National Forest. The county also includes a few ski resorts for winter tourism.

The principle economy of the county is tourism, both for the lake and the woods. The fulltime population of the county is less than 6,000 people, but in the summer, there are approximately 10,000 tourists daily.

The county investigated broadband starting in 2008. At that time there was practically no broadband in the community. The local telephone company was CenturyLink and the DSL barely worked. Businesses complained about the inability to take credit cards. Hotels couldn't take online reservations. Even in 2008 tourists were expecting workable broadband while they visited. The county also had terrible cellular coverage, due largely to the rough terrain. The event that really set the county to find an alternative was a fiber cut an hour south near Duluth that knocked out telephone, broadband, and cellular coverage in the entire county for over a week.

The connectivity issue was solved when a non-profit carrier built a middle-mile fiber ring from the Twin Cities that connected throughout northern Minnesota. The local broadband issue was resolved when the local electric cooperative agreed to sponsor and operate a broadband utility, now named True North Broadband. The network was funded from three sources - a combination of a grant and a loan from the federal agency Rural Utility Service (RUS) and a loan provided by the county that was backed by a one cent increase in sales taxes.

The ISP offers fast broadband that starts at $65.94 for 100 Mbps up through 500 Mbps for $120.94 per month. The ISP also offers telephone service. As would be expected of a rural community, the ISP offers seasonal rates. A customer can suspend service for up to six months each year and pay a $10 rate during the suspended period. Service must be connected for the next six months following the end of a suspended period.

Islesboro, Maine[32]

The small island town of Islesboro began exploring ways to improve broadband in 2012. This is a small town with only 350 homes. The residents agreed to fund a fiber network in 2016, and the network was constructed in 2017. The town floated a bond issue to pay for the project that was backed by a small increase in property taxes plus the revenues from subscribers. The town contracts with a nearby ISP in Biddeford, Maine to light the network, connect customers, and maintain and repair the network.

This is a tourist town and the initial installation connected to 600 locations, many of them businesses that cater to tourists. The pricing for broadband is simple. Customers pay $360 per year and are provided with gigabit broadband. They can buy a few optional services like telephone service or WiFi routers. The town does the billing, which further reduces the fees from the ISP.

College Towns

[32] http://townofislesboro.com/committees/islesboro-municipal-broadband/#c681

There are a number of municipal and commercial fiber overbuilders that serve college towns. I'm not aware of any that serve any of the large, nationally known university towns, but there are quite a few ISPs serving the next lower tiers of colleges. This includes universities like University of Louisiana in Lafayette, LA and Western Oregon University in Monmouth Oregon.

College towns are seasonal and generally empty out during the summer. They also have extremely high churn as students move into and out of the community. This seasonality is different than what is Falmouth because there are paying customers for nine months a year instead of your shorter summer season.

The big issue for ISPs in college towns lies in getting paid. Students are notorious for running out of money before the end of a semester or leaving town with an outstanding balance due to the ISP. ISPs in college towns use two different strategies to deal with the payment issue. The predominant strategy is to sell broadband to landlords and not to individual students or apartment units. It's typical to sell broadband to landlords that have multiple living units at a wholesale rate, meaning cheaper than the normal residential rate. For that cheaper rate the landlord must agree to pay for all living units for the whole year and agree to a term contract. Landlords typically include broadband in the rent. Another strategy used by MINET in Oregon is to sell broadband to students that rent houses by providing a discount but requiring a prepayment for the whole school year. Since parents pay most bills, the municipal ISP has had no problem selling this product every year.

Municipal Networks with no Muni Electric Company

Sandy, Oregon[33]

Sandy, Oregon is 25 miles east of Portland at the base of Mt. Hood. It's a city of 11,000 and is somewhat geographically isolated. The city entered the broadband business back in 2002 when the telephone company wouldn't offer DSL. The city built their own DSL network. Over time they transitioned to a wireless technology including a citywide outdoor WiFi network. In 2014, the city started building a citywide fiber network to replace the older technology.

The city does not have a municipal electric company and instead created a city broadband utility. The city borrowed to build the fiber network, but the effort was eased since the city already had over 70% of the residents as broadband customers on the older technologies.

The primary product is affordable fast Internet service. A 300 Mbps connection costs $41.95 per month. Homes can get a gigabit connection for $59.95. The city offers basic telephone service for $20 per month. The city also sells broadband to the rural areas surrounding the city using fixed wireless technology.

EC Fiber, Vermont[34]

[33] https://www.ci.sandy.or.us/sandynet/

[34] https://www.ecfiber.net/

EC Fiber is an ISP created by a consortium of 24 small towns in Vermont. Altogether the towns have a population of around 31,000. The towns do not have municipal fiber. EC Fiber was created in 2008 as a standalone government entity owned by the 24 communities.

EC Fiber tried to get started just as the 2009 recession hit and was unable to raise money from banks. The entity took a unique path to get started. They started by raising $1 million in loans from local residents. After that they issued promissory notes in increments of $2,500 to local residents who were willing to invest in the business and raised over $7 million from 500 local investors by 2015. At that point they got a $600,000 grant from the State of Vermont and was also granted use of some state-owned dark fiber to provide backhaul.

In 2016, legislation was passed that created EC Fiber as the first Communications Union District, which provided them with the legal authority to issue municipal bonds. Since 2016 EC Fiber has raised over $32 million in revenue bonds and is currently expanding fiber outside each of the towns to the surrounding rural areas. By 2018 they had constructed over 1,400 miles of fiber and passed over 20,000 homes.

Broadband prices range from $64 for 25 Mbps broadband up to $156 per month for 800 Mbps service. Installation is $99 and customers must pay extra if they are located more than 400 feet from the nearest fiber terminal along the road.

Marshall, Michigan

Marshall, Michigan is a community of 7,000 in south central Michigan. The city decided to build a fiber network in 2017 since the city's only broadband option was slow DSL in the range of 2 Mbps, and there was no cable provider. Marshall does not own an electric utility and established the Internet Department as a new department of the city. The broadband business is branded as Marshall Fibernet.

Marshall financed the network by interdepartmental loans from other city departments as well as funding raised by Marshall's Local Development Financing Authority. The city did not issue municipal bonds. Now that the network has been built the city is considering extending the network to nearby townships.

Residential broadband prices range from $40 for 50 Mbps service up to $200 for gigabit service. The city claims it will provide speeds up to 10 Mbps per second upon request.

Municipal Fiber Networks in Cities of a Similar Size

Salisbury, North Carolina

Salisbury is a city of 33,500 that is midway between Charlotte and the research triangle in North Carolina. The city began investigating broadband in 2005. After finding significant public support for the effort the city issued $29 million in revenue bonds and created an ISP, branded as

Fibrant, that was associated with the city's electric utility. In 2015, Fibrant announced it would be the first city to offer 10 gigabit service to residents.

In 2018 the city reached an agreement with Hotwire, a large ISP from Florida, to lease the entire network from the city. Hotwire has rebranded the ISP as Fision Fiber.[35] The city continues to own the network and the lease payments are used to pay the revenue bond debt. The city reached this decision because they felt that they were unable to fulfill their original vision. The municipal electric company serves a number of nearby towns and the city had always planned to expand fiber to serve the entire electric footprint. However, the North Carolina Legislature passed a law that forbid any new construction of municipal fiber and the two existing municipal networks in Salisbury and Wilson were allowed to continue service but are not allowed to expand. The city hopes that Hotwire, as a private ISP, will expand the network to the rest of the surrounding communities.

The lease does raise an interesting side note about municipal broadband. In the last few years, several municipal broadband networks in cities like Bristol, Virginia and Opelika, Alabama have been purchased by private investors – and offers have been made to many other municipal systems. Municipalities may decide to sell for any number of reasons, but most cities that have built fiber networks never had a desire to be a competitive ISP. Their goal was always to get better broadband to the community. Once a municipal network is mature and has customers, a network can be easily sold at a price to recover debt or even make a profit, with the city knowing that they now have a fiber ISP to serve the community.

MINET - Monmouth and Independence, Oregon.[36]

Monmouth and Independence are two cities about 15 miles southwest of Salem. Together, the cities have over 20,000 residents. The communities were served by a local cable company that didn't upgrade to broadband service and in 2005 when MINET was formed a lot of residents were still using dial-up. Since then, Charter purchased the cable company, but the cable network was so old that even today the quality on the network is poor.

Under Orgon law the two cities created a municipal non-profit corporation owned by both cities. The project was funded in bits and pieces with small borrowings over the following six years. Monmouth operates a municipal electric utility, but Independence does not. MINET is separate and not related to the municipal electric. Eventually, the cities issued revenue bonds to refinance the smaller series of debts. MINET is possibly the most successful ISP of their size having gotten over 80% of the customers inside the cities. MINET is currently operating a new fiber network for pay in nearby Dallas, Oregon that was funded by a non-profit.

MINET offers a full range of triple-play products including gigabit Internet access. Broadband starts with 150 Mbps service at $54.65 to gigabit service at $129.65.

Morristown, Tennessee[37]

[35] https://salisbury.fision.com/

[36] https://www.minetfiber.com/

Morristown is a city of 30,000 in east Tennessee. The city entered the fiber business in 2006 after recognizing that the poor broadband in the community was killing jobs and blocking economic development. The city had no incumbent cable provider and residents and busineses had no choice other than DSL. The city owns a municipal electric utility which also opeates the broadband budsinesses branded as MUS Fibernet. The city issued general obligation bonds bonds to finance the network. MUS Fibernet reports having over 15,000 customers and claims to be financially solvent.

The city cites a number of examples of businesses that have located or expanded operations in the city due to the fiber network and the low broadband rates. Prices range from $39.95 for 250 Mbps to 99.95 for gigabit service.

Observations about the Selected Cities. Nearly 200 communities have constructed fiber to the whole community and there are hundreds of communities now considering fiber broadband. There a few issues that all of these communities have in common. The most important commonality is that every community felt that their existing broadband was holding the community back. That's an important characteristic, bucause a new ISP in that kind of market is likely to win a higher percentage of the market than ISPs that compete against a quality broadband provider. Some of the ISPs on the list above have won 70% or even much higher market penetration rates.

Every one of the communities listed above had gathered significant residential and business support before building a broadband network. If the town was to decide to move forward, one of the first steps would be to formally gather public support through the customer engagement process described in this report.

It's interesting to note that even this small sampling of cities found different and interesting ways to pay for a broadband network. What is not captured on this kind of list are the many communities that have the need and desire for broadband but that can't find a way to finance such a venture.

One thing is not obvious from this list. Most of the cities on this list have decided to be the retail ISP and to serve customers as a utility. However, it's been our experience that the majority of communities do not want to be a retail ISP. Most cities that are finding broadband solutions today are doing so through some form of a public-private partnership. The only public-private partnership on the list above is Salisbury North Carolina.

[37] http://www.musfiber.net/service/fibernet/index.php

EXHIBIT I: RESULTS OF THE RESIDENTIAL SURVEY

Total Surveys - 378

Residency:

	Number	Percent
I live in the town of Falmouth I DO rent	10	2%
I live in the town of Falmouth I DO NOT rent	359	95%
I live in the town of Falmouth part time and spend 6 months per year	3	1%
I live in the town of Falmouth part time and spend 7 months per year	1	.33%
I live in the town of Falmouth part time and spend 8 months per year	1	.33%
I live in the town of Falmouth part time, spending 9 months per year	1	.33%
I don't live in Falmouth, but I rent my property there to others	3	1%

2. Who provides internet service to your home now?

	Number	Percent
Comcast	314	83%
Verizon	29	8%
Only use my cell phone data	15	4%
Don't have Internet	20	5%
Other	0	0%

3. Who is your current Cable TV provider?

	Number	Percent
Comcast	298	79%
Verizon	18	5%
Satellite dish	16	4%
Only watch on-line	17	4%
Don’t have cable TV	29	8%

4. If you have a telephone landline, who provides your telephone service?

	Number	Percent
Comcast	209	55%
Verizon	18	5%
Don’t have a landline	151	40%
Other	0	0%

5. What do you pay for the following?

Bundle	$183
Standalone Cable TV	$ 92
Standalone Internet	$ 59
Standalone Telephone	$ 72

6. Does anybody in your household use the Internet connection to work from home?

	Number	Percent
Full Time	17	5%
Several Days per Week	32	8%
Occasionally	51	13%
No	278	74%

7. Do you have students in the home that use internet for school assignments?

	Number	Percent
Yes	84	22%
No	294	78%

8. Using a scale from 1 to 5, where 1 is very dissatisfied and 5 is very satisfied, please rate your Internet Service Provider on the following?

Download Speeds

	Number	Percent
1 Very Dissatisfied	30	8%
2 Dissatisfied	67	19%
3 Okay	143	40%
4 Satisfied	54	15%
5 Very Satisfied	64	18%

Customer Service:

	Number	Percent
1 Very Dissatisfied	40	11%
2 Dissatisfied	77	21%
3 Okay	132	37%
4 Satisfied	49	14%
5 Very Dissatisfied	60	17%

Reliability:

	Number	Percent
1 Very Dissatisfied	34	9%
2 Dissatisfied	97	27%
3 Okay	129	36%
4 Satisfied	46	13%
5 Very Satisfied	55	15%

Value I get compared to the price I pay:

	Number	Percent
1 Very Dissatisfied	68	19%
2 Dissatisfied	122	34%
3 Okay	74	21%
4 Satisfied	38	11%
5 Very Satisfied	54	15%

9. Have you experienced any Internet outages in the last 12 months?

	Number	Percent
Yes	182	51%
No	175	49%

9a. Briefly describe the outages

	Number	Percent
Short Period	27	15%
One Day	73	40%
Multiple Days	82	45%

9b. How bothersome were the outages?

	Number	Percent
Not Inconvenient	4	2%
Somewhat Inconvenient	81	45%
Very Inconvenient	97	53%

10. Have you experienced any Internet slowdowns in the last 12 months?

	Number	Percent
Yes	227	63%
No	131	37%

10a. Briefly describe the slowdowns.

	Number	Percent
Random	117	52%
Daily	110	48%

10b. How bothersome were the slowdowns?

	Number	Percent
Not Bothersome	2	1%
Somewhat Bothersome	67	35%
Very Bothersome	122	64%

11. In general, how do you feel about the idea of Falmouth trying to get better Internet access?

	Number	Percent
I support the idea	264	70%
I do not support the idea	53	14%
I might support the idea but need more information	61	16%

12. If you support having Falmouth trying to get better internet access, what are the reasons for your support?

	Number	Percent
I hope a new network will bring competition.	298	92%
I hope a new network would offer lower prices.	257	79%
I hope a new network means better customer service.	132	41%
I hope a new network will bring more reliable service	179	55%

13. If you do not support getting better Internet access in Falmouth, what are the reasons?

	Number	Percent
I'm happy with my current provider	34	66%
Government should not compete in private business	1	2%
Don't want to switch	8	15%
Don't need services	9	17%

14. What factors might influence your decision to become a customer of a new fiber network?

	Number	Percent
Faster internet speeds for the same price I pay today	185	49%
Lower price than I pay today	311	82%
More reliable service	222	59%
Same price but better customer service	74	20%
A locally owned network would keep the dollars I pay in our community	90	24%

15. Would you buy internet service from the new fiber network if they offer faster speeds than the competition at rates similar to what is currently available?

	Number	Percent
Yes, definitely	136	36%
Probably	112	30%
Maybe	60	16%
Probably Not	27	7%
Definitely Not	43	11%

16. Would you buy traditional TV service from a new fiber network if they offered similar channel line-ups and prices as today, and better picture quality than you get today?

	Number	Percent
Yes, definitely	120	32%
Probably	112	29%
Maybe	71	19%
Probably Not	33	9%
Definitely Not	42	11%

17. Would you buy a landline telephone service from a new fiber network if they could offer affordable prices?

	Number	Percent
Yes, definitely	52	14%
Probably	74	19%
Maybe	72	19%
Probably Not	78	21%
Definitely Not	102	27%

The following two questions are only asked of part-time residents (from question 1)

17. Are you able today to get seasonal billing today so that you don't pay for Internet, telephone and TV services while you are not in Falmouth?

	Number	Percent
Yes	5	83%
Not sure	1	17%

18. How important are part-time/seasonal billing rates to you?

	Number	Percent
I wouldn't buy broadband in Falmouth without seasonal rates	5	83%
I would be willing to pay all year for reliable broadband	1	17%
It all depends on the specific products and prices	0	0%

These questions are only asked to those that rent their homes to others (from question 1)

19. Using a scale from 1 to 5, where 1 is very dissatisfied and 5 is very satisfied, how important is it for your tenants to have good broadband?

	Number	Percent
1 Very Dissatisfied	0	0%
2 Dissatisfied	0	0%
3 Okay	0	0%
4 Satisfied	3	23%
5 Very Satisfied	10	77%

20. Have you ever had your tenants complain about broadband?

	Number	Percent
Yes	4	31%
No	9	69%

20a. What kind of problems did they have?

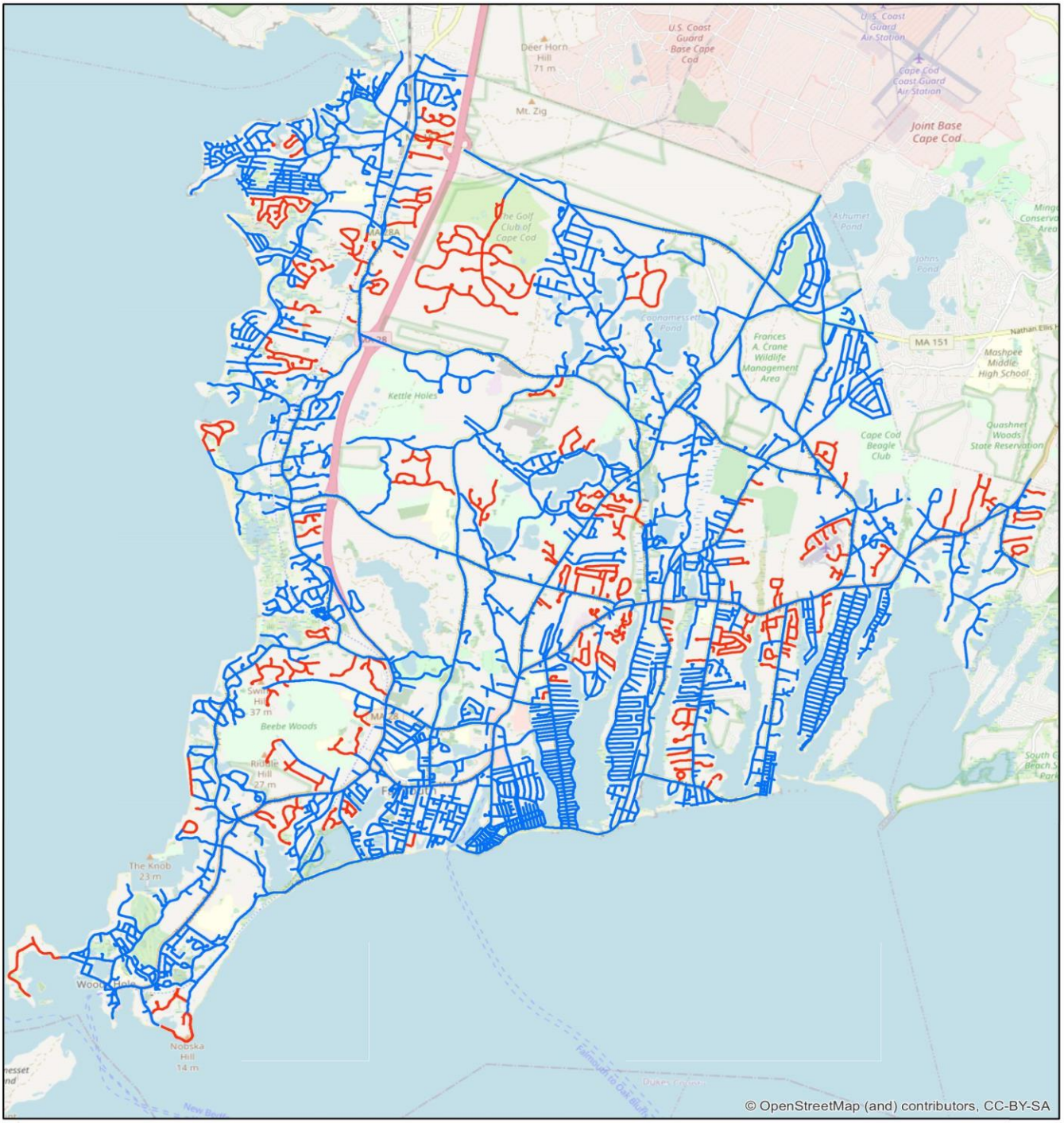
Slow download; Streaming is poor; Internet cuts out

EXHIBIT II: SUMMARY OF FINANCIAL RESULTS

		Assets	Take Rate	Debt	Equity	Total Financing	Cash after 20 Years
Town as the ISP							
1	**General Obligation Bond**	$54.64 M	50%	$62.90 M		$62.90 M	$13.20 M
2	**Revenue Bond**	$54.64 M	50%	$69.40 M		$69.40 M	$ 5.91 M
3	**Higher Interest Rate**	$54.64 M	50%	$71.60 M		$71.60 M	-$ 0.23 M
4	**Lower Interest Rate**	$54.64 M	50%	$66.90 M		$66.90 M	$11.65 M
5	**30-Year Term**	$54.64 M	50%	$66.80 M		$66.80 M	$20.63 M
6	**$5 Higher Prices**	$54.64 M	50%	$69.40 M		$69.40 M	$17.12 M
7	**$5 Lower Prices**	$54.64 M	50%	$69.40 M		$69.40 M	-$ 5.03 M
8	**Rate Increases**	$54.64 M	50%	$69.40 M		$69.40 M	$18.80 M
9	**5% Higher Fiber Cost**	$56.29 M	50%	$71.40 M		$71.40 M	$ 3.53 M
10	**5% Lower Fiber Cost**	$53.29 M	50%	$67.40 M		$67.40 M	$ 8.28 M
11	**55% Penetration**	$55.78 M	55%	$69.00 M		$69.00 M	$19.36 M
12	**60% Penetration**	$56.97 M	60%	$69.70 M		$69.70 M	$32.54 M
13	**Breakeven Penetration**	$54.25 M	48%	$69.10 M		$69.10 M	$ 0.82 M

	Assets	Take Rate	Debt	Equity	Total Financing	Cash after 20 Years
Commercial ISP						
14 **New ISP**	$54.64 M	50%	$52.35 M	$ 7.85 M	$60.20 M	$10.65 M
15 **Existing ISP**	$54.60 M	50%	$50.63 M	$ 7.59 M	$58.22 M	$16.31 M
16 **Higher Interest Rate**	$54.60 M	50%	$51.18 M	$ 7.68 M	$58.85 M	$14.05 M
17 **Lower Interest Rate**	$54.60 M	50%	$50.10 M	$ 7.52 M	$57.62 M	$18.48 M
18 **30-Year Term**	$54.60 M	50%	$49.25 M	$ 7.39 M	$56.64 M	$26.71 M
19 **15-Year Term**	$54.60 M	50%	$53.10 M	$ 7.97 M	$61.07 M	$16.12 M
20 **$5 Higher Prices**	$54.60 M	50%	$49.55 M	$ 7.43 M	$56.98 M	$23.92 M
21 **$5 Lower Prices**	$54.60 M	50%	$51.70 M	$ 7.76 M	$59.46 M	$ 8.69 M
22 **Rate Increases**	$54.60 M	50%	$50.63 M	$ 7.59 M	$58.22 M	$25.25 M
23 **5% Higher Fiber Cost**	$56.24 M	50%	$52.40 M	$ 7.86 M	$60.26 M	$14.75 M
24 **5% Lower Fiber Cost**	$52.95 M	50%	$48.85 M	$ 7.33 M	$56.18 M	$17.86 M
25 **55% Penetration**	$55.73 M	55%	$50.51 M	$ 7.58 M	$58.08 M	$25.38 M
26 **60% Penetration**	$56.92 M	60%	$50.35 M	$ 7.55 M	$57.90 M	$34.43 M
27 **Breakeven Penetration**	$52.77 M	42%	$51.10 M	$ 7.67 M	$58.77 M	$ 1.66 M

EXHIBIT III: MAPS OF THE FIBER NETWORK



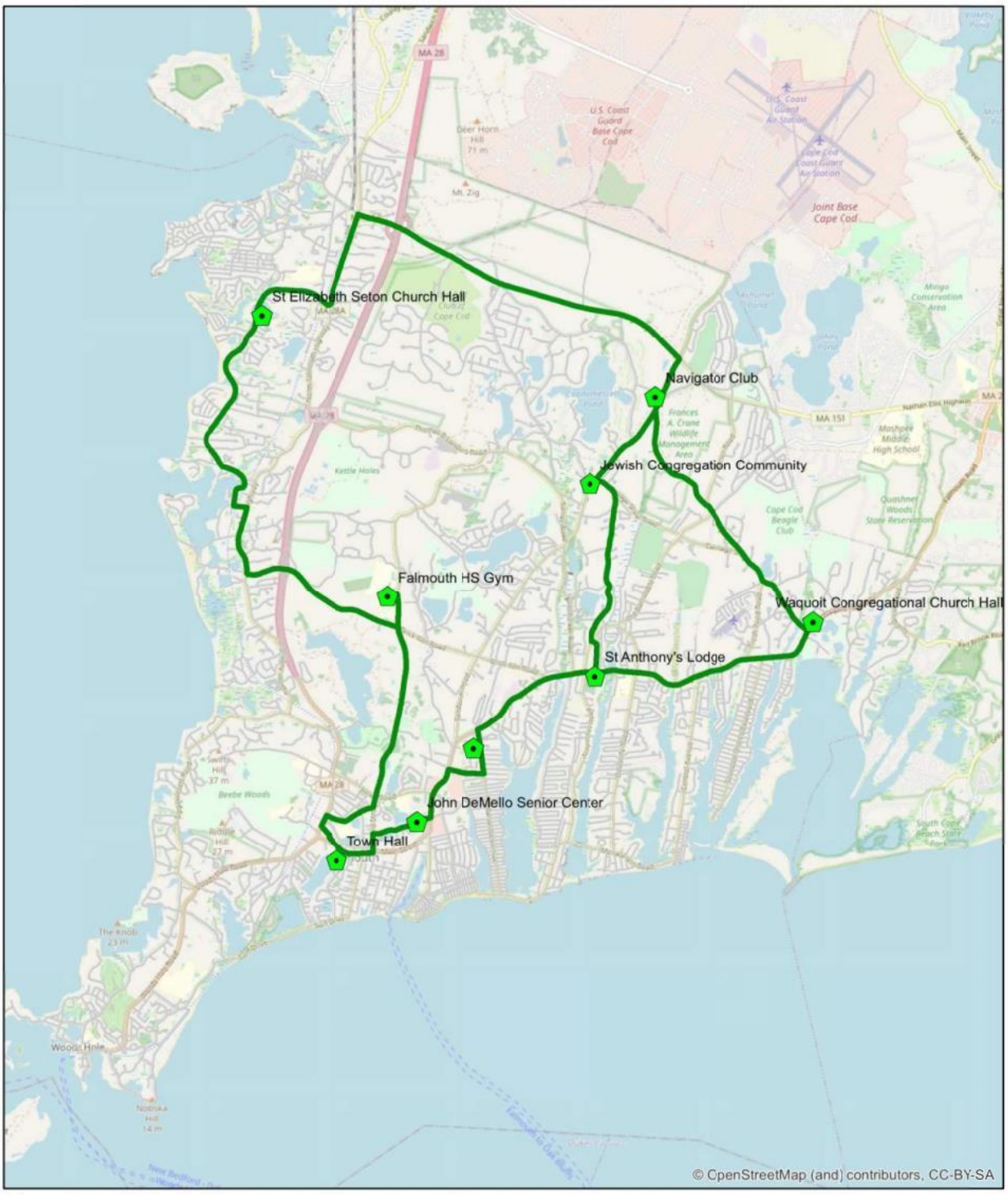
Falmouth EDIC

CCG CONSULTING

PROPOSED ROUTES

AERIAL

BURIED



Falmouth EDIC

CCG CONSULTING

OLT

TRANSPORT

Falmouth EDIC

CCG CONSULTING