REQUEST
This report is provided to elicit feedback from the Utilities Advisory Commission (UAC) on the findings and recommendations prepared by the two consulting firms retained to develop a business plan for the Citywide Ultra High-Speed Broadband System Project (Broadband System Project). Preparation of a business plan for the project was requested by the City Council. No action is required at this time.

To support the development of a business plan for the Broadband System Project, staff has worked with two consulting firms, Columbia Telecommunications Corporation (CTC) and Tellus Venture Associates (Tellus). Both CTC and Tellus work extensively with municipal, county and state governments to support broadband projects. CTC is a telecommunications engineering and consulting firm and Tellus provides a wide variety of telecommunication consulting services, specializing in market research for community-based broadband initiatives.

CTC and Tellus have completed their scope of work and submitted reports which are attached to this report. This report will summarize the findings and recommendations in these reports: Attachment A (CTC report) and Attachment B (Tellus report). Attachment C is a glossary with various telecommunication industry terms.

SUMMARY
The purpose of the Broadband System Project business plan is to respond to the City Council’s directive to explore the use of the Fiber Optics Fund reserve (approximately $9.9 million) to independently proceed with a phased build-out of the existing fiber optic backbone network (“fiber network”). The Fiber Optics Fund reserve is projected to be approximately $11.0 million by the end of FY 2012, based on the proposed budget.

On December 1, 2010, staff provided a report to the UAC about the development of the business plan for the Broadband System Project. The report summarized the work in progress by CTC and Tellus and the components of the proposed plan. The two primary components of the business plan are:

1. Evaluation of potential fiber network extensions and prospective opportunities to increase the dark fiber customer base, including a cost-benefit analysis of each identified extension. This evaluation includes market research performed by Tellus and a technical analysis of the current fiber network by CTC with some general recommendations to expand the presence of the network in the community.
2. Preparation of a phased “conceptual plan” for Fiber-to-the-Premise (FTTP) by CTC. This conceptual plan proposes two phases: (1) construction of broadband telecommunications hub sites at the nine electric substations; and (2) expanding network access from the hub sites to neighborhood access points or “nodes” as a potential platform for FTTP, in addition to supporting other uses related to wireless communications, including communication infrastructure for future Smart Grid applications.

BACKGROUND
The reports from CTC and Tellus will serve as the basis for development of a business plan to fully leverage the City of Palo Alto’s (City) fiber network that is currently used to provide dark fiber service connections for use by City departments, in addition to local businesses, institutions and other end users in Palo Alto. Extensions of the existing fiber network to increase commercial dark fiber customers would be funded through standard Capital Improvement Projects. Options recommended in the CTC report for broadband expansion initiatives would be funded by using Fiber Optics Fund reserves.

The reports produced by CTC and Tellus evaluate the existing fiber network, the dark fiber licensing business, and the opportunities and obstacles to expanding the customer base. In addition to the assessment of the existing dark fiber licensing business, the reports address the feasibility of City of Palo Alto Utilities (CPAU) offering commercial “value-added” telecommunication services in competition with the incumbent carriers (AT&T and Comcast) and other providers serving residential and commercial customers with telecommunication services in Palo Alto. Among these providers are several telecommunication “resellers” that license dark fiber from CPAU for the purpose of provisioning a variety of broadband products to commercial and residential customers in Palo Alto.

CTC’s scope of work asked for the development of a conceptual plan for phased, low-risk initiatives to expand the existing fiber network. Based on the proposal to use the Fiber Optics Fund reserve for these initiatives, potential building blocks would be established for broadband expansion in Palo Alto. Implementation of these initiatives would be mindful of the City Council’s directive to minimize financial risk to the City for broadband expansion and to fully leverage the fiber network to benefit the community.

The conceptual plan developed by CTC proposes a two-phased expansion of the existing fiber network that may provide an economic incentive to attract a private investor/operator for residential and commercial FTTP. CTC evaluated these phased FTTP options within the context of constructing fiber infrastructure that provides a viable “system-level network design” to attract a third-party network operator willing to build-out a last mile “open access” network in Palo Alto in some form of a public-private partnership arrangement. In the event there is no interest from the private sector in building out a last mile FTTP network in Palo Alto, the proposed expanded broadband infrastructure described in CTC’s report would still be useful for other new initiatives that could benefit the community and expand access to broadband services. Examples of these new initiatives include:

- Physical collocation services for wireless carriers seeking to improve their service coverage in Palo Alto;

1 A study published by the Utilities Telecom Council (UTC) in July 2010, indicates 68% of utilities (investor-owned, cooperatives and municipals) offer some form of communications services outside of the utility’s own internal operations; these services include wholesale and
• Wireless access points for City use (e.g., mobile broadband for City departments and a public safety network), in addition to commercial and public use; and
• Developing communication infrastructure necessary to support future Smart Grid applications such as an Advanced Metering Infrastructure (AMI) system.

Tellus Venture’s scope of work focused on market research to assess the amount of new commercial, industrial and institutional demand for dark fiber service connections in Palo Alto. This market research will guide staff in the identification of prospective Capital Improvement Projects to extend the fiber network deeper into areas of Palo Alto where there may be a significant concentration of additional demand for dark fiber service connections and a cost-benefit analysis indicates a sufficient return on investment. This market research also identified commercial multi-tenant buildings that could possibly be pre-connected with dark fiber to support business attraction, business retention and economic development efforts that will be enhanced by the availability of dark fiber service connections for commercial or industrial enterprises and community anchor institutions requiring large amounts of bandwidth.

In addition to analyzing the existing fiber network and opportunities to expand it for new dark fiber licensing opportunities and other broadband expansion initiatives, the reports from CTC and Tellus provide an overview of the residential FTTP market and addresses the business case for another provider of broadband services overbuilding AT&T and Comcast in Palo Alto with an all-fiber network.

**DISCUSSION**
The following is a summary of CTC’s findings and recommendations related to the existing fiber network and opportunities for expansion:

• CPAU should continue to develop its commercial dark fiber licensing service based on identifying specific “targets of opportunity.” For example, these opportunities include pre-connecting multi-tenant commercial buildings or extending the fiber network deeper into commercial and industrial areas where there is verified demand for dark fiber service connections and a cost-benefit analysis shows a sufficient return on investment. There may also be commercial or industrial areas that should be evaluated in terms of enhancing economic development efforts.
• The existing fiber network provides sufficient capacity and coverage to allow for new customers. The network was designed and constructed with significant excess fiber capacity in the form of discrete fiber strands with abundant dark fiber inventory available.
• If market research indicates there is significant new demand for commercial dark fiber service connections in certain commercial and industrial areas of Palo Alto, there should be an effort to enhance outbound marketing and sales efforts to validate this demand and potential customer uptake before specific extensions are considered.
• From a competitive perspective, licensing dark fiber to a variety of end users is a unique service in that it is not normally associated with the traditional telecommunication service providers such as AT&T and Comcast. These providers have traditionally rejected the concept of licensing dark fiber, choosing instead to offer only “managed” network services.

*retail options. In terms of wholesale services, licensing of dark fiber is the most frequently offered option, with an estimated 39% of utilities offering this service. Physical collocation of third-party communication assets on utility facilities (e.g. utility poles, conduit and substations) is the second most frequently offered service, with an estimated 34% of utilities offering this service, followed by wireless collocation (27%), Ethernet (16%), lit fiber (15%). The study estimates that wireless collocation services are the top revenue generator among wholesale options, followed by lit fiber services and dark fiber licenses.*
(e.g., AT&T’s “GigaMAN Service” or Comcast’s “Business Class” service). Dark fiber service connections enable the end users to tailor their internal network configurations to meet bandwidth requirements for specific applications. In contrast, traditional telecommunication service providers only make available certain products within their service options that may not adequately meet the requirements of these specific applications.

- CPAU’s monthly recurring charges for licensing dark fiber service connections are based on the number of fiber miles licensed, i.e., the pricing structure is distance-based. In contrast to traditional managed services from the commercial broadband service providers, once a customer pays the installation cost and connects to the network, the monthly recurring charges are at a fixed cost for use of the fiber, without any usage or traffic volume fees. The fixed price aspect of a dark fiber license agreement is especially attractive to high-bandwidth end users who want to operate and maintain their own systems in order to address their unique requirements – and more importantly, they are able to upgrade and modify the system based on their own demand and needs. Therefore, the end user is not bound to a specific protocol or data transmission rates, which are the norm in managed services from the traditional telecommunication service providers. End users can simply increase capacity by upgrading their own transmission equipment. In contrast, the traditional providers normally base user fees on fixed amounts of bandwidth, offering data transmission rates in defined increments at set prices.

- In some circumstances - especially small and mid-size businesses with limited bandwidth requirements - a dark fiber service connection is not cost-effective because the potential new customer will, under the current CPAU pricing structure for installation, bear the brunt of the total cost for new plant construction and the installation. Therefore, CPAU cost estimates to connect to the fiber network for a dark fiber service connection will likely not be competitive with estimates provided by AT&T, Comcast and other broadband providers offering commercial “managed” service solutions. Additionally, many small and mid-size businesses typically do not have the Information Technology (IT) resources to install and maintain the electronic transmission equipment required to “light” the dark fiber service connection.

- CTC examined the feasibility of CPAU expanding commercial offerings beyond licensing dark fiber to include new products such as active networking services or other managed network solutions. In CTC’s opinion, the likelihood of CPAU capitalizing on this market is minimal and CPAU would in effect be competing with its reseller customers. To address the network services market, CPAU would have to recruit staff or contractors with networking capabilities, develop back office support systems, provide 24x7 customer support and comply with state and federal regulatory requirements for telecommunication service providers.2

Tellus Market Research Report
Tellus Venture Associate’s scope of work for the market research report asked for an evaluation of the following areas:

1. Analysis of the existing CPAU fiber network footprint versus existing and potential dark fiber customers.
2. Analysis of potential network extensions.
3. Assessment of services and market position.

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2 A few municipal utilities in California provide lit or value-added services. For example, City of Burbank Water & Power, in addition to licensing dark fiber, recently launched commercial services such as Virtual Private LAN Services (VPLS – Ethernet-based services which allows multi-point businesses to operate as a single meshed network) SONET and fiber “wavelength services.”
5. Pricing analysis.
6. Cost-benefit analysis of commercial “value-added” service options.
7. Assessment of residential FTTP service and case study benchmarks.

The basic methodology for the market research assumed that existing and potential dark fiber customers would generally share a common electricity usage profile. Once the profile was established, other businesses within Palo Alto with similar profiles could be identified and then located relative to the existing fiber network. To develop the market research findings, the utility customer database was used, in addition to mapping data from the City’s Geographic Information System (GIS) and existing fiber network maps with aerial and underground fiber network routes, service drops and interconnection points. Several existing and potential dark fiber customers were also interviewed, but a formal survey was not part of the scope of work.

Tellus developed two analyses to identify potential new dark fiber customers:

1. Determined the number and location of commercial electric accounts within 200 meters of the existing fiber network and that matched the electricity profile of existing fiber accounts (defined as large, medium and small commercial accounts with billing greater than or equal to $20,000 a month). Two-hundred (200) meters was chosen as being a reasonable distance from a service drop connection. Within 50 and 100 meters was also mapped.
2. Determined the number and locations of all commercial electric accounts greater than 200 meters from existing plant.

The following is a summary of the Tellus’ key findings and recommendations:

1. CPAU’s core competency is providing reliable and relatively inexpensive dark fiber connectivity throughout much of the City.
2. No other telecommunication service providers offer intra-city dark fiber services in Palo Alto, except insofar as the “resellers” resell CPAU fiber. Several providers offer managed network services using a variety of technologies, including Ethernet, SONET, and various wavelength division multiplexing (WDM) technologies. Taken together these are CPAU’s best customers.
3. CPAU’s dark fiber services are effectively marketed to organizations that need a correspondingly high level of bandwidth. Stanford Research Park and downtown Palo Alto are two specific areas where CPAU has been successful. A modest, highly targeted and ongoing advertising and promotion program will help maintain CPAU’s market position over time.
4. Telecommunication service resellers are CPAU’s best customers, and are already positioned to provide higher-value added services. CPAU should consider initiatives that would encourage and enable resellers to make services available to a wider range of businesses, rather than CPAU competing against resellers’ core competencies by attempting to provide lit services. A wider range of commercial properties could be served if CPAU worked more closely with property owners to extend fiber connectivity to unserved office complexes, via a “Fiber-to-the-Basement” business model, particularly one that created a mechanism for contracting out pre-engineering and construction work when necessary to expedite installation of dark fiber service connections. A Request for Proposals (RFP) for such a program should be considered.
5. Mobile phone companies are a category of telecommunication service providers that could be addressed. CPAU should consider developing a comprehensive approach to this market segment, including extension of the existing network and other facilities to better serve its needs by offering dark fiber service connections to provide the communications link for “backhaul”\(^3\) to their network hub sites.

6. There are areas of the City that have concentrations of businesses and institutions that are not easily reached by the CPAU network, but may need large amounts of bandwidth provided by a dark fiber service connections. To license dark fiber to these customers, CPAU should evaluate flat rate service pricing and amortizing construction costs via a flat rate or cost-recovery based increase in the monthly drop fee, which would simplify CPAU’s selling proposition and make the service more attractive to customers at the edges of the network that have a need for large volumes of bandwidth, but cannot afford the construction and installation costs necessary to bring fiber to their facility. Even if no changes are made to the rate and cost recovery structure, it would be worthwhile to evaluate the creation of a packaged selling proposition for multi-tenant office buildings and present it to local property owners.

7. There is no compelling business case for providing fiber service directly to residences at this time. Palo Alto is served by two large incumbent (AT&T and Comcast) retail video and broadband service providers that enjoy decisive competitive advantages resulting from economies of scale. Comparable municipal broadband ventures have failed. It is unlikely that a City-supported FTTP “overbuild” venture with a private network builder/operator would be able to achieve enough market penetration and subscriber revenue to support itself in the near term. However, in the long term the broadband business environment is very likely to change and might do so in a way that makes a FTTP venture with a private sector partner(s) financially viable.

8. CPAU should fully evaluate the feasibility of the CTC conceptual plan to determine if constructing more robust broadband support infrastructure, i.e. constructing hub sites at the electric substations and neighborhood access points, will provide sufficient economic incentive for a third-party to consider building the last mile to the premise.

**Analysis of the Unserved Market**

On the basis of identifying fiber network “extensions” that would result in the acquisition of new dark fiber customers by building plant closer to the area, Tellus evaluated the “unserved” market and identified the following six areas:

1. Along El Camino Real, generally between Stanford Avenue and Del Medio Avenue, with the largest concentration between page Mill Road and Maybell Avenue.
2. Along Sand Hill Road and Welch Road, west of El Camino.
3. Along San Antonio Avenue, between Alma Street and Middlefield Road.
4. Around East Meadow Circle.
5. Along East Bayshore Road, north of Embarcadero Road.
6. In the area of the northeast boundary of the City, generally along University Avenue.

Areas identified along El Camino Real, Sand Hill Road, Welch Road and East Meadow Circle have high concentrations of accounts that are consistent with the electricity usage profile and the general business categories of existing dark fiber customers. El Camino Real in particular also showed a generally high concentration of commercial accounts of all kinds. The East Bayshore

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\(^3\) “Backhaul” is a telecom term used to describe the transmission of customer usage data from a collection point back to a central point or network backbone.
Road and San Antonio Road areas were less promising, but were clearly commercial or industrial areas and adjacent to existing fiber lines. The general northeast area of the City was even less promising and was dropped from further consideration – this area is mostly scattered residential multi-dwelling units.

Tellus evaluated new fiber segments that would bring the fiber backbone closer to potential users in the five unserved areas. These five new segments, totaling 6.8 miles in length, were mapped. Forty-one organizations with a total of 52 different locations within the new service areas were identified as being possible prospects for dark fiber service connections. These 52 locations were similar to existing dark fiber customers (high-technology firms, telecommunication service providers and a variety of professional offices) or represented large retail or property management oriented companies, which are found in the prospective new service areas.

Tellus developed a cost-benefit analysis for each fiber segment. The cost of building the extension was estimated using a fiber construction cost range provided by staff ($30 to $60 per foot). A penetration rate of 17 percent was used to estimate customer uptake on new segments (penetration methodology on page 21 of the report). The number of projected customers was multiplied by the monthly revenue figure, and the net present value (NPV) over 3, 5 and 10 years was calculated using a discount rate of 5 percent. An average installation cost of $5,700 per account was added to produce total estimated revenue per segment over 3, 5 and 10 years. The average installation cost is consistent with the last 50 projects completed by CPAU.

Below is a table summarizing the potential customers in the five areas, fiber extension length and estimated construction cost:

<table>
<thead>
<tr>
<th>Fiber Segment</th>
<th>Est. Locations</th>
<th>Length (miles)</th>
<th>Low Cost - $30/ft (000s)</th>
<th>High Cost - $60/ft (000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 El Camino Real</td>
<td>20</td>
<td>2.5</td>
<td>$393</td>
<td>$785</td>
</tr>
<tr>
<td>#2 Sand Hill/Welch</td>
<td>15</td>
<td>2.6</td>
<td>$407</td>
<td>$814</td>
</tr>
<tr>
<td>#3 San Antonio</td>
<td>1</td>
<td>0.7</td>
<td>$111</td>
<td>$222</td>
</tr>
<tr>
<td>#4 E. Meadow Cr.</td>
<td>12</td>
<td>0.7</td>
<td>$115</td>
<td>$231</td>
</tr>
<tr>
<td>#5 East Bayshore</td>
<td>4</td>
<td>0.3</td>
<td>$44</td>
<td>$87</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52</strong></td>
<td><strong>6.8</strong></td>
<td><strong>$1,069</strong></td>
<td><strong>$2,139</strong></td>
</tr>
</tbody>
</table>

The identified areas have concentrations of businesses and institutions that are not easily reached by the fiber network. East Meadow Circle should be considered a high priority for a network extension and work is already underway to serve that area. The Sand Hill Road and Welch Road areas are another candidate for network extension, particularly if the Stanford Medical Center and its affiliates have an interest. El Camino Real should be considered generally on the basis of the economic development potential of fiber availability and specifically in terms of supporting mobile telephone providers. An East Bayshore Road extension should also be considered on the same basis.

The mapping analysis shows that most Palo Alto Unified School District (PAUSD) sites are reachable with network extensions. At this time, however, with the exception of one site (Terman) it appears PAUSD will continue to use the fiber connections provided through the Comcast Institutional Network (I-Net).

**Conceptual Plan for Phased Fiber Network Expansion and Fiber-to-the-Premise:**
CTC’s conceptual plan to expand the existing CPAU fiber network is divided into two distinct phases:
Phase 1 focuses on creating core access points or hub sites at or adjacent to the nine electric substations. The estimated construction cost for the nine hub sites is $1.0 million (costs itemized in Appendix A-1 of the CTC report). CTC examined the feasibility of using the nine electric substation properties as fiber optic and wireless access points for wireless and fiber optic transport vendors to interconnect to the CPAU fiber network. Most of the substations are well-positioned geographically and are in commercial settings that are suitable to provide access to broadband fiber optic plant and house terminal wireless antennas needed to provide expanded support to personal, mobile, and fixed locations for residential and commercial end users. Each of the substations is connected to the fiber network directly through a dual-entry backbone ring architecture that produces a highly reliable, failsafe connection. A small portion of the existing fiber network backbone infrastructure would be dedicated to establishing the hub access facilities at the substations.

Constructing telecommunication hub sites at the substations presents an opportunity for CPAU to support the expansion of wireless services in Palo Alto for both third party wireless service providers and as a platform for future City needs. This infrastructure can also provide a “jumping-off point” for future fiber expansion to nodal access points in the neighborhoods, which will be described in Phase 2.

Like many communities, the placement or “siting” of wireless communications facilities in Palo Alto is a controversial and politically-charged issue. Examples of these wireless communication facilities are cellular-towers, antennas, low-profile distributed antenna systems atop utility poles, and related equipment housing facilities. Opposition to siting wireless communications facilities is especially contentious in residential neighborhoods and scenic areas where some residents, homeowner associations and environmental groups oppose the facilities based on concerns about aesthetics, impacts on property values, impacts on the environment, and concerns about the potential health risks associated with exposure to radiation from radiofrequency (RF) emissions.

With the rapid proliferation of personal wireless devices (e.g., cell phones, smart phones and tablet PC devices) communities want to have reliable citywide cell coverage for voice and high-speed data connectivity, but some residents do not want a cellular-tower located next door, or in fact even within the neighborhood. On the other hand, wireless service providers are faced with the exponential growth of data, video and voice traffic over their networks and need to alleviate network congestion by boosting coverage through siting more towers and antennas deeper into the community. Until a few years ago, wireless communications facilities were generally located in commercial or industrial areas. As coverage and network capacity issues emerge due to the inexorable consumer adoption of wireless devices and the volume of network traffic generated by these devices, the need for additional wireless communication facilities will continue in the foreseeable future. According to CTC, there will clearly be a need for more towers in and around Palo Alto, in part because of emerging 4G networks, in addition to new wireless spectrum being made available by the Federal Communications Commission (FCC).

In addition to building fiber optic and wireless access points at the substations, CTC proposes that CPAU evaluate the construction of cellular-towers (a.k.a. antenna mast poles or monopoles) within the existing fenced areas of the substations or on CPAU land adjacent to the substation fences. Many of the substations are well-positioned geographically and are generally in commercial settings that are suitable to provide access to broadband fiber optic plant and to house terminal wireless antennas needed to provide expanded support to personal, mobile, and fixed locations (residential and commercial). By developing a proactive cellular-tower
placement program within the confines of existing substations, CPAU would in effect be blending the common aspects of facilities everyone needs and leveraging the common characteristics of both media.

Assuming CPAU would construct and own the towers, CTC recommends development of a Request for Information (RFI) or a Request for Proposal (RFP) to solicit an experienced tower leasing company as a partner that can jointly develop a plan for deployment of citywide antenna facilities to support broadband services. Leasing antenna-mounting space on CPAU towers will provide a rental revenue stream and will be even more attractive because wireless service providers will have the option to license dark fiber from CPAU to provide the communications link for backhaul to their network hub sites.

Hub sites located at the substations would also be available for lease to other wireless service providers and could be used by CPAU as wireless hub collector sites to support communication backhaul links for future Smart Grid applications and to implement strategically located hot spots using the 4.9 GHz mobile public safety band to support law enforcement and other first responders in the field with video and surveillance applications. Other capital upgrades to configure the substations may be required to accommodate antenna mounting space to support commercial carriers and basic site infrastructure for Smart Grid core hub radio equipment and public safety wireless.

CTC estimates the construction cost of a 100 foot self-supporting tower at each substation would be $75,000, a total of $675,000 for the nine locations.

Phase 2 is a broader initiative that would deploy 88 access nodes in neighborhoods throughout the City. The estimated construction cost for Fiber-to-the-Neighborhood (FTTN) access nodes is $5.0 million (costs itemized in Appendix A-2 of the CTC report). Phase 2 proposes three independent but interrelated telecommunications initiatives that would expand the existing CPAU fiber network:

1. Provide an open, vendor-friendly environment for a third-party operator/investor to construct a standards-based citywide FTTP network serving commercial and residential customers.
2. Construct fiber plant to create a Fiber-to-the-Neighborhood (FTTN) network that would provide an access point to connect neighborhood-area backhaul communications links for potential FTTP providers, and to expand the functionality and the choices of technology that can be implemented for the City, including Smart Grid applications, a public safety network, mobile broadband access for City departments, and possibly WiFi access for the public.
3. Provide a neighborhood-based wireless access infrastructure expanding the capabilities initiated under Phase 1 to support neighborhood fiber optic/wireless mesh technology for WiFi, WiMAX, emerging “white space” technology, hot spots for the 4.9 GHz public safety band, and low-profile distributed antenna systems (DAS) for improved cellular coverage.

The implementation of Phase 1 and Phase 2 will call for CPAU to construct only a small portion of a total FTTP network, minimizing CPAU’s role in FTTP deployment, and possibly creating a sufficient economic inducement for a private builder to “plug-in” to the CPAU infrastructure to relatively quickly begin serving customers. It is estimated that to build an end-to-end FTTP network in Palo Alto would require an investment of approximately $40-60 million depending
on the type of system architecture deployed – either an Active Optical Network (AON), or a Passive Optical Network (PON). There are several variations within AON and PON network architectures, with advantages and disadvantages to each to effectively provision broadband services over a FTTP system.

To gain an understanding of the technologies, costs, and construction issues to build-out a FTTP network, CTC prepared a conceptual “system-level design” based on a standard PON architecture. Nonetheless, the intent of the PON model was not to restrict or define the technology a network builder would deploy, but to simply use PON as a baseline to establish preliminary size and costing.

CTC’s report states that since one of the goals of the FTTN network is to support FTTP architecture, it is recommended that Phase 2 be built so that each constructed portion of the FTTN network core is complete; that is, no further fiber or cabinets would be needed along those routes as they are converted to the final FTTP network. The reason for this recommendation is that, below a minimum level of FTTN completeness, converting the FTTN core infrastructure to FTTP may be, to a private sector company, more trouble than it is worth, and thus may put the City at risk. CTC’s report provides a FTTP conceptual design and defines the attributes of a “complete FTTN design.” Selection of AON or PON architecture for FTTP would be dependent on whether the network operator provisioned broadband services using either a “closed” or “open access” network business model. The pros and cons of these models were described in detail in the December 1, 2010, UAC Report regarding the Broadband System Project (Appendix A, “Overview of Telecommunications Industry Market Factors Affecting Municipal Broadband”).

Other inducements that could be offered by CPAU to a potential network builder is a partnership with its engineering resources to assist in design, licensing, and installation of fiber optic plant required to connect subscribers to the hub access points; rapid deployment citywide facilitated by the nine existing hub access points, and the ability to place the type of large, intrusive cabinets required for an FTTP network at existing CPAU facilities, minimally impacting the aesthetics of local neighborhoods and remaining in compliance with local zoning ordinances.

Similar to Tellus Venture’s assessment of the residential FTTP market, CTC’s report explains that the competitive landscape for broadband services would make it difficult for an overbuilder to be successful in Palo Alto at this point in time. The two major terrestrial carriers (AT&T and Comcast) are experienced operators backed by significant technical and financial resources, with a strong track record of product development and marketing broadband services. The well entrenched incumbent presence presents a formidable obstacle to any new service provider gaining significant market share in Palo Alto unless it can rapidly enter the entire citywide market with an enhanced product at a comparable or lower price point for service. Therefore, CTC recommends that implementation of Phase 2 should only be considered in conjunction with Smart Grid initiatives that CPAU may pursue in the future. Smart Grid technology advances in Advanced Metering Infrastructure (AMI) and greater demand for more real-time meter reading is increasing the demand for utility communications further into the neighborhoods. These AMI design requirements are consistent with a Fiber-to-the-Neighborhood (FTTN) approach and can be used to justify and offset the costs of an FTTN network.

Implementing FTTP for Smart Grid applications is a rarity due to the high deployment costs. To provide a sufficient return on investment for deploying FTTP for Smart Grid, a utility must first
deliver “triple-play” (voice, video and data) broadband services. Unlike broadband triple-play services, Smart Grid deployment alone does not require large amounts of bandwidth to transmit bits of data about energy and electrical systems. A fiber backbone integrated with a wireless solution to backhaul data is sufficient for Smart Grid applications. Another option to consider is to outsource the communication backhaul platform for Smart Grid applications over a third-party cellular carrier network using 3G, or emerging 4G WiMAX technology.

**NEXT STEPS**

The findings and recommendations contained in the reports prepared by CTC and Tellus will be used by staff to develop a final business plan for the Broadband System Project. It is anticipated that the business plan will be submitted to the City Council for consideration in the fall of 2011. Action steps to finalize the business plan are as follows:

1. Evaluate Dark Fiber Licensing Rate Schedules to determine if modifications are necessary to support retention of existing customers and to support future customer acquisition efforts:
   a. Prepare a fiber optic rate analysis. An analysis should be performed to determine the rate structure that best meets market needs while ensuring cost recovery. In addition, the current balance in the fiber reserve fund indicates that the current rate structure results in the fund significantly exceeding established guidelines for the minimum reserve level ($1.5 million). A rate analysis should be completed irrespective of any future efforts for broadband expansion.

2. Evaluate the “unserved” areas identified in the Tellus market research report to determine if fiber network extensions are actually required to serve customers in those areas.
   a. Contact the 41 businesses identified as “unserved” in the market research report to determine actual interest in dark fiber service connections.
   b. Evaluate multi-tenant office buildings identified in the market research to determine if pre-connecting them with fiber would generate new dark fiber customers.
   c. Coordinate new customer acquisition efforts with City economic development staff.
   d. Determine if wireless service providers are a potential new market for CPAU dark fiber based on provider needs to use fiber communication links for network backhaul. Initiate exploratory discussions with cellular-tower companies, wireless carriers and distributed antenna system (DAS) vendors through an RFI process.

3. Evaluate CTC recommendations proposed in the Conceptual Plan:
   a. Determine if implementing Phases 1 and 2 would provide a sufficient economic incentive and a viable technical platform for FTTP network builders or wireless service providers to “plug-in” to CPAU infrastructure. Initiate exploratory discussions with network builders and wireless providers through an RFI process. The RFI for FTTP network builders should require the responder to provide an assessment that another facilities-based broadband service provider can acquire enough market share to sustain the capital and operational costs for the network.
   b. Determine if the phased conceptual plan proposed by CTC will provide useful infrastructure to support future City needs related to wireless communication for Smart Grid, mobile broadband service, public safety, and possibly for public access.
   c. Evaluate the feasibility of constructing cellular-towers at some or all of the electric substations. Initiate exploratory discussions with cellular-tower companies and wireless carriers through an RFI process.
RESOURCE IMPACT
The work performed by CTC and Tellus was undertaken at a cost of $50,000 and $18,700, respectively, for a total cost of $68,700.

ATTACHMENTS
C. Glossary of Telecommunication Industry Terms

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1. Executive Summary

This report documents a comprehensive study undertaken by City of Palo Alto Utilities (CPAU) to examine the City’s existing broadband fiber optic network and explore opportunities to expand its current network operations and develop new initiatives that capitalize on the existing infrastructure.

The existing CPAU fiber backbone network is a testimony to the farsighted thinking and creativity of the network planners. Not only does the network fully address the needs of a wide variety of City departments, independent telecommunications providers (“resellers”), local businesses, and other institutions, but it does so in a way that is extremely cost-effective. What’s more, the network provides sufficient transmission capacity, or headroom, to allow each of the user groups to control, operate, and maintain independent networks tailored to address their unique requirements. In contrast, many other municipalities of similar size across the country lack cost-effective high-capacity broadband communications networks. The fiber backbone network is a valuable asset for the City and will continue to be so for many years to come.

At the time the fiber backbone network was planned, in the mid-1990s, broadband network traffic was generally measured in terms of megabits of information; today, the metric of performance is measured in gigabits and beyond. Fiber optic technology is the only viable transmission medium to support this level of traffic. The existing fiber optic cabling infrastructure meets all near-term and projected requirements to support municipal facilities.

In addition to providing broadband interconnection between municipal facilities—a role served by traditional municipal institutional networks (I-Nets)—the CPAU fiber optic cable plant connects major corporations, office parks, and educational campuses throughout the City. This core telecommunications infrastructure for commercial customers has stimulated economic growth and has been one of the critical building blocks that have made the City of Palo Alto a truly high-tech community.

CPAU maintains long-term licensing agreements on portions of the broadband fiber optic transmission plant with a wide variety of commercial clients for purposes of directly addressing this end user group’s unique telecommunications requirements. It is important to note that CPAU comes to the customer with a unique product not normally associated with telecommunications service providers. Specifically, CPAU provides a dark fiber transport service to end users, which enables the end users to tailor internal network configurations that meet the needs of their specific applications. In contrast, traditional telecommunications providers only make available certain products in their repertoire of services; these providers have categorically rejected dark fiber transport services to end users. Under the licensing option with CPAU, end users operate and maintain their own systems in order to address their unique requirements—and, more importantly, they are able to upgrade and modify the system based on their own demand and needs. They are not bound to a specific protocol or data transmission rates, which are the norm in the industry. Further, end users can increase capacity by upgrading their transmission equipment. Under the licensing arrangement with CPAU, end users pay a fixed price for the fiber optic transmission medium, which translates into a fixed cost per access location. The end user pays the same price whether kilobits or gigabits are transferred over the lease period.
Overall, this unique telecommunications service provided by CPAU has to be regarded as a winning strategy. Our recommendations include specific suggestions on how this offering might be improved. These suggestions are not critical in nature; rather, they focus on refining a successful ongoing operation and making a good product even better. The specific recommendations focus on:

- Extending the fiber backbone network footprint closer to commercial and industrial areas that are at a significant distance from network splice points. These distances currently are a barrier to attracting new customers, because bridging them—that is, connecting new customers to the existing CPAU backbone—represents a cost-prohibitive expenditure of several thousand dollars. Many prospective customers (e.g., medium and small businesses) may need the dark fiber plant associated with the current CPAU fee structure, but cannot justify an upfront payment to attach to CPAU.

  Independently of our work, which has focused primarily on engineering issues such as overall network architecture and telecommunications technologies, the City retained Tellus Venture Associates\(^1\) to conduct a preliminary market research study in parallel with the engineering evaluation. The Tellus study supports the need for fiber plant expansion to attract new customers. It defines several candidate areas in the City, beyond the current fiber optic footprint, that appear to offer excellent potential for near-term fiber plant expansion based on the characteristics of the existing projected occupancy.

- Pre-wiring key target-of-opportunity areas that, by their very nature, represent potential economic stimulus to the area (specifically, pre-connecting multi-tenant commercial buildings and office park areas).

- If market research indicates significant new demand for dark fiber service connections in certain commercial or industrial areas of the City, it would be advisable to temporarily expand customer and marketing support staff to assist prospective new users in understanding the benefits of using the CPAU network. This would be advisable assuming that CPAU chooses to move forward with the Tellus recommendations and expand to one or more of the areas targeted.

- If market research indicates significant new demand for dark fiber service connections, it would be advisable to establish long-term contractual relationships with local engineering design and construction contractors that can augment, as needed, CPAU staff to fast-track installation of new fiber plant to rapidly address customer needs.

As part of this study we also examined the practicality and viability of CPAU expanding commercial telecommunications offerings to include new products such as managed networking services (e.g., Ethernet, SONET). Based on our analysis, we have concluded that there multiple, firmly established telecommunications providers that specialize in addressing these types of

\(^1\) Market Research Report, Citywide High-speed Broadband System Project, Tellus Venture Associates, March 2011
services, both locally and nationally. We see no unique opportunity for CPAU here, and believe that, frankly, the likelihood of CPAU capitalizing on this highly competitive market is minimal.

One major impediment is the fact that the CPAU fiber optic plant serves only customers within the Palo Alto city limits. Most end users that need managed network support have requirements for coverage that extends outside the City. CPAU would thus need a partner that could provide a footprint in the outside world. In order to address the managed network services market, CPAU would also have to vastly expand its staff’s networking capability, which no doubt would distract CPAU management from the core utilities activity. Managed network customers expect and generally require 24/7 network oversight from a central network management center. The dark fiber product, on the other hand, consists of infrastructure with maintenance characteristics similar to those of other city utility infrastructure; maintenance of fiber and other utilities is often performed in parallel.) The bottom line here is that CPAU should concentrate on its unique service, the dark fiber transport product.

Our recommendations do, however, include numerous new telecommunications opportunities that focus on capitalizing on existing infrastructure and expanding the presence of the network citywide. Included in this document is a two-phase program that targets the following goals:

- **Phase 1: Formation of broadband telecommunications hubs**
  This is presented as a low-risk expansion initiative focusing on the nine CPAU electrical substations and their use as telecommunications hub sites for the deployment of expanded fiber optic coverage (i.e., to firms providing commercial fiber optic service to end users) and as telecommunications tower sites (i.e., to enable traditional wireless carriers to provide cellular telephone and broadband mobile data services). We estimate that this phase would require a minimum practical budget of $1.7 million to reconfigure fiber optic cable; install enclosures/access facilities that could be leased to commercial wireless and fiber optic carriers; and construct medium-height, 80- to 100-foot wireless antenna mounting facilities. (See Appendix A for cost estimates.)

- **Phase 2: Expanding network access from hub sites to neighborhood access points**
  Phase 2 represents a longer-range, more aggressive strategy of expanding fiber optic coverage to serve nodal or neighborhood areas and address the City’s emerging need to address Smart Grid technology and new wireless technologies, and to provide a platform for the migration of fiber technology and supporting infrastructure deeper into the community. Under this phase a total of $5.0 million would be budgeted to deploy fiber cable to serve 88 nodal areas, each containing approximately 250 residential or commercial subscriber locations. (See Appendix A for cost estimates.) This recommendation assumes that the Phase 1 implementation will be undertaken either prior to or together with Phase 2. The proposed budget for both phases is about $6.7 million.

The strategy laid out in this report builds on the City’s highly successful backbone fiber model, which has shown the promise and the reality of a high-capacity broadband infrastructure in a sophisticated high-tech market. The recommendations focus on expanding on those successes—and capitalizing on emerging opportunities in Smart Grid deployment, expanded wireless mobile services, and high-capacity access for all citizens.
2. History and Operating Strategy of the CPAU Fiber Network

The fiber backbone network was originally conceived in the mid-1990s. The City’s initial telecommunications strategy was to build a dark fiber ring around Palo Alto that would be “capable of supporting multiple network developers and/or service providers with significant growth potential.” The backbone was built in part in response to service providers such as Competitive Local Exchange Carriers (CLECs) that have since ceased to use the backbone. In the mid-1990s, there was also high demand for fiber transport facilities to support the expansion of bandwidth-intensive broadband services. However, these network developers and service providers either built their own fiber infrastructure, licensed fiber from national providers, or left the market altogether. Therefore, the anticipated demand in the original target market proved to be somewhat limited. By the late 1990s there was a glut of available dark fiber in many areas of the country. Nonetheless, it became apparent that a citywide backbone fiber network would be a valuable asset for control and oversight of CPAU facilities and would also support a wide range of broadband voice, data and video telecommunications applications for City government departments, various commercial users, telecommunications service providers, and the community as a whole.

The initial fiber backbone network construction occurred in 1996-1997. The initial portions of the network were constructed in a backbone ring architecture in existing utility rights-of-way; they were routed to pass and provide access to key CPAU facilities and all of the City’s offices. The majority of the City’s business parks and commercial properties are also served by the fiber backbone.

The original fiber backbone network consisted of 33 route miles with 144 or more strands of single-mode fiber along most routes. The fiber backbone has been expanded to approximately 41 route miles of mostly 144- or 288-count single-mode fiber.

The initial network construction was financed internally by the Electric Enterprise Fund through a 20-year, $2 million loan at a 0% interest rate. These funds were used to construct the network and to cover operating expenses. At the end of Fiscal Year 2008, the fiber optics business completed the loan repayment to the Electric Enterprise Fund for all capital and operating expenses from the beginning of the project. A separate Fiber Optics Enterprise Fund, capable of maintaining its own capital and operating budgets and financial operating reserve, was also created. In Fiscal Year 2009, a Fiber Optics Enterprise Fund Rate Stabilization Reserve (RSR) was established. The Fiber Optics Enterprise Fund RSR is projected to be at $9.0 million for Fiscal Year 2011. This level of reserves is above the RSR maximum guideline level of $1.5 million for Fiscal Year 2011.

2.1 Licensing Dark Fiber to Commercial Users

Within a few years of the initial network construction, it became apparent that excess fiber strands within the CPAU fiber optic cable plant had a significant potential commercial market for licensing or lease to organizations outside the City government. Fiber optic cable in itself is not a communications network; rather, it is a passive transmission path from one point to another. When connected to optical electronic transmission devices, it has a tremendous capacity to transport communications traffic in the form of light energy. “Dark fiber,” then, is the name
given to installed fiber optic cable plant that is not carrying a signal (i.e., through which no light is transmitted).

To construct a network that will support modern communications traffic, specialized electronic interface equipment is installed to convert digital signals into optical energy that is exchanged through the fiber from one point to another. Generally, different applications use different interface equipment; for example, interface equipment used by CPAU to monitor substations differs significantly from the equipment used for generic data networks or video transmission. The electronic interface equipment encodes and decodes the applied information signals at each end. It is the interface devices that control the transmission protocol (internal language), the transmission rate (speed), and the oversight (network management) of the network.

Because the network was designed and constructed with significant excess fiber capacity (in the form of discrete fiber strands), CPAU had abundant dark fiber inventory. Also, the only potential competitors in the local dark fiber market are commercial telecommunications companies; those providers have traditionally rejected the concept of licensing dark fiber, choosing instead to sell only managed telecommunications services that allow them to operate the transmission medium and control throughput, protocols and pricing.

In the late 1990s, the City began to license dark fiber to commercial customers, with the businesses responsible for providing and maintaining the electronics equipment needed to “light up” or provision their licensed fiber stands. Licensing fiber optic cable to entities outside the City government has proved to be win-win for CPAU and the business community. Providing dark fiber point-to-point and point-to-multipoint links is the core business model for generating revenue for the network. The individual dark fiber strands within the fiber plant cabling connect a wide range of commercial, public institution, utility, and government facilities within the Palo Alto city limits. Having this fiber backbone in place creates an incentive to businesses and public institutions to locate and expand within the City.

The City currently licenses 173 active dark fiber connections to 68 customers (63 private and five governmental). The City’s competitive construction and monthly access pricing for dark fiber has continued to drive customer growth, with FY 2011 projected annual revenue of $3.3 million, an increase of approximately 10 percent over FY 2010.

Annual gross dark fiber license revenues come from three customer segments:

- City internal telecommunication needs: 27 percent of gross revenues
- Private sector dark fiber resellers: 42 percent of gross revenues
- Private end users: 31 percent of gross revenues

The City licenses dark fiber to 10 resellers, which are telecommunication companies that purchase large amounts of transmission capacity and resell it to smaller end users. The resellers provide broadband services (voice, video, and data) to commercial and residential customers, and in some cases also license dark fiber to other carriers.
Examples of private end users are companies involved in various broadband-intensive businesses such as Web hosting, social media, finance, healthcare, pharmaceuticals, research and development, and software, as well as law firms, consulting firms, and e-commerce firms.

By connecting to the City’s fiber backbone network, customers gain fiber access to their Internet Service Provider (ISP) of choice. A dark fiber customer can interconnect communications systems or computer networks across multiple Palo Alto locations and can also connect directly to their local and/or long-distance carrier(s) of choice with a full range of communications services. Dark fiber customers can also have redundant telecommunication connections for enhanced reliability.

Many of the City’s commercial dark fiber customers gain access to the Internet through the Palo Alto Internet Exchange (PAIX, now known as Equinix). PAIX is a carrier-neutral collocation facility that hosts more than 70 ISPs at its facility in downtown Palo Alto. Equinix has 21 similar facilities in the United States and other collocation facilities in Asia and Europe.

### 2.2 Dark Fiber Service Offerings

The government of the City of Palo Alto is a dark fiber customer of CPAU. The City’s Administrative Services Department (ASD) operates a high-capacity citywide network using the fiber cable to interconnect facilities. The ASD City network provides and supports the electronic interface equipment used to deliver citywide data services. Other City departments operate individual networks to support specialized applications such as utility system monitor and control systems (e.g., SCADA), traffic signals, and point-to-point links. Each of the user groups (e.g., utility, traffic, IT applications) pays a regular license fee for use of the fiber optic cable.

Dark fiber backbone license fees are based on the number of fiber miles leased per month. The base license price is $272.25 per fiber mile, per month; in contrast to traditional leased services from network providers, this is a fixed cost for line use without any usage or traffic volume fees. The fixed-price aspect of a dark fiber license agreement is especially attractive to high-volume users because competitive commercial service providers normally base fees on throughput, either in the form of a defined transmission speed or net number of packet transfers.

The minimum ring access fee is $425 per month. Lateral connection fees are based on the length and type of the lateral (premises-to-backbone), with a minimum fee of $210 per month. The total per project minimum fee is $635. Available configurations include point-to-point and diverse rings.

CPAU will custom-configure fiber optic pathways on the backbone as requested. Customer backbone configurations include:

1. **Point-to-Point**: Directly connect any two points in Palo Alto.

2. **Route-Diverse Ring/Single Drops**: With the proper network equipment, a configuration can be developed to enhance reliability. Two diverse paths are available on the backbone to prevent service interruptions even if the fiber backbone is damaged along one of two paths.
3. **Route-Diverse Ring/Dual Drops:** With the proper equipment, this fiber configuration can be used to further enhance reliability. Two diverse paths are available to prevent service interruptions even if the fiber backbone and/or drop cable are damaged along one of the two paths.

4. **Star Configurations:** This configuration can be used to establish a single location as a hub from which individual point-to-point connections can be made.

5. **Hybrid Configurations:** Options 1 through 4 may also be combined for a customized network solution consisting of a hybrid of the other configuration options.

### 2.3 Future Outlook

There remains a significant amount of unused or unassigned fibers in inventory that is not needed for City government applications or for existing private customers. Thus, the CPAU fiber backbone is optimally positioned to accommodate considerable expansion in network activity and growth in the number of customers throughout the City. Supporting market research will be a critical component in developing a matrix for the expansion of the existing network.

From a cost standpoint, too, the fiber optic cable is an asset that will effectively serve the community for decades to come. Experience indicates that the overall maintenance costs for the fiber are relatively low—and new developments in transmission technology permit ever-growing transmission capacity with overall reductions in cost.
3. Extending the Network Based on Market Demand

3.1 Opportunities and Challenges

While this study has focused on alternatives for developing new customers and providing new services within Palo Alto, the existing CPAU network represents a highly viable ongoing telecommunications service. Not only does the network address the needs of the internal operations of CPAU, but it also provides substantial services to a wide range of City agencies and departments. Those services are provided in a cost-effective manner and in a format that is extremely flexible and permits each user to employ network interface equipment and protocols that clearly satisfy its unique service applications.

In addition to addressing City government needs, the network has also provided alternatives to commercial and institutional customers for which service would otherwise be limited to telephone and broadband cable providers. The dark fiber product supplied by CPAU is unique; while other commercial operators are providing a similar type of service in so-called “dim” or fiber defined optical wavelength services, they are not as readily available or as cost-effective to the end customer. The technique employed in the dim fiber product is wave division multiplexing (WDM). Individual customers license one or more optical wavelengths within a fiber strand over a specific path. In contrast, the CPAU dark fiber provides the customer with the entire optical spectrum of each licensed fiber span. Customers can determine and control all of the optical interface equipment.

On the downside of the equation, the CPAU network service area is restricted to an area within the City boundaries. And, while CPAU continues to expand the fiber footprint, the expansion is generally application driven. That is, additional fiber is only added when a defined customer has a specific application. Often, the addition of the new service is not cost-effective because the new user will, under the current CPAU business plan, by and large bear the brunt of the total costs for new plant construction. In other words, CPAU cost estimates for dark fiber service connections will likely not be competitive with estimates provided by commercial entities such as the local telephone and cable companies, which provide managed broadband service solutions and generally have ubiquitous citywide coverage. Commercial users with high bandwidth needs and who want the flexibility provided by dark fiber will typically agree to pay the one-time cost of new plant construction; however, small and mid-size commercial users who are price sensitive and may not need large amounts of bandwidth will often opt instead for managed commercial services from the telephone or cable TV company, which can offer relatively low installation fees due to their ubiquitous coverage. This is especially true for small and mid-size commercial users whose business locations are at a significant distance from the backbone.

Two specific recent examples of potential customers that have approached CPAU for fiber optic transport service illustrate the nature of the market and the need for a wider network-accessible area to significantly expand the customer base:

1. The Palo Alto Unified School District (PAUSD) approached CPAU about interconnecting 17 schools and the District Office with dark fiber. Based on an advanced engineering study, CPAU determined that construction costs would be
about $425,000—likely making that a cost-prohibitive project relative to licensing dark fiber from Comcast.

As background, PAUSD currently receives its physical connection to the Internet and between school sites and the District Office through dark fiber provided by Comcast as part of an Institutional Network (I-Net). Under Comcast’s franchise agreement, this service has been provided to PAUSD at no charge. On January 1, 2007, however, the Digital Infrastructure and Video Competition Act (DIVCA) of 2006 went into effect in California—permanently changing the state’s franchise and regulatory structure for provisioning Internet and video services. Under DIVCA, Comcast’s obligation to provide an I-Net expired in July 2010, and Comcast has been able to charge for its services since then.

PAUSD has been actively negotiating with Comcast for the past two years to be able to continue using the network. Comcast agreed to continue to provide services to all parties associated with the I-Net at no charge until at least December 2010. PAUSD also issued a request for proposal (RFP) for dark fiber service connections, to which CPAU and Comcast responded in March 2011.

CPAU’s proposal was competitive with Comcast’s proposal in terms of the monthly recurring charges for a dark fiber license agreement. Further, the proposed CPAU design more closely meets PAUSD’s long-term needs and better addresses its concerns about network redundancy and reliability. However, because Comcast’s fiber is already serving the schools through the I-Net, there would be no significant construction costs under Comcast’s proposal.

2. A second opportunity that has been presented involves constructing fiber cable to interconnect a network of distributed antennas to be used for wireless cellular service (i.e., a Distributed Antenna System, or DAS). DAS networks are small, generally utility pole-mounted, short-range cellular antenna systems that provide multi-carrier cellular service to users en route in their vehicles. DAS antenna sites are typically spaced 500 to 1,000 feet apart, interconnected by a fiber strand (either continuous or in some other configuration) and linked by fiber to a base station or central office center. To support this type of application CPAU would be contracted to install additional fiber to connect to the individual distributed antennas and provide a backhaul capability that would network the antennas to one or two central locations. Once again, the lack of fiber coverage in areas where a customer needed service worked against CPAU in attracting new customers. In order for CPAU to offer service in a timely manner at a reasonable cost, the fiber plant footprint needs to be expanded.

Finally another factor hampering expansion of the existing system on a customer-by-customer basis is the fact that CPAU is limited to providing service within the boundaries of the City of Palo Alto. Existing commercial customers again have the advantage of not only having plant in place citywide, but additionally having franchises or authorization to construct and maintain interconnect services outside of Palo Alto.
3.2 Recommendations for Improvement and Next Steps

We recommend that the City continue to expand the plant on a case-by-case basis, as opportunities present themselves—and that consideration be given to the following changes in the current business practices that might not only expand the customer base but also provide for extended infrastructure coverage within the City and new sources of funding for long-term network development:

1. Get the “story” of the CPAU network in front of prospective customers. This includes commercial businesses, public institutions, and other telecommunications providers. A good starting point might be Chamber of Commerce meetings and other similar public forums. Business associations and commercial real estate firms may be another resource.

2. Based on actual market demand, establish additional staffing resources to focus on the broadband initiative with the responsibility to support the construction and implementation of new fiber plant, specifically in the areas of marketing, network expansion design, budget estimating, and licensing support.2

3. Develop a capital expansion funding account to provide capital that will fund the construction of new plant in areas where there is a high potential for providing new services. Specifically we would target residential multi-dwelling units and commercial office facilities. Additionally, the network should expand into new industrial park areas in a similar fashion to the planning and augmentation that takes place in support of CPAU’s power utility expansion work. Finally, where major new projects are being explored such as the school network expansion project or new commercial projects such as pre-wiring multi-tenant buildings with fiber, CPAU should consider utilizing capital funds as part of an in-kind share for expanding plant.

In addition to these independent recommendations and a continued focus on seizing network expansion opportunities as they present themselves, we propose a systematic approach for expanding the existing CPAU network. Our recommendations are divided into two distinct phases. Phase 1 focuses on creating nine core access points at or adjacent to the CPAU substations. A broader Phase 2 initiative would implement 88 access nodes in neighborhoods throughout the City. The following sections provide the details and rationale for our recommendations, along with an analysis of the specific citywide end-user applications—such as fiber-to-the-premises (FTTP), enhanced wireless services, and Smart Grid technologies—that provide a framework for integrating near-term projects into a comprehensive long-range overall strategy.

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2 Expanding staffing might consist of a mix of CPAU full- or part-time positions and on-call contract support (i.e., system engineering, plant design, and construction).
4. Phase 1 Initiative: Leveraging CPAU Infrastructure to Support Broadband Deployment

The CPAU infrastructure includes nine electrical substations dispersed more or less uniformly within the City boundaries. As a part of our study we have examined the feasibility of using the substation properties as fiber optic and wireless access points to expand broadband services within the City. Our analysis confirms there are a number of opportunities to use these facilities in conjunction with the fiber optic backbone network to serve areas around the substations with both fiber optic and wireless services.

We are proposing to establish core distribution centers or hub site to provide access points for wireless and fiber optic transport vendors to interconnect to the CPAU broadband network. Many of the substations are well-positioned geographically and are in commercial settings that are suitable to provide access to broadband fiber optic plant and house terminal wireless antennas needed to provide expanded support to personal, mobile, and fixed locations (residential and commercial).

The nine substations are located within one to 1.5 miles of adjacent substations. The substations are housed in secure, fenced-in open areas (200 feet by 300 feet or larger) containing large transformers, switching equipment, and control buildings. Each of the substations is connected to the fiber optic network directly through a dual-entry backbone ring architecture that produces a highly reliable, failsafe connection.

4.1 Commercial Wireless Services

These sites offer an opportunity for CPAU to support the expansion and introduction of a wide array of wireless services. Under this initiative the substations will be evaluated on a site-by-site basis to determine what modifications might be needed to install one or more self-supporting antenna mast poles within the existing fenced areas or on CPAU land adjacent to the substation.

To be attractive for commercial leasing the antenna masts will need to be at least 75 feet tall to address reasonable coverage requirements; the masts would no doubt be limited in height to 125 feet or less to conform to easement requirements and minimize visual pollution. Under the proposal, the monopoles will need to support multiple users. It is envisioned that each monopole will support numerous wireless services (e.g., paging, cellular, and the multimedia Smartphone) operating in VHF, UHF, and SHF radio bands (typical 150 MHz to 6 GHz).

This Phase 1 initiative has numerous potential benefits that will accrue to residents of the City and to CPAU as the operating authority. The potential benefits include:

1. A readily available inventory of tower locations to support potential carriers in pre-approved sites
2. CPAU backbone fiber in place and available to prospective licensees for backhaul between towers
3. Pre-installed power and equipment housing shelters
4. Revenue to CPAU under long-term licenses for these facilities
While it would be feasible for CPAU to independently undertake this project, we recommend that a partnership arrangement be established with a firm that is experienced in dealing with the tower-leasing portion of the activity. There are numerous firms that specialize in this line of work and maintain close contact with the end-user community (i.e., cellular carriers). We propose the towers (antenna structures) and associated equipment-housing facilities be owned and managed by CPAU, and marketed by the commercial partner. Under this arrangement CPAU would retain full control of the facilities and any construction, while antenna arrangements or system modifications will be coordinated through a single commercial partner. Individual facility designs are to be developed jointly with the partner firm, ensuring that the facilities properly address client user requirements and at the same time comply with safety, security, and aesthetics requirements set by CPAU.

The Federal Communications Commission (FCC) requires that all towers in excess of 200 feet be registered—and owners of shorter towers often voluntarily register their towers to obtain visibility to attract new tenants. A review of the FCC database indicates that there are seven towers registered within about three miles (5 kilometers) of Palo Alto City Hall. These include towers owned or represented by two of the larger national tower leasing firms, American Tower and Crown Castle. All of the registered towers associated with cellular applications are shorter than 200 feet; they range in height from 50 feet to 155 feet.

There will clearly be a need for more towers in and around Palo Alto, in part because new wireless antenna systems associated with WiMAX and 700 MHz cellular deployment are on the horizon as a result of new spectrum being made available by the FCC. Typical monthly lease rates for tower ground space for tower owners to construct in California’s metropolitan areas ranges from $2,000 to $2,700 per month. Assuming that CPAU would own and construct the facilities to the specifications of the tower leasing companies, it is reasonable to assume that revenues would certainly be at the ground space rental rate or greater. Leasing antenna-mounting space on CPAU’s mast poles will be even more attractive because wireless service providers will have the option (at an additional fee) to use the CPAU fiber optic infrastructure to provide the communications link for backhaul within the City.

We recommend that CPAU develop a competitive RFI to solicit an experienced tower leasing company as a partner that can jointly develop a plan for deployment of citywide antenna facilities to support emerging broadband services.

We are aware that an initiative of this type is not without political challenges. This is especially true with regard to the aesthetics of cell towers. Everyone wants to have reliable citywide cell coverage for voice and high-speed data connectivity, but hardly anyone wants a cell tower located next door, or in fact even within the neighborhood. By developing a proactive cell tower placement program within the confines of existing electric substations, CPAU would in effect be blending the common aspects of facilities everyone needs and leveraging the common characteristics of both media. The goal should be to address each substation as an individual entity and develop a site-specific architectural plan that will minimize the visual impact of the cell towers.

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3 Based on a 2007 survey of 32 California communities compiled by the City of Morgan Hill, CA
CTC has more than a decade of experience working with local governments nationwide on cellular towers issues. In making recommendations for CPAU to undertake this tower initiative, we come to the table with a clear understanding that it will not be welcomed by all. On the other hand, we view this approach as both a responsible form of stewardship of CPAU facilities and communications assets, and a reasonable way to address a highly charged urban problem. While there will be challenges implementing this strategy, it is our view that the strategy will address the common goals of minimizing visual impact and providing greatly enhanced wireless services to the community.

In addition to the aesthetic issues, there are other environmental assessment issues that need to be considered as a part of the design and implementation of cellular towers within the confines of the substation properties. The FCC guidelines associated with radio transmission towers includes a list of environmental issues that need to be addressed as a part of the construction of new towers. These include:

- Lighting requirements associated with towers
- Locating towers in or near wildlife preserves
- Potential threats to endangered species
- Areas, districts, buildings, structures, and objects of significant American historical interest, such as facilities listed on the National Register of Historic Places
- Native American religious sites
- Floodplains
- Surface construction that requires significant change in water diversion
- Compliance with established FCC guidelines for electromagnetic exposure (as per OET bulletin 65)\(^4\)

Figure 1 is a map illustrating the locations of the nine electrical substations. Note that the substations are rather uniformly distributed across the City. Each site is connected to the fiber backbone ring. There are currently reserved fiber strands (unused) within the backbone fiber that can be leased to multiple wireless carriers at each site using independent interconnecting networks.

---

Figure 1 includes circles that indicate a one-mile and 1.5-mile radius around each of the substations. This is representative of the distance under which reliable communications could generally be maintained with radio systems operating in the cellular bands. The one-mile circle represents the higher UHF frequencies (1.2 GHz to 2.5 GHz) and the larger, 1.5-mile circles represent the 700 MHz to 900 MHz frequencies. These are gross approximations, because service coverage is dependent on many factors beyond the scope of this document; they are intended to provide the lay reader a scope of the order of magnitude of the service area of short cell towers in a high-foliage urban environment and hence the carriers’ needs for multiple sites in the community.

As illustrated in Figure 1, virtually the entire City can be served in this manner using existing substation facilities. Further, there are other existing facilities and resources (e.g., other City facilities, and poles and structures owned by CPAU) that could be used to fill in coverage, if required, in areas outside the targeted primary coverage areas.

In summary, while this analysis is preliminary in nature, it has been initiated to provide, at a conceptual level, what options CPAU may have to expand its broadband products to wireless service providers. Under such a scenario, CPAU would be in no case responsible for the system engineering design or performance; rather the individual service providers would be drawing on their own knowledge and system requirements in order to form the parameters under which a system would meet their specific needs.
What CPAU brings to the table in a very attractive wireless facilities package is:

- Readily available, cost-effective antenna mounting citywide
- Sites pre-approved by zoning authorities
- A highly reliable, high-capacity backbone to interconnect each site
- Enclosures or leasable space for site terminal equipment
- Ready access to reliable, 24/7 commercial power
- Remote security monitoring of the facilities

**4.2 Smart Grid and Public Safety**

The same facilities that would be available for lease to outside providers could also be used by CPAU as wireless hub collector sites to support communications backhaul links to support Smart Grid applications and implement strategically located hot spots for 4.9 GHz mobile public safety wireless to support officers in the field and video surveillance applications.

CPAU is currently examining the feasibility of implementing Smart Grid technology. A number of emerging Smart Grid technologies employ the use of low-power wireless transmission devices to establish communications between the customer and the power utility control/monitor center. These sites could serve as collector or aggregation points for dedicated wireless links to communicate with individual residences and commercial buildings to support the implementation of emerging Smart Grid technology.5 (A primer prepared by CTC on Smart Grid technology is included as Appendix B to this report.)

In addition to supporting Smart Grid applications, the wireless access hotspots could be used to support high-speed data access to mobile and first responder units using the 4.9 GHz public safety band. This technology supports data rates in excess of 50 Mbps to units in the field operating in licensed spectrum. While the range is generally limited by the high radio frequency (which results in rapid signal degradation) and the low transmission power used, the addition of intermediate access points using radio mesh repeater technology can provide essentially continuous coverage over a relatively large area. High-speed access in the field is useful for rapid exchange of GIS databases and high-quality, real-time video.

**4.3 Phase 1 Implementation Considerations**

We recommend that the City and its leasing partner examine substations individually to design best-fit configurations for siting within each facility. The addition of the telecommunications equipment should not materially affect the facility’s overall appearance or operation.

Wherever possible antenna mounting structures should be configured in a manner such that maintenance personnel associated with the system can access all critical components rapidly and without the assistance or support of CPAU staff. For example, CPAU may require the construction of cabinets or shelters outside existing fences or the subdividing of fenced areas.

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5“Assessment of Smart Grid Applications for City of Palo Alto,” EnerNex Corp., Feb. 2011, recommends the use of wireless backhaul technology to interconnect local AMI networks to a central management/monitoring system.
We estimate that CPAU’s capital upgrades to configure substations to support wireless tenants will range from $150,000 to $250,000 per site. This investment should provide sufficient antenna mounting space to support a minimum of three commercial carriers, and a basic site infrastructure for supporting Smart Grid core hub radio equipment and public safety wireless.

Figure 2, Figure 3, and Figure 4 are photographs of three of the nine substations that are representative of this class of facility. These three stations illustrate how the addition of the wireless access masts might be undertaken with minimal visual impact to the surrounding areas.

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6 Site clients (e.g., other telecom providers, wireless carriers) will have their own site-/application-specific costs.
5. Phase 2 Initiative: Expanding CPAU’s Fiber Optic Footprint

Palo Alto, one of the world’s signature “high-tech” centers, is a logical candidate to invest in new state-of-the-art telecommunications concepts and services. It is a city that is large enough to validate the concepts, yet small enough to minimize the required financial investment. And because of the City’s demographics and its high national visibility, participation among innovative corporations and public interest foundations will likely be high.

This section of the report examines three independent yet interrelated telecommunications initiatives that would leverage and expand the existing CPAU fiber network capacity:

- **Provide an open, vendor-friendly environment for a third-party operator/investor to construct a standards-based citywide fiber-to-the-premises (FTTP) network serving both residential and commercial subscribers, in line with the City Council’s directive to explore the use of the Fiber Optics Fund reserves to independently proceed with a phased build-out of the existing fiber network to achieve the City’s vision of a “universally fiber-connected City.”**

- **Construct fiber to create a fiber-to-the-neighborhood (FTTN) network that would provide an access point to connect neighborhood-area backhaul communications links, lower the barriers for potential FTTP providers, and expand the functionality and the choices of technology that can be implemented for CPAU, including for Smart Grid and public safety.**

- **Provide a neighborhood-based wireless access infrastructure expanding the capabilities initiated under Phase 1 to support neighborhood fiber optic/wireless mesh technology for WiFi, WiMAX, emerging “white space technology,” 4.9 GHz public safety, and low-profile distributed antenna system (DAS) deployment.**

Under this Phase we are proposing to expand the fiber footprint beyond the nine substations to create 88 new nodal access points throughout the City at a cost of approximately $6.7 million. Each node would aim to provide access or connectivity to an average of 250 homes and businesses in the City.

5.1 **Facilitating a Third-Party FTTP Deployment**

There are presently two major terrestrial carriers providing broadband services within the City—Comcast, with a hybrid fiber-coaxial network, and AT&T with a hybrid fiber-wire network (U-Verse); both are experienced operators backed by significant technical and financial resources. They have a strong track record of product development and marketing of broadband services.

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7 “White space” refers to locally unused portions of the broadcast television spectrum, which the FCC has opened up for unlicensed use. See Section 5.3.4.

8 A DAS employs antennas placed atop utility poles approximately every half mile alongside a road to provide coverage to vehicles and to nearby neighborhoods. The antennas generally transmit a usable signal about one-quarter mile. While a DAS cannot provide extensive coverage far from a road, due to the fact that utility poles are generally somewhat lower than towers and monopoles, a DAS can sometimes be an ideal solution to a carrier’s on-street service needs in areas where such extensive coverage is not necessary.
Their entrenched presence represents a formidable obstacle to any new service provider gaining significant market share unless it can rapidly enter the entire citywide market with an enhanced product at a comparable or lower price point for service.

In addition to facing a high level of competition, a new broadband service provider would need to make a significant financial investment. Based on the City’s prior experience in soliciting proposals from private entities, it has been established that an investment of roughly $40 million to $60 million is needed to construct and place into operation a modern FTTP network to serve all of Palo Alto.

As an initial phase (Phase 1, above), we propose a conceptual network plan to dedicate a portion of the City’s existing backbone infrastructure to establish hub access facilities at nine CPAU substations. We believe that this core ring network could create an attractive scenario for a private investor to facilitate the rapid deployment of a citywide FTTP network.

This conceptual approach calls for the City to construct only a small portion of a total FTTP network, with most of the expenditures to be associated with the construction of enclosures and access facilities at the substations. It would also minimize CPAU’s role in FTTP deployment to establishing the network core facilities at the substations and offering in-house staffing resources to support a private operator throughout the building of the fiber optic plant required to link the hub access points to residential and commercial customers. The objective is for the CPAU backbone network to be modified at a minimum of cost to form a magnet to attract an operating company to construct and manage the FTTP system. We see this as a prudent approach in that it will set an FTTP initiative into motion while minimizing the risk of public monies at a time when factors such as the prevailing economic cycle, continued changes in technology, and market entry costs dampen prospects to secure investments for a full FTTP deployment.

We believe that this conceptual design—and Palo Alto’s characteristics—create a framework that will facilitate rapid construction, at predetermined costs, by a third-party operator.

Compared with other cities of similar size, Palo Alto offers a potential fiber network overbuilder significant advantages, including:

- Partnership with CPAU engineering resources to assist in design, licensing, and installation of fiber optic plant required to connect the subscribers to the hub access points
- Rapid network deployment citywide facilitated by the nine existing hub access points
- Ability to place the type of large, intrusive cabinets required for an FTTP network at existing CPAU facilities, minimally impacting the aesthetics of local neighborhoods and remaining in compliance with local zoning requirements

We feel it is appropriate for CPAU to consider this conservative approach to leverage the existing infrastructure for deployment of an FTTP system by a third party. While the existing substation fiber optic ring configuration may not fully address the requirements of all prospective
service providers, the CPAU fiber infrastructure with minor modification can go a long way toward making FTTP a reality. Importantly, configuring the substations to serve as hubs will not involve a major capital outlay. Any upgrade of the facilities to support telecommunications applications should be considered in the context of initiatives into wireless support facilities and future energy management and Smart Grid initiatives that the City may be pursuing.

5.1.1 System-Level Design

As part of our work on this project we examined from a system-level point of view what would make it possible for a future FTTP provider to “plug in” to the CPAU infrastructure to relatively quickly begin serving customers near the initial City fiber optic network, and to minimize or possibly eliminate the need to construct any additional fiber to meet hub requirements. While we have not interacted directly with any potential service providers, performed detailed surveys, or developed business plans for potential private sector service providers, the system-level design has the following attributes for a service provider:

1. The backbone fiber ring and the hub equipment housing facilities would be in place and paid for by CPAU.

2. The provider would have the ability to immediately activate citywide customers in or near the core fiber ring network at up to nine separate locations, providing revenues to offset the cost of the remaining construction on a “day one,” start-up basis.

3. The connection between subscribers and the core fiber network can be implemented with any fiber or wireless technology selected by the service provider.

Figure 5 is a map illustrating the locations of the anchor fiber to the hub access points located at each of the nine substations. An equipment facility will be constructed and maintained at each substation for the purpose of interconnecting the service partner network to the network core.
Figure 6 is a map illustrating how the fiber hub could be interconnected to passive interconnection cabinets and linked to the individual subscribers by the third-party FTTP network. A Phase 2 deployment following the hub implementation for FTTP might piggyback on a Smart Grid deployment under which fiber plant can be installed from the hubs to form distribution areas with access nodes. The nodal points can be used to provide direct connection to subscribers under a FTTP deployment. They can also be used for access points to provide wireless connection to Smart Grid transponder devices.
5.1.2 Fiber Distribution Plant Design Considerations

In order to gain an understanding of the technologies, costs, and construction issues associated with a project of this magnitude, CTC prepared a system-level FTTP design based on a standard Passive Optical Network (PON) architecture. The PON architecture uses the nodal access points to link directly to the business and residential customers. PON avoids the high fiber counts required by Home Run architecture (which comprises a fiber strand to each premises from the hub) and the large, climate-controlled cabinets required in residential neighborhoods by Active Ethernet architecture.

The intent in preparing this model was not to restrict or define the technology—rather we are using PON as a baseline to establish preliminary size and costing data. The technology selected no doubt will focus more on the state-of-the-art at time of construction, the ability to support open network technologies, and naturally the technical preferences of the builder/operator.

The PON architecture used to develop our Phase 1 and 2 cost estimates has the following characteristics:
• No active electronics (and therefore no power or climate control) required in the field beyond the substation hub sites
  o Optical line terminal (OLT) equipment at each hub
  o Optical network terminal (ONT) at subscriber premises
  o 16 to 32 homes served from each hub fiber, with each hub fiber split and combined in a Fiber Distribution Cabinet (FDC) (see Figure 7)
  o FDCs located throughout the City
      § Each serves up to 500 premises (250 average for this estimate)
      § Each measures roughly 4’ x 3’ x 3’ and contains passive (no power) optical splitters
  o Taps located on overhead fiber lines or in small pedestals will connect fiber to two to 12 homes

• Typical speeds per premises of 50 Mbps to 150 Mbps, depending on the details of the design and the services marketed by the provider

• Scalability of capacity to 1 Gbps and beyond using more advanced electronics and DWDM technologies, without the need to augment or modify the fiber

Relative to PON, Active Ethernet is an alternative that may reduce fiber counts within certain segments of the network; however, it requires large cabinets (Figure 8) with power supplies and HVAC equipment to house outdoor electronics to be located throughout the City. A citywide deployment in Palo Alto would require up to 100 of these cabinets, which would raise the project’s installation and equipment costs; locating the cabinets in the field can be difficult, too, particularly in urban environments. The PON architecture also eliminates the need for acquiring external power and maintaining electronics in the field (and thus leads to lower operational and maintenance expenses). Given the size of the cabinets and the potential difficulty in locating these cabinets within the City, we do not foresee Active Ethernet as a viable technology approach for the City.
Figure 7: Fiber Distribution Cabinet at Node (for PON or Smart Grid Deployment)

Figure 8: Fiber Distribution Cabinet (for Active Ethernet)
5.2 Constructing an FTTN Network in Conjunction with Other City Initiatives

This Phase 2 activity would be to construct additional fiber optics into neighborhoods to create a fiber-to-the-neighborhood (FTTN) network. This would involve constructing distribution fibers and fiber distribution cabinets within the City at approximately 88 nodal access points. This approach is significantly more involved than only constructing the fiber optic hubs, but it provides the City with fiber into the neighborhood—and, in turn, provides:

- A greater economic incentive to potential FTTP providers by lowering the barriers and costs of entry into the market
- An expanded footprint of the City’s existing fiber optic network, which could lower the cost of providing CPAU’s existing services to new subscribers
- A base for implementing new City initiatives, including Smart Grid technologies like Advanced Metering Infrastructure (AMI), a public safety wireless network, or WiFi access points

Our recommendation would be that the City should only entertain constructing an FTTN network in conjunction with other planned Smart Grid initiatives that CPAU is planning to implement. Technology advances in AMI and a greater demand for more real-time meter reading is increasing the demand for utility communications further into the neighborhoods. These AMI design requirements are consistent with an FTTN network approach and can be used to justify and offset the costs of an FTTN network. Given that one of the goals of the FTTN network is to support an FTTP architecture, we suggest the FTTN core be built so that each constructed portion of the FTTN core is complete (i.e., no further fiber or cabinets would be needed along those routes as they are converted to the final FTTP network).

The reason for this recommendation is that, below a minimum level of FTTN completeness, converting the FTTN core to FTTP may be, to a private sector company, more trouble than it is worth, and thus may put the City at risk. As a practical matter, making the FTTN core complete means:

1. Starting first with a system-level design of a practical FTTP implementation network, so that the needed fiber count along each street is sized in advance, and the potential locations of cabinets and taps are known. This practical FTTP implementation should take into consideration any planned AMI design as well.

2. Ensuring that each street that is constructed as part of the FTTN core has the fiber count, conduit, and cabinets in place for the completed FTTP network, so that the FTTP completion does not require adding cables, cutting fiber, and reopening streets along constructed routes. (Generally, material costs for larger fiber counts are negligible compared to the potential costs associated with overlashing and overbuilding fiber routes.)
3. Selecting demarcation points in advance, so that the private sector FTTP operator can interface with the FTTN core without redesigning the network.

4. Using standard design architecture, so that the core network is consistent with the business plans and operations of private sector companies already operating FTTP.

5.2.1 Attributes of a Complete FTTN Design

The conceptual complete FTTN design and cost estimate is based on the following assumptions:

- The FTTN is designed to provide a foundation for an FTTP network (shown in Figure 9) that will ultimately reach 20,876 passings (potential subscribers)
  - The design minimizes City investment, yet provides a foundation that substantially reduces market entry barriers for a private FTTP builder and reaches all neighborhoods, avoiding red-lining

- The FTTN identifies the City’s nine substations as hub locations and establishes a redundant fiber backbone ring between them
  - Assumes space is available at each substation property to construct facility outside of the existing substation building (for security reasons)
  - Each hub enclosure area at the substations requires approximately 450 to 600 square feet
  - Each hub must house redundant power, HVAC, and networking equipment
  - Hub sites are connected together through backbone fiber ring
  - Existing CPAU 144- to 288-count fiber cable should be adequate

- A total of 88 FDCs are required
  - One FDC serves on average 250 passings
    - A 24-count fiber from the hub is used to serve each FDC
    - Spare fiber is run to each cabinet for future-proofing (e.g., to enable direct connections to power users and provide connectivity to AMI and other Smart Grid initiatives)
    - This design is consistent with current AMI technologies and can be further subdivided by running additional fiber optics to reduce the number of passings per connection
  - On average there are ten FDCs per hub, netting a total of 88 citywide

- The hub at the substation is the demarcation point between the City’s infrastructure and a commercial FTTP provider. The FTTP provider will extend one fiber strand from the FDC cabinet to every premises (by way of fiber taps), and must install an ONT at each premises as residents sign up for service. This design:
  - Allows the FTTP network provider to add infrastructure as service is required
  - Ensures that adequate access points exist to provide universal coverage

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9 Detailed cost estimates are provided in Appendix A.
We estimate that the cost of constructing the Phase 2 FTTN network throughout the City to be $6.7 million. While the cost of Phase 2 is far less than a total FTTP network it does represent a significant investment towards a city-wide FTTP deployment.

The conceptual FTTP design is shown in Figure 9. The proposed FTTN core network includes the backbone fiber distribution fiber, FDCs, and hubs. The FTTP provider will add OLTs at hubs (not shown), taps, feeder fiber, drop fiber, and ONTs at the premises (ONT not shown).

![Figure 9: FTTP Architecture](image)

### 5.3 Citywide Broadband Wireless Deployment

This portion of the report focuses on the concept of using an expanded CPAU fiber backbone network to support development of new wireless technologies and related services which can be supported as a part of the Phase 2 nodal area expansion concept. Figure 10 illustrates the overall system concept.

Within each of the proposed 88 nodal service area, directly connected intelligent wireless access points are to be constructed to coincide with the fiber infrastructure to support the fiber-to-the-home implementation. These nodal locations will include preplanned facilities for mounting small wireless access units, providing power, and, if required, mounting facilities for covert antennas. Depending on the wireless technology employed by the wireless provider it may be necessary to include additional wireless access points beyond the planned fiber nodes in order to provide reliable coverage. These additional units will communicate with the fiber-connected access points through an internal mesh communications wireless infrastructure. The number and location of the mesh-connected access points will depend on a number of factors, including the operational radio bands, power levels, and data rates. The plan is for a wireless access support capability that can provide universal coverage to both vehicles and in-building users. An
important factor to be considered in planning the Palo Alto design is the high density of foliage in residential areas. The high concentration of trees along with the high signal attenuation of buildings, particularly in the frequency range above 1 GHz, limit the overall range for wireless equipment, particularly when deployed to support high data transfer rates.

As illustrated in Figure 10, the nodal access points serve a dual purpose. They provide access to the fiber network for applications such as FTTP and Smart Grid technologies. They also connect to the fiber as the backhaul mechanism for wireless network implementation.

![Figure 10: Nodal Area Configured to Support Wireless Technology](image)

5.3.1 Wireless Spectrum Availability

The availability of spectrum within the various wireless network frequency bands will have a significant impact on the level and degree to which enhanced wireless is deployed within Palo Alto using the CPAU fiber backbone. The FCC, which has the authority to define the segmentation of radio frequency (RF) spectrum in the United States, coordinates the allocation of frequency bands to provide equitable distribution of spectrum resources. The FCC defines the technical parameters for use within each frequency allocation, and licenses users and wireless equipment manufacturers accordingly. Most frequencies require the user to obtain an FCC license to operate within the particular spectrum, though the FCC has set aside certain frequency bands for unlicensed operation by anyone using devices that meet FCC requirements (e.g., RF emission limits, antenna gain, height, etc.) for that particular band. Figure 11 provides a simplified overview of several common frequency bands, user groups, and applications.
Figure 11: RF Spectrum Overview
5.3.2 Licensed Versus Unlicensed Spectrum

Compared to unlicensed technologies, networks using licensed frequencies are typically permitted to operate at higher power levels and, accordingly, cover greater service areas. The licensee “acquires the right” to operate or serve a given area, and secures a defined level of protection from other users operating in the same geographic area. The FCC licensing process normally requires prospective users to file an application, often requiring an engineering study to demonstrate compliance with all FCC licensing requirements. Licenses are available to the general public, businesses, broadcasters, utilities, local and state governments, and wireless telephone carriers. Federal government spectrum allocation is coordinated with the FCC.

Wireless access devices authorized for use in unlicensed frequencies must typically operate at relatively low RF power so that many users and devices can “reuse” the same frequencies without causing mutual interference. A variety of consumer-oriented devices use unlicensed spectrum, including cordless phones, baby monitors, garage door openers, and WiFi access points, all of which are intended for short-range transmission in the immediate vicinity of the user. The unlicensed frequencies are public, and no single person or entity owns the exclusive right to use them. Therefore, users of unlicensed spectrum must accept all interference they encounter. Users of unlicensed spectrum have limited ability to solve problems caused by interference from other authorized users of the spectrum.

Unlicensed wireless devices can be set up immediately, by anyone, and deployed without site planning or engineering. As a result, the cost of deployment and time to deploy is significantly lower than for licensed communications. However, the range and performance of each device is limited by power restrictions and by interference with other nearby users of the spectrum. In the City of Palo Alto, unlicensed frequency users might include residents and businesses, such as coffee shops and restaurants offering commercial WiFi services.

5.3.3 Licensed Spectrum Available to Government and Public Users

As a governmental entity providing municipal utility (CPAU), public safety, and other day-to-day services, the City of Palo Alto is eligible to use a wide range of licensed spectrum.10 Options exist to operate in the following radio bands:

- VHF11 (150 MHz band) for land mobile radio and AMI;
- VHF 220 MHz band for AMI;
- UHF12 (450-470 MHz band) for land mobile radio and AMI; and
- UHF (700-950) MHz band for public safety land mobile radio and AMI
  - GHz public safety band for broadband public safety applications

The narrowband13 channels in the VHF and UHF bands listed above for two-way services can be used for a variety of applications, including mobile voice communications, paging, and data communications up to 19.2 kbps.

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10 For more details see Federal Communication Rules and Regulations Part 90, 47 C.F.R.
11 Very High Frequency (VHF) refers to the 30 to 300 MHz spectrum of the electromagnetic spectrum
12 Ultra High Frequency (UHF) refers to the 300 to 3,000 MHz spectrum of the electromagnetic spectrum
13 GHz refers to the 3,000 to 30,000 MHz spectrum of the electromagnetic spectrum
The AMI vendors (Smart Grid communications infrastructure) can operate on a wide range of licensed narrowband channels in the VHF and UHF bands.

The 4.9 GHz spectrum has been allocated to the public safety community and is available for licensing to a rather broadly defined list of public safety and related organizations. The 4.9 GHz spectrum was developed to provide licensed WiFi-like broadband services.

5.3.4 White Space Technology (Unlicensed Television Band Devices)
On September 23, 2010 the FCC adopted rules for the operation of unlicensed equipment within the TV broadcast bands. In the Second Memorandum Opinion and Order the Commission set standards and procedures for permitting a new service of unlicensed wireless devices (so-called TV band devices, or TVBD) to operate in the unused portions of the UHF and VHF television broadcast spectrum. The availability of spectrum for this service is highly market dependent. In markets with a larger number of operational broadcast stations, available spectrum for this application is more limited than in rural areas with fewer off-air TV channels. The FCC defines these channels that are not locally in use as “white spaces” or locally unused spectrum.

In order to minimize the potential for interference to licensed broadcast services and other unlicensed devices (e.g., wireless microphones), the TVBD units must have certain interference-avoidance capabilities. Specifically, TVBD devices will be restricted in operation to authorized candidate white space channels based on geographic location of the device. Moreover, transmission power limitations set for TVBDs is similar to those required for WiFi hardware, with an additional restriction placed on mobile devices limiting transmission power to 100 mW.

“White space” equipment is anticipated to be available for implementation in the last quarter of 2012. Subject to local spectrum, this technology could conceivably permit the implementation of a new generation of WiFi network supporting 160 Mbps to 300 Mbps data transfer rates. Firms such as Dell and Google have been strong proponents in developing this emerging technology.

5.3.5 Licensed 4.9 GHz Public Safety Wireless
The FCC assigned a band at 4.9 GHz for local government public safety applications. The FCC rules provide for 50 MHz of total contiguous spectrum, with up to 18 overlapping channels and maximum channel widths of 20 MHz. Additionally, the rules specify transmission power limitations and emissions requirements similar to those for WiFi standards. However, most of the equipment manufacturers use proprietary protocols, which hinder interoperability and multivendor sourcing.

Unlike unlicensed WiFi, 4.9 GHz can only be used by (i.e., licensed to) entities performing public safety functions. It is not susceptible to interference from a wide range of consumer devices. However, it is possible within a given region for interference to occur among public

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13 Typical channels with a limited bandwidth of 30 kHz less limited to a single voice channel or data rates of 19.2 kbps or less
safety entities having overlapping jurisdictions, for which a certain degree of regional coordination might be necessary if specific areas of interference occur.

Interference can be minimized through coordination of channel assignments and radiation control with neighboring communities.

Several major vendors of WiFi hardware also manufacture equipment for the 4.9 GHz band. Consequently, these products offer similar operational features and capabilities as commercial unlicensed WiFi, from supported security mechanisms to capacity. Like WiFi, most 4.9 GHz systems operate at speeds up to 54 Mbps, and can often be used interchangeably within hardware platforms supporting radios for WiFi bands.

The 4.9 GHz technology uses small antennas and base stations that can be mounted with the same level of effort as WiFi hardware, and often using multi-radio hardware capable of supporting both. Most 4.9 GHz radios offer the flexibility of serving non-public safety users by also operating at 2.4 GHz and other unlicensed bands with modular upgrades. With a clear line-of-sight, it is possible to provide speeds up to 54 Mbps, which meets the needs of video applications and future applications, such as transfer of large data files, maps, police records, and missing person images.

4.9 GHz WiMax-compliant technology is also available, and may offer certain benefits for critical quality of service (QoS) applications.

4.9 GHz equipment is readily available, therefore there is low risk related to delivery and ongoing support. Equipment from multiple manufacturers can work simultaneously on the same network, although some proprietary features may be limited to equipment from the same manufacturer.
6. Energy Management

The 88 nodes proposed as part of the Phase 2 implementation would provide CPAU with a wide range of options on using the fiber backhaul to communicate with AMI equipment in residential and commercial buildings. Appendix B to this report includes a number of AMI backhaul options that either have been implemented or are being proposed by various vendors. Assuming Phase 2 is implemented within Palo Alto, CPAU will have the option of supporting AMI backhaul through:

1. Wireless LAN technology from AMI collector points to the nine substation hubs
2. Using the 88 node locations as collector points for internal AMI–900 MHz network access
3. Direct connection to residential and commercial buildings through fiber drops

15 Strategy advanced in the EnerNex report
16 Assumes that fiber-to-the-premise becomes a reality
Appendix A:

Cost Estimates
### Appendix A1: Phase 1 - Hub Construction Cost Estimates

#### Hub Facility Costs

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<th>Description</th>
<th>Cost</th>
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<td>Estimated Square Footage Required</td>
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<td>Facility Modifications and/or Construction</td>
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<td>Splicing, Equipment Racks, and Cabling Management per hub</td>
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<td>Hub Facility Costs</td>
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<td>Number of Hubs</td>
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**Total Hub Construction Costs**: $1,035,000

#### Additional Costs

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<td>Construction of a 100’ Self Supporting Tower</td>
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<td>Tower installation costs for all hub sites</td>
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**Potential Total Hub Investment**: $1,710,000
Appendix A2: Phase 2 - Fiber to the Neighborhood Construction Cost Estimates

**Assumptions**

- 9 Hubs in the city
- 24 Count fiber from hub site to node
- 4,000 Average footage to hub site per node (FDC)
- 3 Nodes per service area
- 29 Service areas in the City
- $7,000 Cost of passive node
- $52,610 Average cost per mile of fiber construction to node

**Budgetary Cost Summary**

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<th>Description</th>
<th>Notes</th>
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<td>$885,741</td>
<td>Make Ready for Node Placement</td>
<td>Does not include tree trimming, street cut fees, or contingencies.</td>
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<td>$3,467,468</td>
<td>Total FTTP Design Cost Estimate</td>
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<td>$609,000</td>
<td>Cost of node placement in City</td>
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<td>$1,710,000</td>
<td>Cost From Phase 1</td>
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<tr>
<td>$6,672,209</td>
<td><strong>Budgetary estimate of construction costs to the node within the city</strong></td>
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Appendix B: Advanced Metering Infrastructure (AMI) Technology Primer
1. Executive Summary

“Smart Grid” and Advanced Metering Infrastructure (AMI) are recently defined terms, but there is now a common understanding of the evolving technologies among stakeholders. Equipment manufacturers are developing increasingly capable equipment and leading-edge utilities are achieving workable results with their implementations of millions of meters.

The definition of Smart Grid contained in the Energy Independence and Security Act of 2007 indicate that today’s AMI implementations will be the foundation of future Smart Grid implementations, and must therefore either be highly scalable, or easily replaced by second-generation equipment.

CTC has performed a wide range of work within the AMI industry including analysis and evaluations of the equipment of various AMI manufacturers. CTC’s analysis covers a range of technologies, each with its respective strengths and weaknesses.

Our research has found that AMI infrastructure can be categorized based on four primary architectures: Power Line Communications (PLC), Radio Frequency (RF) communications, Broadband over Power Line (BPL) communications, and Fiber-to-the-Premises (FTTP). Use of a customer’s broadband connection is a fifth architecture that offers extremely high capacity, but also presents significant disadvantages and limitations.
2. Introduction

Smart Grid and Advanced Metering Infrastructure (AMI) technologies are now in an intermediate stage of evolution. While both Smart Grid and AMI are newly defined terms, there is now a common understanding among utilities and stakeholders of what is expected from the technologies. Leading-edge utilities are implementing the technologies and are achieving workable results. Implementations are now taking place with millions of meters, and the AMI technology itself is progressing beyond the pilot stage.

Examples of maturity in the industry include the diversity of manufacturers and common expectations of the functionality of AMI, including daily reading of data with hourly granularity, compliance with preliminary security standards, and the ability to perform direct load control (DLC) and distribution automation (DA) functions with the same platform. Other common characteristics that are emerging include the increasing physical integration of the AMI communications functionality into the meter; the use of standardized ZigBee technology for communications with appliances, thermostats, and home displays; the use of a separate utility-operated network to connect with the meters; and the increasing dominance of wireless technology as a transport medium.

However, there are several key areas where the AMI industry is still developing, some of which are listed below:

- All AMI communications systems are proprietary to their specific manufacturers, both in their overall architecture and in their lack of interoperability with the equipment of other manufacturers. AMI interoperability standards are in their early stages of development relative to cellular, telephone, fiber optics, local area network, and cable TV technologies.

- The utility industry, manufacturers, and the National Institute of Standards and Technology (NIST) are in the process of developing a roadmap and framework that will include protocols and standards, allowing interoperability between the AMI devices and systems. At the conclusion of the first phase of this process, NIST released the *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0* identifying applicable standards and a reference model for the Smart Grid.

- ZigBee technology, identified for home area networking (HAN) connections to appliances, thermostats, and home displays, has not been unanimously adopted by manufacturers and is still in the formative stages.

- To date, there is no clear technological roadmap for the communications and processing demands of Smart Grid and AMI implementations. It is not clear how many times meters will need to be read, what granularity of information will eventually be needed, and what other functionality will be required for future developments, which will include distributed generation, plug-in vehicles, increasing energy prices, and cap-and-trade requirements.
The research and analysis performed by CTC has revealed a range of technologies, as shown in the figure below. These include PLC equipment (Type 7) that communicate through existing power lines, but are limited in their capacity and scalability and are already insufficient for daily system-wide reads of hourly information. At the high-speed end of the spectrum are fiber-to-the-premises (FTTP) (Type 1) and Broadband over Power Line (BPL) communications (Type 2), which have sufficient capacity to support all conceivable Smart Grid and AMI needs, as well as providing the ability to provide broadband data, video, and voice services. However, implementing either of these technologies requires the installation of high-cost infrastructure which needs considerations of benefits beyond AMI to justify.
We have also found equipment with an intermediate level of capacity that primarily uses wireless, or radio frequency (RF) communications. RF communications includes point (hub or node)-to-multipoint communications resembling cellular services, with large base stations communicating with each meter (Type 3); mesh communications using unlicensed frequencies within neighborhoods to hop between small radios and meters (Type 4); and hybrids of the two technologies (Types 5 and 6). RF equipment is significantly less expensive than FTTP or BPL, and has significantly more capacity than PLC. The figure below depicts the relative data-handling capacity of the various AMI architectures.
Appendix B

Region A represents the percentage of meter data that can be accommodated by a slow-speed solution such as power line communications technologies and simple RF networks. At these low data capacities, fewer meters in the installed base can be read if the reading frequency is increased, say to four times per hour. Region C represents the high-capacity, fiber-based broadband solutions, in which fiber is brought into, or near, customers’ homes. These technologies are best able to accommodate the higher data flows of several meters being read multiple times per hour.

Advanced wireless AMI architectures are represented by Region B. The capacity of these technologies is intermediate, between that of slow-speed power line technologies and that of fiber-based solutions. More meter data from a greater fraction of installed meters can be accommodated by wireless technologies than by power line technologies.
3. AMI and Smart Grid Defined

Advanced Metering Infrastructure (AMI) is a subset of the Smart Grid concept. Although the utility industry does not have a consensus on a single, ubiquitous definition for “AMI,” typical system attributes might include:

- A minimum of hourly meter reads delivered one time per day.
- Non-discriminatory access for retail electric suppliers and curtailment service providers to meter data and demand response control functions that is equivalent to the electric company’s own access to those functions.
- AMI shall be implemented for all customers of the electric company.
- Metering and meter data management (MDM) should generally continue to be an electric company function, including the implementation of AMI/MDM. Metering and data management options may be considered for larger non-residential customers (this does not exclude any customers from a requirement that their AMI shall at a minimum be fully consistent with all AMI standards). For example, if an industrial or commercial customer (and its retail supplier of CSP) requires more frequent meter reads or downloads, the utility shall work in good faith to accommodate such requirements for meters such as:
  - Ability to monitor voltage at each meter and report the data in a manner that allows the utility to react to the information.
  - Remote programming capability.
  - Two-way communications capability.
  - Time-stamp capability.
  - A minimum of 15 or more days’ of data storage capability on the meter.
  - Communicate outages and restorations.
  - Capable of net metering and bi-directional metering.

Additionally, a proposed definition for “Smart Grid” is also provided in the Energy Independence and Security Act (EISA) of 2007:

“Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid… [d]evelopment and incorporation of demand response, demand-side resources, and energy-efficiency resources… [d]eployment of ‘smart’ technologies… for metering, communications concerning grid operations and status, and distribution automation.”

Taken together, both definitions require an evolving utility grid for an AMI to be deployed. Initial AMI deployments will need to serve as the basis for the future Smart Grid infrastructure contemplated for the utility’s service areas. Therefore, the deployed equipment should be scalable for these requirements—or the industry must consider a shorter lifespan for this first round of AMI infrastructure, with replacement (i.e., installation of a second generation of equipment) as new needs emerge.

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17 Energy Independence and Security Act (P.L. 110-140, H.R. 6)
This primer describes the AMI approaches that are currently available within the industry. It also discusses the wide variety of hardware and software elements related to these approaches, and the advantages and limitations of each.

AMI networks comprise several components (see figure below):

- An electronic meter located on the customers’ premises;
- A home area network (HAN) connecting the meter, home appliances, thermostats, and home displays;
- An AMI communications device attached to the meter (a module typically installed in the meter by the meter manufacturer);
- A local area network (LAN) connecting the AMI communications device to the AMI communications system;
- Depending on the choice of architecture:
  - An intermediate network connecting LAN access points or collector devices to a backhaul network, or
  - A high-capacity, high-availability backhaul network, often passing through utility substations and other facilities and the network headend or network operations center; and
  - A Meter Data Management System (MDMS) and other associated software systems, to receive and analyze data from each meter.
4. Principal AMI Technologies

Several technologies can be used to provide AMI capabilities. As discussed below, the three principal approaches are Power Line Communications (PLC), Radio Frequency (RF) communications, and Broadband over Power Line (BPL) communications. (There is currently no major manufacturer of FTTP technology specifically for AMI.\textsuperscript{18} Even utilities that operate FTTP systems to provide communications services do not connect directly to all meters with their fiber optics, because of the high cost of making those connections and the unavailability of suitable equipment.)

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Each of these categories and sub-categories is described in detail in the following sections.

**Power Line Communications (PLC) (Type 7)**

The principal advantage of PLC technology is that it is the simplest to implement, in that no additional antennas or cables need to be constructed. The technology uses the existing power line wires as the communications channel. However, it has the lowest data rates of any existing AMI technology. Equipment is required at the customer premises (AMI communications system in a “smart” meter) and at the serving substation (signal injector on the high-voltage distribution line).

By inserting data directly onto the service drop wires, it is possible to send a few bits of digital data (ones and zeroes) with each cycle of the 60 Hertz (Hz) power line. Because the data is sent at power line frequencies it can pass through obstructions like distribution power transformers with very little signal loss. The data signal also experiences very little loss as it travels along the

\textsuperscript{18} Tantalus offers a FTTP based access point that collects information from meters comprising a mesh radio network.
power line between the meter and the MDMS. On the other hand, the data stream is very slow; data rates are usually under 100 bits per second. (As a reference, dial-up Internet access can support data rates up to 42,000 bits per second.)

Obviously, only limited data transmission can be accommodated with this form of power line carrier technology. For example, if a power usage table or other desired information is 500 bytes (4,000 bits) of information, it would require approximately one minute to read each meter. Using this technology, it would then require 10 hours to read 600 meters. Moreover, the scalability of the technology is limited, as multiple channels are not available on the power lines, and the power grid is not readily divided into separate segmented service areas. Reads are usually conducted from communications equipment at the substations, connecting relatively large numbers of customers over each connection.

Although PLC has significant limitations, it has proven to be adequate for some electric utilities. PLC equipment has many of the features available in higher-speed RF equipment, including support for control of distribution automation equipment, voltage monitoring, remote programming, and time-stamp capability.

Higher-speed communications requires transmission at higher frequencies; however, these frequencies are filtered by transformers and require equipment to bypass the transformers. When transformer bypass is incorporated, the architecture becomes Broadband over Power Line (BPL, Type 2), described below.

**RF Technology**

In general, RF-based AMI technologies offer utilities greater data rates than PLC technologies. They do not connect to the high-voltage power lines, so no interface devices are required to bypass the pole-mounted transformers. However, RF technologies require connecting radio receivers and transmitters to each meter. They require construction, or leverage, of a market-covering radio network, either between smart meters at customer premises or between the meters and a nearby pole-mounted antenna or radio tower. Also, interference from other users that share radio frequencies with AMI can potentially be disruptive of AMI operation.

RF AMI technologies typically include an AMI module with a complete wireless transmitter and receiver, on a separate card or module mounted inside the smart meter. This module can be installed by the meter manufacturer and shipped to the utility to install the module inside the meter. Communications can be over a wide range of speeds and architectures, from high-speed broadband communications connecting a single tower to thousands of meters simultaneously (comparable to a cellular system), to a mesh providing lower speeds but hundreds of potential pathways and RF channels from each meter to the utility.

**Licensed and Unlicensed Frequencies**

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19 Some PLC vendors collect information sequentially (one meter at a time); others (Hunt Technologies) can record incoming information from a few thousand meters simultaneously.
RF AMI technologies use licensed and unlicensed communications. Licensed communications refers to frequencies or channels that are specifically assigned and licensed by the Federal Communications Commission (FCC) to a particular user or for particular purpose. The FCC also stipulates the maximum power that may be transmitted by a device operating in the respective licensed or unlicensed frequencies. The possibility of interference for a licensed channel(s) is extremely low. Therefore, the utility can expect to be able to utilize its radio channel to the fullest, and not experience network slowdown or disruptions due to an interfering radio signal. Also higher power levels are permitted for transmitters operating in the licensed frequencies as compared to those operating in the unlicensed frequencies. A licensed transmitter acting as a collector device or an access point (as mentioned in Section 3 above), once installed at a location, will thus provide coverage to a wider geographical region, and as a result, fewer licensed transmitters are required to provide the requisite radio coverage for a given area. However, these access points or collector devices are generally mounted on towers or monopoles in visible locations, and may require special siting and permitting arrangements. Further, the placement of these access points or collectors and their required numbers will also depend on the terrain of the area serviced by the utility (such as rural areas with a lot of foliage, urban areas containing tall buildings, etc.).

Examples of such transmitters include cellular or paging communications (licensed to the operating company), point-to-point microwave communications, and television and radio broadcasters. The FCC has the authority to grant radio operating licenses in certain bands to qualified entities such as electric utilities. Most licensed frequencies specifically for AMI are found on discrete channels within the 220 MHz, 450–470 MHz, and 900–950 MHz bands. A utility may select an AMI technology that requires cellular or broadband connectivity from a commercial wireless service provider; these systems operate in the 800–940 MHz, 1900 MHz, and 2500–2700 MHz bands.

In addition, the FCC has established bands of radio frequencies in which unlicensed radio transmitters may operate with restrictions on the transmitted power as well as the antennas. The power on unlicensed transmitter is restricted to minimize the likelihood of interference to other devices that might be sharing the same unlicensed radio channel. Thus, unlicensed radios have a reduced range as compared to licensed radios that may operate at significantly greater transmit power levels.

An unlicensed transmitter is required to share the radio frequency with a potentially unlimited number of additional transmitters in a given area, including cordless telephones, wireless intercoms, and home wireless computer networks. Interference is possible in these instances and the utility’s AMI operation could be adversely affected by such interference.

The main advantages to using an unlicensed frequency are that the spectrum is readily available, and that the transmitting equipment is relatively inexpensive. High consumer demand for appliances such as cordless telephones, nursery monitors, and WiFi cards for laptop computers has reduced prices for this technology, and AMI equipment designers have exploited this cost savings.
Appendix B

Radio Frequency Characteristics
AMI network equipment may be designed to operate within several frequency bands. These bands are located at approximately 220 MHz (VHF), 450–470 MHz, 900–960 MHz, 2400 MHz (UHF), 5300 MHz, and 5800 MHz (SHF). Each of these bands has certain advantages and disadvantages. The selection of frequency bands for AMI operation depends to a great extent upon the choice of vendor equipment, because not all vendors offer equipment in all radio bands.

In general, the lower the frequency, the greater the range, or distance of acceptable performance, over which the radio device will operate. All other things being equal, for example, a transmitter operating at 450 MHz will be able to reach receivers farther away than transmitters operating at 960 MHz or higher frequencies. It is possible, though, to increase the range of higher-frequency transmitters by using gain antennas at one or both ends of the radio link. However, this might not always be possible, especially if the transmitter, receiver, and antenna must also be mounted inside a standard meter enclosure.

In addition to differences in range, radio signals operating at different frequencies are also affected differently by obstructions. The lower frequencies are better able to “fill in” the areas behind buildings and hills than are higher frequencies. Lower frequencies also are better able to pass through forested areas and shrubbery without much loss of signal as compared to higher frequencies. This is especially important for an AMI meter that might be mounted on the side of a house behind ornamental bushes or facing away from the utility’s collection point. A meter operating at a higher frequency will have greater difficulty being heard by its corresponding collection point when operating from one of these locations.

Higher-frequency radio signals have more difficulty penetrating into buildings than do lower-frequency signals. For this reason, 900 MHz band communications may be better-suited to reach meters that are located in basements and other subterranean locations than 2.4 GHz communications. ZigBee home area networking, proposed by manufacturers to connect meters with appliances, thermostats, and home displays, typically operates in the 2.4 GHz band—so one challenge will be to verify that ZigBee is able to adequately communicate with the meters through buildings, and operate effectively despite the interference from Wi-Fi and other unlicensed devices in most homes and businesses.

Star or Point-To-Multipoint RF Architecture (Type 3)
In a star or point-to-multipoint (P-MP) AMI architecture, each electronic meter directly communicates, via a radio, with its corresponding collection point, such as a tower or distribution pole. Some of the manufacturers using this architecture are Aclara, GE, and SmartSynch.

This architecture most closely resembles a cellular or paging system. For example, during the course of CTC’s research and work in AMI, we found that GE and SmartSynch may use commercial wireless communications operated by a separate commercial carrier.

An advantage of this configuration is that the network is designed for each meter to have a dedicated connection from the base station to the collection point, which reduces the maximum latency, or delay, in the reading of the meters. Although in theory this would mean that special
reads of meters can be accomplished more quickly than can be using other architectures, CTC’s vendor research within the AMI industry has shown that comparing metrics such as “time taken for a special read” does not show any appreciable difference between the point-to-multipoint and mesh architectures. This is perhaps an indication that hardware and software performance as well as other factors play a more critical role.

A disadvantage of the point-to-multipoint architecture is that the signal travelling to and from the meter must be strong enough, to reach its end point, without having to use any intermediate relays. As is the case with cellular networks, this architecture also may contain “dead spots”—areas with poor or nonexistent service, typically in low-lying or remote areas. Some meters may be on the side of the house that faces away from the utility’s antenna, too. Thus the signal received by the AMI meter or at the collection point will be weaker. In some meter locations there may be insufficient signal strength for the meter to function at all.

**Meter-to-Meter Mesh (Type 4)**

In a meter-to-meter mesh AMI system, all utility meters establish communications with the neighboring meters and automatically generate paths from each meter to the utility headend. The meters in a mesh network pass information through “hops”, that is through paths from one meter to another meter till the information can finally reach a collector radio, which is connected to the backhaul network.20 For example, during the course of CTC’s research and work in AMI, we found that Itron and Silver Spring Networks use this architecture.

The advantage of this architecture is that meter communications do not rely on a single path or component. In effect, there are multiple paths for each meter to reach the nearest collector radio, or to any other collector radio. Because meters are likely to be close to each other, low-power radio transmitters can be used in unlicensed communications bands, with all of the corresponding cost benefits and simplification.

One disadvantage of mesh architectures is the potential latency, or delay in processing, of end-device data. The data from each AMI meter must be forwarded from one device to another before it reaches the local collection point at a tower or utility pole. However, as can be seen from CTC’s research special reads can be accomplished in 30 or 60 seconds (depending on the manufacturer), which is comparable to the point-to-multipoint RF technology. As mentioned earlier, other factors in the systems, such as hardware, software, and design, apparently have a greater effect than architecture in terms of latency.

**Combination RF Architectures (Types 5 and 6)**

Some manufacturers offer RF-based AMI solutions that are combinations of point-to-multipoint and mesh. For example, the solution might use mesh architecture among the collectors on the utility pole tops throughout the served neighborhood, while employing P-MP architecture to connect each pole-top collector to the meters it serves (Type 5). As revealed by CTC’s research and work in the AMI industry, this architecture, called the “Pole Top-to-Pole Top Mesh,” is used

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20 Or, alternatively, to an intermediate backbone network, which is in turn connected to a backhaul network. The intermediate network may be a cellular network, a point-to-point wireless network. The backhaul is typically a fiber optic network.
by Trilliant. The advantage of this architecture is that the pole-top mesh network provides the redundancy benefits of mesh in the intermediate network (between the local area network and the backhaul) while the P-MP network between the collectors and the meters ensures low latency. This architecture provides the lowest reported time for a special read—approximately two seconds.

The Layered Point-to-Multipoint architecture (Type 6) uses two separate layers of cellular-like communications, one for the local area network to the meters and one for the intermediate network between the local network and the backhaul.

**Broadband over Power Line (BPL) (Type 2)**

BPL offers high-speed data service of several megabits per second, but at a considerably higher cost than lower-frequency PLC technology. BPL is also considerably more complex, requiring additional hardware along the distribution lines in addition to equipment at the ends, but can accommodate other services such as voice, video, and Internet access in addition to AMI.

During the course of CTC’s research and work in the AMI industry, we found that manufacturers using this architecture include Current Technologies and MainNet. As with PLC technology, BPL uses the existing power line wires as the physical medium to carry data signals. However, the higher carrier frequency used in BPL architectures provides more capacity than do the PLC systems. Depending on the specific manufacturer, BPL’s carrier frequency stretches from approximately 1.7 MHz to 80 MHz. This span covers the parts of the RF spectrum that are commonly known as shortwave or lower VHF. Expected data rates for BPL systems are in the multi-megabits-per-second range.

High-frequency BPL signals cannot pass through distribution transformers. As a result, additional components are required to allow the BPL carrier signal to bypass the distribution transformer outside the home or business. From the low-voltage side of the transformer the data signal can be brought into or out of the home or business via the service drop wires.

Some implementations of BPL include power line access to intelligent appliance controllers inside the home or business. In this manner the home or business can use its inside wiring as a network to connect computers and access the Internet, as well as to control appliances and lights.

One major drawback with BPL technology is that since the distribution wires are long enough to act as antennas, the shortwave and VHF signals can “leak” out of the system and cause interference to other radio services. However, manufacturers and utility operators are working towards addressing this problem by using a range of options, including “notching” out the frequencies that must be avoided (e.g., frequencies used by amateur radio operators).

A second drawback with this technology is that BPL signals lose strength rapidly as they traverse the power lines. Therefore, boosters must be installed at regular intervals on the power lines to restore the signals.

A third drawback is that, as with PLC, installation of these devices on the utility distribution facilities must be done by skilled power utility crews.
A fourth drawback is that implementation cost is relatively high since in the United States, the design of the electrical system requires significant expenditure on equipment to bypass distribution transformers.

For many utilities, the main business case for BPL was to provide broadband services, but this objective received a mixed success. For example, after six years of operation, the BPL network implemented by Manassas Public Utilities in Manassas, VA generated only 650 customers. Manassas recently joined a list of other utilities, including PPL in Allentown, PA, and Progress Electric in Raleigh, NC, that have discontinued their BPL services due to poor technical or economic performance. As one article points out, “While proponents of BPL sing the merits of easy installation and ubiquitous infrastructure, pundits are quick to point out that BPL is coming into its own just as fiber-to-the-home technologies are hitting their stride.”

**Fiber to the Premises (FTTP) (Type 1)**

Dozens of power utilities, mostly public power, have constructed FTTP networks. The networks provide broadband services such as data, video, and voice and have almost unlimited capacity. Typical speeds on FTTP systems are 50 Mbps, but this limit is only imposed by the network electronics and can easily be increased. FTTP networks have fiber optics installed from each customer’s premises to the substations and network operation centers.

In theory, FTTP is an ideal platform for AMI, mainly because it is almost infinitely scalable. However, none of the networks researched during CTC’s course of work in the AMI industry directly connects AMI equipment to the fiber optics due to a variety of reasons. One reason is that there are no substantial manufacturers providing equipment that would enable such a connection. Another reason is that it is too costly to connect each meter to the fiber—for example, Hometown Utilicom in Kutztown, Pennsylvania, attempted FTTP meter reading but is now using a PLC-based system because of the lower costs of such a system. Pulaski Electric System in Pulaski, Tennessee, uses its FTTP system to communicate with wireless access points, which in turn communicate with the meters using Tantalus wireless technology. In this case, the FTTP network provides the ability to shrink the size of the meter-to-meter mesh which greatly increases the AMI network throughput and substantially decreases network latency.

**Use of a Customer’s Broadband Connection**

Another potential AMI architecture is use of the customer’s broadband connection for reporting usage data. While an obvious advantage of leveraging the customer’s broadband connection is the availability of a high bandwidth low latency connection, without having to deploy and maintain a wide-area network, this approach has significant disadvantages and limitations. A few of these are:

- Not all customers have a broadband connection and not all customers that have a broadband connection will allow the utility to have access. Absence of broadband connection for any customer will mean that the utility’s AMI network will not be able to cover all the meters. Thus either alternative means of connecting these meters to the AMI

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network may need to be deployed, which may result in complexity as well as high integration efforts and high costs.

- The utility will need either access to a port on a customer router or have the customers ISP grant the utility access to a port on the cable modem, DSL modem, or other broadband interface. The ISP is not likely to provide this access for free.
- The equipment required to interface to the customer’s broadband connection is powered after the service entrance and can easily be unplugged by the consumer.
- When a customer moves, the broadband connection is no longer available. This greatly reduces or eliminates AMI utility benefits such as final reads, beginning reads, and service disconnect.

The above disadvantages and limitations are similar to those faced by telephone based AMR vendors a decade ago—which they or the utilities were able to overcome. Use of broadband (FTTP or other) for AMI will likely be valid for utilities that own, operate, and maintain a broadband network. For utilities that do, such as Pulaski Tennessee, can reap the benefits of a high bandwidth and low latency connection, while preserving essential control over reliability and availability of the network.
Common Issues

Network Security
All networks researched during CTC’s course of work in the AMI industry incorporate some form of network security to prevent unauthorized interception and use of AMI data. In power line systems, one element of security is the fact that the data rides on the energized conductors of the utility grid. It would be extremely dangerous to attempt to intercept PLC data. All of the power line and RF-based AMI solutions include significant encryption of data before it is transmitted over the communications medium. Thus all data is protected from unauthorized interception and use.

The AMI industry is in the process of developing standards for security and overall systems interoperability.22 The industry completed preliminary meter and end-to-end security requirements, also known as the AMI-SEC requirements, in 2008.23

1. During the course of CTC’s research and work within the AMI industry it was revealed that while some manufacturers confirmed as being compliant with the AMI-SEC requirements, data is not readily available verifying the compliance, or lack of compliance, of the security standards by all manufacturers, such as compliance with the ANSI standards that address parts of security. Further the sources of information and identity of manufacturers who do comply with the ANSI standards, is regarded confidential and hence not disclosed.

2. The NIST document *Smart Grid Cyber Security Strategy and Requirements*24 was first issued in draft form in September 2009, and an expanded draft was later released in the February 2010. A final report is expected to be published by NIST by early summer.

3. It is likely that new standards and new threats over the years will require modification and upgrade of meters and AMI systems. Therefore, a manufacturer must develop a highly flexible and upgradeable platform, and demonstrate the ability to quickly, stably, and securely receive automatic upgrades.

4. An assessment of end-to-end system security should include a systematic approach incorporating all relevant NIST and industry standards, including protecting access to personal information and usage information, remote disconnection and reconnection, access to appliances on ZigBee, potentially a trial “Smart House” with ZigBee devices (investigating the risk of damage, disconnection, and malicious shutdown of those devices), access to distribution automation systems, denial of service, disruption of mesh communications, viruses, and worms, and the ability to upgrade to address problems.

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Scalability

The data-carrying capacities of power line and RF AMI networks will need to be increased over their economic lives. Increases in data capacity will be necessitated by growth in the number of customers as new housing developments and apartment buildings are constructed. In addition, more network capacity will be required due to increases in the frequency that meters on the network are read during the normal billing cycle. Initially the utility may adjust its AMI network to read all customers’ meters once per hour and store those readings in the meters until late at night when they can be retrieved over the AMI network. However, within a few years the utility may find it necessary to read all of its (increasing number of) meters every 15 minutes, and retrieve that data once each hour or more frequently. The AMI network must be flexible enough to provide such growth in data-handling capacity without major disruption to the utility’s normal operations. All elements of the AMI network, from the meter memory to the radio channel bandwidth or capacity, must be expandable to accommodate growth at minimal cost.

1. The means of scaling the network depends on the network architecture. In a PLC network there is little or no means to scale the network. The communications system aggregates all of the users on the line, and there are no additional channels of communications. The maximum frequency is limited by the presence of distribution transformers.

2. In a wireless point-to-multipoint network, devices must communicate with the most-favorably located base station. Scalability would require deploying more base stations, which would usually require placing antennas and equipment in high locations favorable for radio signal propagation. Depending on the specifics of the technology, this type of upgrade may require reprogramming devices (meters) to communicate with the new stations. Other alternatives include obtaining more spectrum and upgrading equipment to use spectrum more efficiently.

3. If more capacity is needed in a mesh network, an additional collector, or backbone access point, can be placed within the mesh. The collector would not need to have a line of sight to several radios, such as by its placement on hilltop or the top of a tower or a building; it would simply need to be in a place where it could communicate with other devices in a mesh. If a collector fails, the mesh will enable communications to converge over other routes. Typical collectors are approximately 9 x 8 x 4 in size and are mounted on standard utility poles in the power space. In the cases cited above that use a point-to-multipoint network and a mesh network, or a combination of both, placement of the collectors or access points will be governed to a large extent by the terrain (such as rural areas with a lot of foliage, urban areas containing tall buildings, etc.). Thus the terrain must also be expected to influence the performance within the AMI network that uses the RF medium.

BPL networks are more limited in their scalability (although most scalability will be needed for non-AMI broadband applications, because there is more than sufficient capacity for any foreseeable AMI application). The most significant bottleneck is the speed of the power line communications portion of the network. That portion could be upgraded by switching the BPL technology as more complex modulation schemes become available. However, even this type of
An upgrade will be limited by the frequency limit of the medium; if a substantial upgrade is required, the likely next step is conversion to a FTTP network.

Like BPL, FTTP networks have more capacity than will be needed for any foreseeable AMI application. Scaling the technology is straightforward—requiring simply an upgrade to a more advanced set of electronics, incorporating higher wire speeds, or transmission over multiple wavelengths (also known as wave division multiplexing, WDM).

**History**

During CTC’s course of research and work in the AMI field, a significant observation made was the amount of time each manufacturer had been in the industry. While most of the manufacturers are new to the AMI field with one to four years in production, and little track record, very few of the manufacturers have been in the industry for longer periods of around 10 to 20 years. It is notable that even large companies, such as Motorola, have produced AMI and AMR technologies and discontinued them—so just the presence of a familiar name does not guarantee that a product will be continued, supported and viable.

**Communications During a Power Outage**

During CTC’s course of research and work in the AMI field, it was found that very few systems will continue to operate during a power outage, usually by operating over a battery installed in the system. Other systems will either fail slowly (operating in the meantime via stored energy in capacitors), fail shortly (issuing a “last gasp” transmission), or fail immediately. A utility needs to plan the type of response it desires from the meters in the event of a power failure, and how the failures or continued operation can be used to track outages and restoration of power. It is also important to note that other elements of the network, such as the cellular network used in the intermediate network or the backhaul network, may also be vulnerable to sustained power outages.
Market Research Report

Citywide Ultra High-Speed Broadband System Project

19 May 2011

CITY of PALO ALTO

Tellus Venture Associates

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1. Executive Summary

This study evaluated the current coverage, marketing and market potential of the City of Palo Alto Utility Department’s (CPAU) dark fiber network. The key findings are:

- CPAU has a high market share and brand awareness among organizations that need the quantity and quality of bandwidth provided by direct fiber optic connections. A modest, highly targeted advertising and promotion program will help maintain this market position over time.

- CPAU's best customers are telecommunications companies. Initiatives that support mobile telecommunications providers and/or enable resellers to provide connectivity to a wider range of businesses and commercial properties will encourage greater use of CPAU's dark fiber network.

- These initiatives could include a modified flat-rate pricing policy and a commercial property initiative that recovers upfront costs over time.

- CPAU should consider extending its network to the few unserved clusters of commercial users identified by this study.

- Many public schools in the City of Palo Alto are within reach of the current network, and all can be reached via relatively modest extensions.

- It is unlikely that an “overbuild” fiber-to-the-home (FTTH) service in Palo Alto would be able to support itself or be financially justified in the near term.

Geographic analysis of Palo Alto businesses and fiber network

To evaluate the potential for new business, an electricity usage profile of existing dark fiber customers was developed and compared to CPAU’s commercial electric account database. Businesses that matched the profile were mapped and classified according to distance from the network. These potential customers generally fell into two categories: 1. already within the current fiber service area or 2. located in a handful of unserved clusters. Public schools were a third category. This mapping analysis was then validated through field research.

Profile matches within the current service area were sorted into three groups: accounts located in 1. Stanford Research Park, 2. downtown Palo Alto and 3. the rest of the City. In Stanford Research Park, 83% of these potential customers have already discussed dark fiber service with CPAU staff. In downtown Palo Alto and the rest of the City, about a fifth had already been contacted and another fifth appeared to be good prospects. More than half of
the matches in those two areas were small retail operations or other businesses that would not be likely dark fiber customers.

Figure 1.1 - CPAU fiber map showing businesses (color coded dots) and schools (orange parcels) within 200 meters of existing network (blue and red lines) and prospective extensions (green lines).

The businesses identified as prospective customers are generally technology, medical or professional organizations that can be reached by modest marketing initiatives, or telecommunications companies and multi-tenant commercial properties that can be addressed by initiatives specifically tailored to their needs.
Clusters of potential fiber customers were identified in unreached areas of the City. A cost/benefit analysis showed that extending the network to the East Meadow Circle area (as CPAU staff are already doing) would be justified and extensions along Welch Road and Sand Hill Road would also be supported by current market potential.

Extensions along El Camino Real and East Bayshore Road could be supported if initiatives addressing telecommunications companies and commercial properties were successful, and could also have economic development benefits.

**Pricing analysis**

Potential users who were contacted cited perceived high costs as an obstacle to adoption. Currently, CPAU charges new customers upfront for construction work, and usually determines monthly rates by the distance from the customer to downtown Palo Alto. New pricing options were evaluated as ways of overcoming objections to cost.

A maximum flat total monthly cost of $1,610 would reduce current revenue by about a tenth, which could be recovered by gaining a couple dozen new customers. This price point would be a significant benefit for new and existing customers in Stanford Research Park and the southeast area of the City, and for mobile telecommunications companies.

Flat rate pricing would also simplify selling to telecommunications resellers and/or multi-tenant commercial properties. A bigger incentive in this sector, though, would be to amortize the cost of new construction via a slightly higher monthly rate, which would be competitive if even a few end users shared a single connection.

**Residential service**

To support the high cost of building an FTTH system, an “overbuilder” would need to take a controlling share of cable television and Internet service subscriptions from Comcast and AT&T and achieve a high rate of monthly revenue per customer. Given the ongoing uncertainty and business model disruption in the industry, increasing and uncontrollable costs, intense competition and the failure of benchmark systems in other cities, there is no viable business case for FTTH in Palo Alto.

The telecommunications and television industries are rapidly changing. Some form of FTTH service might become financially justified in the future. It should be one of the many factors considered when evaluating fiber network extensions and upgrades. However, these changes are also opening up other opportunities, such as mobile broadband, the growing digitization of the medical field and the continuing attraction of Palo Alto to new technology and professional enterprises, which are more immediate and better proven.
2. **Introduction**

The City of Palo retained Tellus Venture Associates to conduct market research for its business plan for the Citywide Ultra High-Speed Broadband System Project. This research included:

1. Analysis of the existing City of Palo Alto Utility Department (CPAU) fiber network footprint versus existing and potential dark fiber customers.
2. Analysis of potential extensions of the network.
3. Assessment of services and market position.
5. Cost-benefit analysis of commercial valued-added service options.
6. Case study benchmark analysis of retail service options.

These steps were carried out in close cooperation with CPAU staff, and included review of research methodology, results and analysis.

Note regarding directions: north-south-east-west directions are based on a grid convention. For example, Middlefield Road and Alma Avenue would be considered running generally from north to south, while Oregon Expressway and Page Mill Road would be considered running generally from east to west.
3. Geographic Analysis

3.1. Methodology

The City of Palo Alto provides several different kinds of utility services, including electricity, water, waste water, gas and fiber optic facilities. As a result, it has an excellent database that contains utility usage and location information for businesses and residences in the City.

The beginning assumption was that existing dark fiber customers would generally share a common electricity usage profile. Electrical usage patterns are good rough indicators of broadband service potential. In general, larger companies have larger broadband needs and use larger amounts of electricity. Specifically, the more data a company transmits and receives, the more electricity-consuming devices are necessary to generate, process and access it.

Once the profile was determined, other businesses within the City with similar profiles could be identified, and then located relative to the existing fiber network.

A preliminary list of potential dark fiber customers within reach of the existing network could then be developed and preliminary identification made of any clusters of potential dark fiber customers that are not currently reachable.

3.2. Utility Database Analysis

The analysis began with a spreadsheet drawn from the utility customer database by CPAU staff, which showed the Fiscal Year 2010 billing amounts and rate codes for each utility contract account number. The data were reorganized to show the billing information, the electric rate code and status as a fiber customer for each account number.

The data were sorted and tallied by electric rate code, and the result is shown in Table 2.1.

Of the 61 account numbers with current or past fiber service, 14 also had electric rate codes attached. Of those, one was large commercial, one was small commercial and 12 were medium commercial.

The remaining 47 were matched by address to electric accounts. Most of these fiber service accounts are attributable to resellers, which license fiber from CPAU to deliver broadband services.
Where the address showed multiple electric accounts with the same name, the billing amounts were combined. When there were multiple electric accounts at an address but no match with a company name, the largest account was chosen.

In some cases there was more than one fiber account associated with a particular address, but only one electric account. In those cases, the gross electric account data was used for all fiber accounts at that address. Where no address was associated to the fiber account, the largest electric account attributable to the respective company name was used. When there was more than one fiber account associated with one company name and one or more of the accounts did not have an associated address, the accounts without an address were deleted. Two redundant account numbers were eliminated in this way. A de minimis redundant account was also eliminated.

Of the remaining 58 fiber accounts, eight could not be associated with electrical service either by address or company name in the master utility customer database. Two were large telecommunication companies, one was located in Stanford Research Park and one was located in Menlo Park. Four were located in Palo Alto but did not appear to be materially different from the other fiber accounts. Because these accounts appeared to have characteristics that were consistent with the other 50 fiber accounts, it would not be necessary to use them in building a profile.

In reviewing the remaining 50 accounts, 43 (86%) were coded as medium or large commercial electric accounts. Seven were coded as small commercial electric accounts. Of those, one (2%) had electrical billing over $20,000, three (6%) were just over 10,000, and three (6%) were under $10,000.

<table>
<thead>
<tr>
<th>Customer Electric Account Profile</th>
<th>Number of Accounts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large commercial</td>
<td>41</td>
</tr>
<tr>
<td>Medium commercial</td>
<td>728</td>
</tr>
<tr>
<td>Small commercial</td>
<td>3,224</td>
</tr>
<tr>
<td>Small commercial greater than $10,000</td>
<td>204</td>
</tr>
<tr>
<td>Small commercial greater than $20,000</td>
<td>73</td>
</tr>
<tr>
<td>No code</td>
<td>56</td>
</tr>
</tbody>
</table>
For the purposes of the preliminary evaluation, the master database was sorted into six discrete types:

A. Large commercial electric accounts.
B. Medium commercial electric accounts.
C. Small commercial accounts with electric billing greater than or equal to $20,000.
D. Small commercial accounts with electric billing greater than or equal to $10,000 and less than $20,000.
E. Small commercial accounts with electric billing less than $10,000.
F. Existing fiber accounts.

Electric accounts with no associated address were deleted from the database and not used in the analysis.

3.3. Mapping

Using information provided by CPAU staff, a Geographic Information System-based (GIS) parcel map of the City was created. Existing fiber network routes, including identification of aerial plant, underground plant, service drops and connection points, were added to this map.

With the exception of existing fiber accounts, the location of commercial electric accounts were added to the database and labeled A through E, based on the types identified above. Existing fiber accounts were not included because maps showing those locations already exist and the objective of this mapping analysis was to identify potential new customers.

Two analyses were run. The first was to determine the number and location of commercial electric accounts within 200 meters of the existing fiber network which matched the electricity usage profile of existing fiber accounts, which was defined as large commercial accounts, medium commercial accounts and small commercial accounts with billing greater than or equal to $20,000 (Types A, B and C). Two hundred meters was chosen as being a reasonable distance for a service drop connection; however as a check accounts within 50 and 100 meters were also mapped.

The second analysis determined the number and location of all commercial electric accounts greater than 200 meters from the existing plant. Two sets of maps were produced, one showing all commercial electric accounts and the other showing just Types A, B and C.

These accounts were evaluated using GIS spatial analysis tools and the results are shown in Table 2.2. As an additional check, a second run was made showing accounts greater than 100 meters from the existing network, accounts within 50, 100 and 200 meters of existing
network connection points and accounts greater than 100 and 200 meters from existing network connection points.

Numerically, these alternatives differed little from the first data run, and the overall mapping patterns did not change at all. The same was true of the 50 and 100 meter cuts in the first run. As a result, the data from the 200 meter cut were used in the analysis below.

<table>
<thead>
<tr>
<th>Commercial Account Type</th>
<th>Within 50 meters or less</th>
<th>Within 100 meters or less</th>
<th>Within 200 meters or less</th>
<th>Greater than 200 meters (Types A, B, C)</th>
<th>Greater than 200 meters (all Types)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>34</td>
<td>34</td>
<td>35</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>509</td>
<td>577</td>
<td>619</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>C</td>
<td>53</td>
<td>57</td>
<td>61</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>479</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>596</strong></td>
<td><strong>668</strong></td>
<td><strong>715</strong></td>
<td><strong>85</strong></td>
<td><strong>578</strong></td>
</tr>
</tbody>
</table>

Subsequent error checking uncovered a mismatch between the utility and GIS databases, and a third run was made. The mismatch turned out to be minor and, with one exception, the changes in results were insignificant. The one exception was a small group of commercial accounts which were originally mapped to a residential area. These accounts were mapped to their correct locations, eliminating an anomalous cluster. The corrected, third run data set is used in this report.
4. Analysis of Existing Network

4.1. Overview

“There are definitely high-end online content users who need you and will find you.”

Comment by a Palo Alto commercial property management executive.

Figure 4.1 - Fiber map of City of Palo Alto. Areas shaded blue are within 200 meters of existing CPAU network. Stanford Research Park and downtown Palo Alto are completely covered.
Over the past twelve years, CPAU staff have evaluated providing service to private sector organizations which represent a total of 257 separate addresses. Most of these addresses can be matched to electrical accounts, although some guesswork is involved because a given location’s electrical account might be handled by one entity, such as a property manager, while the fiber account or inquiry might be the responsibility of a tenant or a telecommunications reseller.

Geographically, these projects and inquiries can be broken up into three similarly sized groups. Stanford Research Park accounts for a third of the total. The downtown Palo Alto area is another large cluster, and the remainder are spread throughout the rest of the City.

<table>
<thead>
<tr>
<th>Geographic Group</th>
<th>Number of Projects/Inquiries</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanford Research Park</td>
<td>85</td>
<td>33%</td>
</tr>
<tr>
<td>Downtown Palo Alto</td>
<td>72</td>
<td>28%</td>
</tr>
<tr>
<td>Other Type A, B, C within 200 meters of network</td>
<td>60</td>
<td>23%</td>
</tr>
<tr>
<td>Other Type D and E and Unknown</td>
<td>40</td>
<td>16%</td>
</tr>
<tr>
<td>Total</td>
<td>257</td>
<td>100%</td>
</tr>
</tbody>
</table>

CPAU’s dark fiber services have excellent brand awareness within the City’s technology and real estate communities. Most major technology companies and properties serving those companies already either use CPAU fiber, or have worked with CPAU staff to evaluate it.

<table>
<thead>
<tr>
<th>Geographic Group</th>
<th>Electricity Usage Profile Matches</th>
<th>CPAU Fiber Database Matches</th>
<th>Technology, Medical &amp; Professional</th>
<th>Commercial Property Company</th>
<th>Retail or Other Non-Prospect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanford Research Park</td>
<td>145</td>
<td>120</td>
<td>13</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Downtown Palo Alto</td>
<td>177</td>
<td>39</td>
<td>20</td>
<td>24</td>
<td>94</td>
</tr>
<tr>
<td>Other Type A, B, C within 200 meters of network</td>
<td>395</td>
<td>73</td>
<td>48</td>
<td>58</td>
<td>216</td>
</tr>
<tr>
<td>Total</td>
<td>717</td>
<td>226</td>
<td>79</td>
<td>85</td>
<td>314</td>
</tr>
</tbody>
</table>
The major factor limiting the growth of CPAU’s fiber business are the needs and capabilities of prospective customers. CPAU’s selling proposition is very attractive to a customer that needs a large amount of bandwidth and has or can acquire the necessary resources to light up dark fiber and connect it to either the Internet or a corporate network.

<table>
<thead>
<tr>
<th>Geographic Group</th>
<th>Electricity Usage Profile Matches</th>
<th>CPAU Fiber Database Matches</th>
<th>Technology, Medical &amp; Professional</th>
<th>Commercial Property Company</th>
<th>Retail or Other Non-Prospect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanford Research Park</td>
<td>145</td>
<td>83%</td>
<td>9%</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Downtown Palo Alto</td>
<td>177</td>
<td>22%</td>
<td>11%</td>
<td>14%</td>
<td>53%</td>
</tr>
<tr>
<td>Other Type A, B, C within 200 meters of network</td>
<td>395</td>
<td>18%</td>
<td>12%</td>
<td>15%</td>
<td>55%</td>
</tr>
<tr>
<td>Total</td>
<td>717</td>
<td>32%</td>
<td>11%</td>
<td>12%</td>
<td>44%</td>
</tr>
</tbody>
</table>

CPAU has done a good job of reaching out to these sorts of customers, and will continue to both add and drop customers as existing companies grow, new companies move to the City and as companies’ needs change for better and worse. CPAU key account and large commercial account representatives are very effective in providing information about new fiber prospects and other changes in the market.

One area of concern is CPAU’s ability to quickly provide construction cost quotes to prospective customers, and to rapidly fulfill orders. Section 6 below discusses possible changes in pricing policy which can help address these concerns. These changes could also make it easier to develop a program for contracting out certain kinds of construction work, including generating cost estimates. Marketing initiatives should be matched by complementary enhancements to fulfillment resources.

Developing a modest ongoing advertising and promotion program will help maintain this market position over time. Creating initiatives aimed specifically at mobile telephone companies and commercial properties could also help create new opportunities for CPAU fiber services within the existing network. Although there is excellent general awareness of CPAU dark fiber services, prospective customers don’t always know how those services can specifically benefit them.
4.2. Stanford Research Park

The current CPAU fiber network effectively covers all of Stanford Research Park (SRP). Every parcel is within 100 meters of the network and most are within 50 meters or less. One-third of all CPAU fiber projects and inquiries have involved SRP properties and companies.

Figure 4.2 - Fiber map of Stanford Research Park. Areas shaded blue are within 50 meters of existing CPAU network. Figure 4.1 above shows complete coverage at 200 meters.
SRP tenants seem to be well aware of the availability of dark fiber from the City. Eighty-three percent of the properties that match the electricity usage profile of existing fiber customers are either on the network already or have been investigated for connection to the City’s network or are controlled by companies that are past or present CPAU fiber customers.

Only 13 of the 144 profile matches are accounts that might be considered as immediate prospects. Of those, four are professional firms such as consultants or law firms that in all likelihood do not need large amounts of bandwidth. The remaining nine are made up of seven companies, three of which have FY2010 electrical billings of more than $100,000.

CPAU staff have been very effective in communicating with SRP tenants, and have achieved very high market share and awareness. If a program is developed to address large commercial property owners and managers, as discussed below, then SRP would be a good location to introduce it. The same would be true of any other general marketing initiative. Otherwise, current marketing and sales efforts should be maintained.

### 4.3. Downtown Palo Alto

Most companies in downtown Palo Alto that match the electricity usage profile of existing dark fiber customers (53%) are small to medium-sized retailers or similar organizations that typically do not require large amounts of bandwidth. Of the balance (22% of the total) are either on the network already or have been investigated for connection to the City’s network or are controlled by companies that are past or present CPAU fiber customers.

The rest are about evenly split between professional or technology-related companies and locations where the electric accounts are held by property management companies. It’s reasonable to assume that the tenants at these locations break out approximately the same way: 80% retail and service, 20% professional and technology.
Adding in an allowance for tenants of property management companies, that leads to a rough estimate of approximately 25 sales prospects in downtown Palo Alto that have business and electricity usage profiles that are similar to existing CPAU fiber customers. Two are large telecommunications companies, the rest are mostly small to mid-sized companies with FY 2010 electricity billing in the low five-figure range.

The current CPAU marketing program appears to be very effective in downtown Palo Alto. Along with Stanford Research Park, the downtown area would be a good place to try out any new marketing initiatives that might be developed. Even so, maintaining current efforts should continue to produce good results.

4.4. Technology, Medical and Professional

Technology companies, medical research and treatment organizations and professional firms comprise the bulk of current CPAU dark fiber customers. Although CPAU’s general citywide market share and awareness within these companies is slightly less than in the downtown area, it is still relatively high.

Eighteen percent of profile-matching accounts outside of Stanford Research Park and the downtown area are either on the network already or have been investigated for connection to the City’s network or are controlled by companies that are past or present CPAU fiber customers. Similar to the downtown area, 55% are retail, service or other companies that are not typically heavy consumers of bandwidth.

Of the remainder, 58 are represented by property management companies, which are discussed in the next section and 48 can be characterized as technology, medical or professional service firms.

Two of these accounts are large telecommunications providers. The remaining 46 accounts are composed of 35 different companies. Twelve had FY 2010 electricity billings of more than $50,000, one of those was over $1 million and four others were more than $100,000.

These 35 companies represent a wide cross section of industry sectors and would have widely varying bandwidth needs. It is likely, however, that some are prospective customers and should be contacted as time permits.

CPAU dark fiber services seem to have very good market penetration and awareness within technology, medical and professional firms throughout the City. Current sales and marketing efforts appear to be very effective in that regard.
That said, Palo Alto is a magnet for both startup and established technology and medical companies, and the employee turnover within those companies is high. An ongoing program of targeted advertising and promotions and co-marketing efforts with select organizations would be useful in maintaining awareness and generating additional business for both CPAU and its telecommunications reseller customers.

**4.5. Commercial Properties**

Property management companies control approximately one-eighth of the electric accounts matching the profile of current fiber customers. In many cases, the tenants are small to medium sized firms. Typically the individual bandwidth needs of these companies are moderate, but can be significantly large when aggregated.

Some large companies or property managers, for example Stanford University or Space Systems-Loral, have considerable in-house information technology resources to complement their high demand for bandwidth. Most office and retail developments, however, do not.

One property management executive said that cost would be a determining factor for traditional tenants such as smaller professional services companies. But, he said, there appears to be a long term shift toward laboratory and medical device firms which could have more intensive bandwidth needs.

Another manager of large commercial properties in Palo Alto said he believed CPAU could achieve market penetration of 30% or more of office tenants in downtown if the monthly fee was $1,000 or less and installation costs were a few hundred dollars.

It could be possible to work directly with owners of large commercial properties or telecommunications resellers to bring CPAU fiber into office complexes. The model might involve CPAU (or an outside contractor) constructing a service drop to an access point on or near a given building. Then the property owner or, more likely, a telecommunications reseller would pull fiber inside to a managed hub. The economics of this “fiber to the basement” model are examined in Section 6 below, and could be explored further via an RFP process.

**4.6. Telecommunications Companies**

There are three primary types of telecommunications companies doing business in Palo Alto: mobile phone companies, facilities-based carriers and telecommunications resellers.
CPAU is a direct competitor to facilities based carriers. Even so, one is a current dark fiber customer, and others might be if they had a specific problem that CPAU could solve. However, it can be assumed that these carriers are aware of CPAU’s network and little needs to be done other than maintaining a cordial professional relationship.

At the other end of the spectrum, CPAU already has an excellent customer base of telecommunications resellers. As discussed below, an ongoing marketing program aimed at maintaining CPAU’s brand awareness within closely targeted industry segments such as the mobile telecommunications sector would be useful.

Mobile telephone and broadband companies fall somewhere in between. Presently, CPAU is not directly providing fiber to any mobile companies. However, backhaul bandwidth is rapidly becoming a critical bottleneck for that industry. A Sacramento-area fiber company, Surewest, is currently generating $1 million per year by filling those gaps and expects to grow this business to $2 or $3 million per year in the near term. In Palo Alto, AT&T is already building 80 new small cell sites on utility poles.

Although companies with nationwide operations prefer nationwide vendors, there are no perfect broadband backhaul solutions. Telecommunications companies have local and regional staff who have to solve specific and unique problems on a daily basis. As Surewest has discovered, it is particularly true in the mobile telecommunications sector, where localized gaps in coverage frequently occur.

CPAU staff is already looking at ways to directly target mobile telecommunications companies, and those efforts should be encouraged. As noted below, fiber network extensions would bring CPAU’s services within reach of more cellular facilities. The more complete the solution offered to a given mobile company, the more willing that company will be to consider it.
5. Analysis of Unserved Market

“Palo Alto is unique in that tenants aren't price-focused. Quality and reliability, are more important than price, within reason.”

*Comment by a Palo Alto commercial property investor.*

5.1. Identification of Unserved Areas

![Figure 5.1 - Concentrations of unreached electric accounts matching fiber customer profile.](image)
Examination of the maps of potential customers more than 200 meters from the existing fiber networks showed three distinct unserved clusters and two additional areas that warranted additional investigation. The same patterns appeared on maps showing just Types A, B and C accounts and all commercial electric accounts (Types A through E).

The five areas were:

1. Along El Camino Real, generally between Stanford Avenue and Del Medio Avenue, with the largest concentration between Page Mill Road and Maybell Avenue.
2. Along Sand Hill Road and Welch Road, west of El Camino.
3. Along San Antonio Avenue, between Alma Street and Middlefield Road.
4. Around East Meadow Circle.
5. Along East Bayshore Road, north of Embarcadero Road.

These five areas were more closely examined. The commercial accounts identified were investigated using a spreadsheet of the individual accounts, Google Maps and Street View, company websites, by driving and walking through the areas and via email, phone and in-person interviews.

The areas along El Camino Real, Sand Hill and Welch Roads and East Meadow Circle had high concentrations of accounts that were consistent with the electricity usage profile and the general business categories of existing dark fiber customers. El Camino Real, in particular, also showed a generally high concentration of commercial accounts of all kinds.

The East Bayshore Road and San Antonio Road areas were less promising but were clearly commercial or industrial in nature and adjacent to existing fiber lines, so both were included in the next stage of analysis.

5.2. Identification of Network Extensions

New fiber segments were drawn to reach these five unserved areas. As discussed below, new segments were also drawn to reach specific, unserved schools.

These five new segments, totaling 10.9 kilometers (6 ¾ miles) in length, were mapped. The location of commercial accounts (Types A through E) greater than 100 meters from the existing network and 200 meters or less from the new segments were plotted and tabulated.
5.3. Validation

A total of 752 commercial accounts of all types were located within these prospective new service areas. Of these, 34 accounts at 27 unique addresses were already current or past dark fiber customers, or had been formally evaluated as prospective customers by CPAU staff.
The remaining accounts were summarily evaluated against the electric usage and business profile of existing dark fiber customers. Forty-one organizations with a total of 52 different locations within the new service areas were identified as being good prospects. These organizations were either similar to existing dark fiber customers, such as high technology, telecommunications or medical and dental companies, or represented large retail or property management-oriented companies, which are commonly found in the prospective new service areas.

These 41 organizations were further investigated via web searches, email correspondence, telephone conversations, site surveys, onsite visits and discussions with CPAU staff.
5.4. Cost/Benefit Analysis

The cost of building the five potential network extension segments was estimated using a fiber construction cost range of $30 to $60 per foot. This range was provided by CPAU staff and is consistent with actual and estimated costs obtained from other fiber projects.

<table>
<thead>
<tr>
<th>Fiber segment</th>
<th>Length (miles)</th>
<th>Low cost ($30/foot)</th>
<th>High cost ($60/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - El Camino Real</td>
<td>2.5</td>
<td>$393</td>
<td>$785</td>
</tr>
<tr>
<td>2 - Sand Hill/Welch</td>
<td>2.6</td>
<td>$407</td>
<td>$814</td>
</tr>
<tr>
<td>3 - San Antonio</td>
<td>0.7</td>
<td>$111</td>
<td>$222</td>
</tr>
<tr>
<td>4 - East Meadow Circle</td>
<td>0.7</td>
<td>$115</td>
<td>$231</td>
</tr>
<tr>
<td>5 - East Bayshore</td>
<td>0.3</td>
<td>$44</td>
<td>$87</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6.8</strong></td>
<td><strong>$1,069</strong></td>
<td><strong>$2,139</strong></td>
</tr>
</tbody>
</table>

A penetration rate of 17% was used to estimate customer uptake on new segments. This rough estimate was calculated by taking the total number of profile matches in the existing network (704) and adding in the number of fiber accounts in that area (61) to get a total of 765 addressable accounts within the current network.

<table>
<thead>
<tr>
<th>Fiber segment</th>
<th>3 Years</th>
<th>5 Years</th>
<th>10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - El Camino Real</td>
<td>$156</td>
<td>$238</td>
<td>$411</td>
</tr>
<tr>
<td>2 - Sand Hill/Welch</td>
<td>$53</td>
<td>$77</td>
<td>$129</td>
</tr>
<tr>
<td>3 - San Antonio</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>4 - East Meadow Circle</td>
<td>$104</td>
<td>$159</td>
<td>$274</td>
</tr>
<tr>
<td>5 - East Bayshore</td>
<td>$52</td>
<td>$79</td>
<td>$137</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$365</strong></td>
<td><strong>$553</strong></td>
<td><strong>$951</strong></td>
</tr>
</tbody>
</table>

This figure was then multiplied by 48%, which is the portion of the total that represent “good prospects” (current and past fiber customers, CPAU fiber database matches and
technology, medical and professional organizations). The number of actual fiber accounts was divided by the result (367) to produce the estimated penetration rate.

The number of raw prospects in each segment, as identified in Table 5.1 above, was multiplied by the estimated penetration rate and the result was rounded to the nearest integer. The monthly revenue per customer in each segment was estimated according to distance from the downtown area, in keeping with current CPAU pricing policy. The number of projected customers was multiplied by the monthly revenue figure, and the net present value (NPV) over 3, 5 and 10 years was calculated using a discount rate of 5%. An average installation cost of $5,700 per account was added in to produce total estimated revenue per segment over 3, 5 and 10 years.

Table 5.5 - Cost/Benefit Comparison - Low Cost Scenario (000s)

<table>
<thead>
<tr>
<th>Fiber segment</th>
<th>NPV 3 Years</th>
<th>NPV 5 Years</th>
<th>NPV 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - El Camino Real</td>
<td>-$237</td>
<td>-$155</td>
<td>$19</td>
</tr>
<tr>
<td>2 - Sand Hill/Welch</td>
<td>-$354</td>
<td>-$330</td>
<td>-$278</td>
</tr>
<tr>
<td>3 - San Antonio</td>
<td>-$111</td>
<td>-$111</td>
<td>-$111</td>
</tr>
<tr>
<td>4 - East Meadow Circle</td>
<td>-$11</td>
<td>$43</td>
<td>$159</td>
</tr>
<tr>
<td>5 - East Bayshore</td>
<td>$8</td>
<td>$36</td>
<td>$93</td>
</tr>
<tr>
<td>Total</td>
<td>-$704</td>
<td>-$516</td>
<td>-$118</td>
</tr>
</tbody>
</table>

Table 5.6 - Cost/Benefit Comparison - High Cost Scenario (000s)

<table>
<thead>
<tr>
<th>Fiber segment</th>
<th>NPV 3 Years</th>
<th>NPV 5 Years</th>
<th>NPV 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - El Camino Real</td>
<td>-$629</td>
<td>-$547</td>
<td>-$374</td>
</tr>
<tr>
<td>2 - Sand Hill/Welch</td>
<td>-$761</td>
<td>-$736</td>
<td>-$685</td>
</tr>
<tr>
<td>3 - San Antonio</td>
<td>-$222</td>
<td>-$222</td>
<td>-$222</td>
</tr>
<tr>
<td>4 - East Meadow Circle</td>
<td>-$127</td>
<td>-$72</td>
<td>$44</td>
</tr>
<tr>
<td>5 - East Bayshore</td>
<td>-$35</td>
<td>-$8</td>
<td>$50</td>
</tr>
<tr>
<td>Total</td>
<td>-$1,774</td>
<td>-$1,585</td>
<td>-$1,187</td>
</tr>
</tbody>
</table>

The construction estimates were subtracted from the revenue figures, to produce a rough cost/benefit comparison.
5.5. Evaluation by Segment

Segment 1 - El Camino Real

El Camino Real (State Route 82) is typical of older state-maintained intercity roads. It is a mix of strip malls and other highway-commercial type uses. There is wide variety of businesses along this segment. Stanford University is located on the west side of El Camino Real, toward the northern end.

![Figure 5.3 - Concentrations of unreached electric accounts of all types along El Camino Real.](image1)

Although the existing fiber network crosses El Camino Real at four locations, with laterals and service drops running along parallel streets to the east and west, there is no other CPAU fiber directly on the street.

![Figure 5.4 - El Camino Real](image2)
The larger organizations represented, such as Bank of America, are typically national companies with centrally managed information technology and telecommunications facilities. One-off broadband solutions for a single location would not be particularly attractive.

Some technology-related retail companies are located on or near El Camino Real, such as Frys and We-Fix-Macs, as well as smaller professional offices. However, there is a bare handful of genuine high technology company prospects along its entire length that cannot already be reached by the existing four crossing fibers and associated drops and laterals.

Telecommunications companies are one class of potential dark fiber customer that can be found in several locations on El Camino Real. Mobile phone companies, such as T-Mobile and AT&T, have towers along the route, and other providers such as Comcast and AT&T, have technical facilities.

The cost benefit analysis shows this segment more or less breaking even after ten years under the low cost ($30 per foot) scenario, but it would show a loss at any higher construction cost rate. However, given the types of businesses located along the route, this assessment is probably overly optimistic.

As discussed above, mobile telephone companies have been identified as a class of dark fiber customer that could be pursued systematically throughout the City. Additionally, the
presence of fiber optic facilities could serve as an economic development resource for the area. Although the near-term prospects are less attractive, from an economic and business development point of view extending the CPAU fiber network along El Camino Real could be economically justified in the long run. However it does not appear to be justified based solely on current circumstances.

**Segment 2 - Sand Hill/Welch Roads**

The prospective dark fiber customers in the Sand Hill and Welch Roads area are tenants in Stanford Shopping Center and in the extensive medical and dental facilities along Welch Road. The existing network already reaches a corner of Stanford Shopping Center on Quarry Rd., but extending it along Arboretum Rd. and Sand Hill Rd. greatly increases access. Consequently, Stanford Shopping Center was included in the evaluation of this segment.

Although Stanford Shopping Center is home to several large and/or high technology retail outlets, existing broadband service providers appear to be meeting the needs of individual stores. It is a good example of a common situation in Palo Alto, where individual tenants of a large retail or office complex do not need gigabit or even 100 megabit-class Internet connections, but the aggregated demand of the property is well into that range.

Figure 5.7 - Concentrations of unreached electric accounts of all types in the Welch Road/Sand Hill Road area.
Store managers contacted were not interested in dealing directly with CPAU for Internet access, due to the cost. Retail operations, even in a high end shopping center, are very cost conscious and can satisfy their bandwidth needs with commercially available services for less than $200 per month. However, there was interest in being part of a bulk bandwidth purchase if it was organized by the property’s management or someone else.

There are several large medical facilities along Welch Road, along with a scattering of smaller medical-detail office complexes. This industry is already a large consumer of bandwidth, and demand is expected to rise rapidly as the medical field continues to digitize. With the increasing use of digital imaging technology, even small dental offices have large bandwidth needs, both within and between offices and into the Internet.

This segment could generate considerable dark fiber business for CPAU, if the two primary landlords – Stanford Shopping Center and Stanford University’s medical arm – are interested. The cost benefit analysis shows a deficit even after ten years. However, that result assumes the entire segment is built as mapped and that only two new customers would be gained.

The best customer prospects are located relatively close to the existing network, and could be reach via a reduced extension costing perhaps 25% of the full figure. If dark fiber service is attractive to those prospects, then it’s not unreasonable to assume that more than two would buy service.

Assuming a 75% shorter segment and six customers, the rough cost/benefit analysis shows a gain of $82,000 over ten years under the low construction cost scenario, although it is still negative under the high cost scenario.

If there is significant interest among the medical research and treatment facilities on Welch Road and construction costs can be managed toward the lower half of the range, construction of this segment would be justified. At a minimum, it’s enough to warrant
discussing the possibility with potential users, particularly Stanford University and Stanford Medical Center.

Segment 3 - San Antonio Avenue

This segment does not appear to be an attractive prospect for new fiber construction on a business basis. Although the mapping analysis showed several large electrical accounts in the area, none are likely customers of a dark fiber network extension in the area.

It would be difficult to justify building this segment on economic grounds, as indicated by the cost/benefit analysis.

Segment 4 - East Meadow Circle

East Meadow Circle is the best immediate prospect for extension of the CPAU fiber network. It is an industrial area with several high technology companies such as Space Systems-Loral and Dell Computers. Companies located along East Meadow Circle very closely match both the electricity usage and industry profile of existing fiber customers.

The cost/benefit analysis shows this segment paying for itself after ten years even under the high cost scenario. CPAU staff is already aware of the opportunity and is actively pursuing it. The feasibility of this segment could be confirmed by an advance agreement for service.

Segment 5 - East Bayshore Road

The CPAU fiber network already runs along a portion of East Bayshore Road. Extending it another 400 to 500 meters (roughly a quarter of a mile) to the City limits would bring it within reach of several more large office complexes and cellular telephone towers.

As discussed above, there are possible initiatives that could make this segment attractive to construct. A comprehensive marketing effort aimed at mobile phone companies could make the business case feasible. So might programs to encourage existing resellers to develop offerings appropriate to smaller enterprises or work with property owners to bring fiber into
buildings. Either would be necessary to sign up the identified prospects. Should that happen, then the cost of construction would be easily covered by the revenue gained.

5.6. Unserved School Sites

CPAU explored the possibility of bringing all Palo Alto Unified School District (PAUSD) sites onto the network. PAUSD has 17 school sites and the District Office.

<table>
<thead>
<tr>
<th>Fiber segment</th>
<th>Length (miles)</th>
<th>Low cost ($30/foot)</th>
<th>High cost ($60/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 - Coulombe Drive</td>
<td>0.1</td>
<td>$10,703</td>
<td>$21,407</td>
</tr>
<tr>
<td>7 - Barron Avenue</td>
<td>0.4</td>
<td>$63,599</td>
<td>$127,199</td>
</tr>
<tr>
<td>8 - Heather Lane</td>
<td>0.3</td>
<td>$42,033</td>
<td>$84,066</td>
</tr>
<tr>
<td>9 - Amarillo Avenue</td>
<td>0.1</td>
<td>$19,686</td>
<td>$39,372</td>
</tr>
<tr>
<td>10 - Louis Road</td>
<td>0.5</td>
<td>$71,394</td>
<td>$142,787</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.3</strong></td>
<td><strong>$207,416</strong></td>
<td><strong>$414,831</strong></td>
</tr>
</tbody>
</table>

The mapping analysis shows that most sites are currently reachable, and all sites within the City limits are reachable through network extensions. The approximate cost to extend the fiber network to the school sites is $415,000. There are two schools on the Stanford campus that could be served if the schools met the City’s network at the border, either by building a fiber line or using existing facilities. At this time, however, with the exception of one site (Terman), it appears that PAUSD will continue to use the fiber connections provided through the Comcast Institutional Network (I-Net).
6. Pricing Analysis

“The general impression is that it is several thousand dollars to hook up and very expensive for service...many more clients would be interested if they knew that the installation and service fees were reasonable.”

Comment by a Palo Alto property owner.

6.1. Alternative Providers

No other telecommunications service provider offers intra-city dark fiber services in Palo Alto, except insofar as they resell CPAU fiber. Several providers offer managed services using a variety of technologies, including Ethernet, SONET and wavelength technologies such as DWDM and CWDM. Taken together, these carriers are CPAU’s best customers.

Santa Clara and San Mateo Counties generally have very competitive broadband service pricing. Monthly transport costs for managed service range from around $300 for a dedicated 10 Mbps circuit to $10,000 or more for 10 Gbps and up.

6.2. Current Pricing

CPAU’s current dark fiber pricing is based on a fixed drop fee of $210 per month plus a distance-based charge that ranges from $425 to $2,443 per month. Some customers are still on an older rate schedule, but that pricing is being brought into line with the current schedule over time.

For $300 per month, plus the cost of installing and maintaining the necessary equipment, a CPAU dark fiber customer can hook up directly to PAIX (originally named Palo Alto Internet Exchange, now called Peering and Internet Exchange), which allows them to buy Internet bandwidth at a very low rate. For a total of $1,000 per month plus the cost of CPAU’s fiber, a customer can have access to 100 Mbps or more of dedicated Internet bandwidth.

For something like $1,500 to $3,500 per month, a business can have access to hundreds of megabits per second or more of dedicated Internet bandwidth via CPAU fiber. It is more bandwidth than some businesses need, and from that perspective it appears costly, but compared to the alternatives it is an extremely good value for companies that need that level of service.
6.3. Flat Rate Pricing

One method for encouraging greater use of the CPAU dark fiber network is to use a flat-rate pricing system, rather than a distance-based one. To determine the effect of changing to flat rate pricing, 123 non-government fiber accounts which had monthly billings from $635 to $2,700 (the range of single connection pricing, including the $210 fixed monthly drop fee) were used to determine the percentage reduction in revenue that would result from setting a flat monthly rate at a given price. This percentage reduction was then applied to total CPAU non-government billing to estimate the number of new customers required to make up the resulting decrease in revenue.

It was assumed that any current customers paying less than a given fixed rate price point would continue to pay their current rate.

<table>
<thead>
<tr>
<th>Monthly maximum service fee</th>
<th>$800</th>
<th>$1,000</th>
<th>$1,200</th>
<th>$1,400</th>
<th>$1,600</th>
<th>$1,800</th>
<th>$2,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly revenue reduction (%)</td>
<td>32%</td>
<td>23%</td>
<td>16%</td>
<td>11%</td>
<td>7%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>New subs to break even</td>
<td>115</td>
<td>69</td>
<td>42</td>
<td>24</td>
<td>13</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>
A (maximum) flat rate for service of $1,400 (total monthly cost of $1,610) would result in a revenue decrease of 11% or require that 24 new accounts be gained in order to maintain current total revenue. As discussed below, it is doubtful that as many as 24 new accounts would be gained in the near term by adopting a flat rate pricing strategy. This approach would, in all likelihood, result in a decrease in revenue.

Based on current connection patterns, where customer connections commonly terminate at PAIX, adoption of a flat maximum rate would have no impact on customers in the downtown area.

For customers and prospective customers in the Stanford Research Park area, a flat rate of $1,400 would put all tenants on a more or less equal footing. The current monthly service cost for tenants closest to downtown (in the California Ave./Page Mill Rd./El Camino Real area) ranges from $1,115 to $1,429, with the rest paying more, up to $2,443.

Elsewhere in Palo Alto, a flat rate of $1,400 would have a significant impact on pricing for the southeast area of the City, along San Antonio Rd, Fabian Way and East Meadow Circle (where extension of the current network is already planned). In that area, current service rates range from $1,972 to $2,435 per month.

However, a $1,400 flat rate would have little effect on current and prospective customers in the northeast area of the City (around East Bayshore Rd. and Embarcadero Rd.), where current service rates range from $1,147 to $1,510 per month. To have an impact in that area, the flat monthly service rate would have to be something like $1,000 per month, which would result in a 23% decrease in total system revenue and require an additional 69 customers to break even.

### 6.4. Commercial Property Pricing

“We have a $300 per month line of site antenna...plus a T1 line for our phones. So, we easily spend $500 per month or more. We’d be willing to pay more for better, faster service. Our tenants have similar opinions. They are willing to pay more for a better service but not five-times. So, at $700 per month it might be a ‘go’ whereas at $2,500 per month it’s not.”

“For ‘regular’ office users, many would sign up if the price was in the $500 to $1000 per month range.”

Comments by Palo Alto commercial property managers.

Flat rate pricing of $1,400 per month would not have much impact on smaller businesses. Factoring in the drop fee and approximately $1,000 per month for Internet bandwidth and a
connection at PAIX, the total cost would be about $2,600 per month, a maximum savings of about $1,000. Dropping the flat rate to $1,000 would put the monthly cost at about $2,200, still more than twice what most of those businesses would consider.

On the other hand, $2,600 per month would be easily affordable if several tenants of a commercial property were to share a connection. The major obstacle for this type of multiple customer scenario are the capital costs, which break out into CPAU costs for reaching the property, the cost of pulling fiber into a central point in a building and the cost of the associated electronics and internal cabling.

CPAU can only directly affect the cost of building an extension or drop to the edge of a property. The market perception that this cost is “several thousand dollars” is correct. Over the past 12 years, CPAU has estimated the cost of 530 non-government connections. The median price quoted is $7,619.

Based on an analysis of 293 CPAU fiber accounts that are either currently active or inactive accounts that show both project completion and disconnect dates, the average (mean) customer lifetime is 4.1 years.

<table>
<thead>
<tr>
<th>Years</th>
<th>All customers</th>
<th>Active customers</th>
<th>Disconnected customers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.1</td>
<td>5.8</td>
<td>2.0</td>
</tr>
</tbody>
</table>

If CPAU were to waive the non-recurring installation fee for multi-tenant commercial properties and raise the monthly drop fee by $200 to $410 per month, the average installation cost would be paid back in 3.5 years, well within the lifespan of an average customer. This estimate is based on the net present value of the extra monthly revenue and assumes a 5% cost of capital (a lower cost would result in a faster payback).

Internet service to tenants of a commercial office building could be provided by the property owner or an outside contractor. Either way, the business case for doing do is feasible.

This analysis assumes a CPAU flat monthly service rate of $1,400, a $410 monthly drop fee and no charge for constructing a fiber drop to the property line. If CPAU kept the monthly drop fee at $210 and charged the average construction cost, this capital cost would be shifted to the service provider, but the overall result would be very similar.

On the service provider side, this analysis assumes a monthly cost of $1,000 for an interconnection at PAIX and Internet bandwidth, and a monthly operating cost of $50 per
subscribing tenant, for equipment maintenance, customer support and billing, electricity and similar expenses.

<table>
<thead>
<tr>
<th></th>
<th>+$100</th>
<th>+$200</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV 1 year</td>
<td>$1,143</td>
<td>$2,286</td>
</tr>
<tr>
<td>NPV 2 years</td>
<td>$2,231</td>
<td>$4,463</td>
</tr>
<tr>
<td>NPV 3 years</td>
<td>$3,268</td>
<td>$6,536</td>
</tr>
<tr>
<td>NPV 4 years</td>
<td>$4,255</td>
<td>$8,510</td>
</tr>
<tr>
<td>NPV 5 years</td>
<td>$5,195</td>
<td>$10,391</td>
</tr>
<tr>
<td>NPV 6 years</td>
<td>$6,091</td>
<td>$12,182</td>
</tr>
<tr>
<td>NPV 7 years</td>
<td>$6,944</td>
<td>$13,887</td>
</tr>
<tr>
<td>NPV 8 years</td>
<td>$7,756</td>
<td>$15,512</td>
</tr>
<tr>
<td>NPV 9 years</td>
<td>$8,529</td>
<td>$17,059</td>
</tr>
<tr>
<td>NPV 10 years</td>
<td>$9,266</td>
<td>$18,532</td>
</tr>
<tr>
<td>Years to payback</td>
<td>7.8</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Discount rate: 5%

Two different capital cost levels were considered: $5,000 and $20,000, which would pay for bringing the fiber into a central point in the building, purchasing minimal distribution equipment and connecting to and/or supplementing the building’s existing interior cabling. A 10% cost of capital was used.

Any number of assumptions can be made, since properties and tenant needs differ widely, but these assumptions provide two examples of how such a business case might turn out.

The number of subscribing tenants needed to pay back the initial investment within the average lifespan of a CPAU customer, range from four tenants paying $1,000 per month (assuming $5,000 capital expense) to fourteen tenants paying $300 per month (at $20,000 capital expense). Eight scenarios were examined: Monthly tenant costs of $300, $500, $700 and $1,000, at both the $5,000 and $20,000 capital expense level. In all these scenarios, payback would be achieved in less than three years.
This “Fiber to the Basement” business model could be pursued by CPAU without any changes to the current rate schedule or cost recovery structure. As noted above, many commercial properties are close enough to downtown to qualify for a monthly service fee of $1,400 or less, and CPAU’s construction costs can be shifted to the service provider.

<table>
<thead>
<tr>
<th>Table 6.3 - “Fiber to the Basement” – Private Sector Provider Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Fee</td>
</tr>
<tr>
<td>NPV 1 year</td>
</tr>
<tr>
<td>NPV 2 years</td>
</tr>
<tr>
<td>NPV 3 years</td>
</tr>
<tr>
<td>NPV 4 years</td>
</tr>
<tr>
<td>NPV 5 years</td>
</tr>
<tr>
<td>NPV 6 years</td>
</tr>
<tr>
<td>NPV 7 years</td>
</tr>
<tr>
<td>NPV 8 years</td>
</tr>
<tr>
<td>NPV 9 years</td>
</tr>
<tr>
<td>NPV 10 years</td>
</tr>
<tr>
<td>Years to payback</td>
</tr>
<tr>
<td>Subscribing tenants</td>
</tr>
</tbody>
</table>

Discount rate: 10%

However, by setting a flat monthly service rate and amortizing the construction costs by increasing the monthly drop fee (either on a permanent or temporary cost recovery basis), CPAU can present a simple, easily understood selling proposition to local property owners and potential third-party providers. CPAU would save time and money by simplifying the proposal and estimating process, and could create a mechanism for contracting out the required pre-engineering and construction work, once a deal has been signed.

### 6.5. Recommendations

Setting a maximum flat rate monthly service price would simplify CPAU’s sales process and encourage greater adoption by customers at the lesser-used edges of the network, including mobile telecommunications companies with widely scattered locations. A
maximum flat rate of $1,400 would be particularly attractive to prospects in the Stanford Research Park area, where a third of current customers are located.

Even if no changes are made to the rate and cost recovery structure, it would be worthwhile to create a packaged selling proposition for multi-tenant office buildings and present it to local property owners. However, simplifying the pricing model, as described above, would make it easier to sell the service to commercial property owners who have limited expertise and interest in Internet services.

A simplified pricing model would also make CPAU’s fiber network more attractive to value-added resellers, who could devote the time and capital needed to develop the commercial property market. These third-party providers might be interested in negotiating a comprehensive agreement with CPAU, which could include initial outside plant engineering and construction services as well as customer premise expenses and ongoing operating costs. The actual level of third party provider interest could be explored via a request for proposal (RFP) process.
7. Residential Market

7.1. Overview

One possible use for the CPAU fiber network is to support residential broadband service. In the past, the City has explored different options for developing residential service, including building a City-operated fiber-to-the-home system and partnering with private companies. Studies have been done, a pilot project was started and eventually shut down and RFPs have been issued. To date, no viable option for deploying an FTTH network in Palo Alto has been found.

A City-operated FTTH network has been considered, tested, studied and ultimately shelved. Although the market for broadband services – including television, telephone and Internet access – is rapidly changing and the demand for Internet bandwidth is increasing, the fundamental economics still do not support the business case for a overbuild of the existing AT&T and Comcast networks.

Even though the existing CPAU fiber network provides a good base to build upon, deploying a citywide FTTH system would be very costly. Because the only way at present to generate sufficient income to support the operating and capital costs is by selling subscription television service, substantial market share, likely greater than 50%, and high average monthly revenue per subscriber, approaching $100 or more, would be necessary.

Palo Alto is served by two consumer-oriented, full service broadband providers (Comcast and AT&T) who offer high speed residential Internet service, extensive television lineups and telephone service. Although both companies are the target of complaints, they generally meet the broadband needs of most people in their service areas, including Palo Alto. Both companies have a national presence and millions of customers. They enjoy substantial operating economies of scale, including the ability to negotiate relatively good terms with television programming providers.

City-run systems do not have that ability. Consequently, it is usually impossible to compete with entrenched incumbents on the basis of price. Although an FTTH system could theoretically offer more television programming options, this competitive strategy usually results in lower net revenue and is not compelling to most prospective subscribers, particularly when employed against full-service providers such as AT&T or Comcast.

In Palo Alto's case, there is even less opportunity to finance the construction and operation of an FTTH system with television revenue. Median household income in Palo Alto is about double the statewide average. Generally speaking, higher income households perceive less value in subscription television service.
7.2. FTTH system comparisons

Results from FTTH deployments elsewhere are mixed. Bristol, a small town in rural Virginia, is considered a municipal FTTH success story. It reports positive net income with a market share of more than 60% and monthly revenue per subscriber near $100, competing successfully with Charter Communications.

Cedar Falls, Iowa is another community that has had success with municipal broadband. It went to market in 1996 using an HFC (hybrid fiber coaxial cable) system. It has achieved a market share of more than 50%, in competition with Mediacom Communications, and is currently in the process of converting to an FTTH system and expanding into neighboring areas, aided in part by a stimulus grant from the U.S. Department of Agriculture’s Rural Utilities Service.

On the other hand, iProvo, a municipally funded FTTH system in Provo, Utah, has struggled. It originally used a wholesale business model (sometimes referred to as an “open access” model), selling access to a variety of companies that, in turn, offered retail television, Internet and telephone services to residents. Financially, the venture was a failure. At one point, the city had to raise tax revenue to fund a shortfall. The system was finally sold to one of the retail providers, Broadweave, which then merged with the only other remaining retail provider on the system, Veracity. The first request of the combined company was to ask the city for additional financial relief.

Private sector companies that have built competitive broadband systems on top of incumbents (commonly called “overbuilders”) also have a mixed record. Last year, Abry Partners bought out RCN, an overbuilder that had been in failing financial health for some time, for $1.2 billion. Most of that amount was debt accumulated by RCN and assumed by Abry. One of Abry’s first moves was to separate RCN’s middle mile services (similar to CPAU’s dark fiber service) from its consumer and small business units.

In Sacramento, a company called Winfirst built an extensive FTTH system that failed financially. The Roseville Telephone Company, later renamed Surewest, bought the system out of bankruptcy for about a dime on the dollar and has been able to survive with a market penetration of around 34%, albeit with share values that have fallen by more than half over the past five years.

Surewest expanded into Kansas, through the acquisition of another overbuilder, Everest Broadband. The company sees Kansas as its principal growth opportunity and is not considering expansion in California, due to what it considers to be a less attractive business climate. Evidently, Google agrees that Kansas has potential, choosing Kansas City, Kansas
as the pilot community for its FTTH project. Surewest’s acquisition is near Google’s project area.

Strictly speaking, as an incumbent telephone company, Verizon Communications is not an overbuilder. In 2004 it started extending its fiber optic network directly to homes in its service area. At the end of 2010, Verizon reported its fiber network was available to 15.6 million homes with 3.5 million (22%) subscribing to television service and 4.1 million (26%) buying Internet access. The company has stopped most new FTTH construction and has no immediate plans to complete its build out.

7.3. Case study: City of Alameda

Like the City of Palo Alto, the City of Alameda operates its own electric utility. In 1996, when the Alameda Bureau of Electricity (later called Alameda Power & Telecom – APT) began investigating the establishment of a cable television business, the incumbent cable operator was TCI. At that time, TCI did not have a reputation in the industry for having state of the art facilities and it was perceived in the market as providing poor service.

In 1999, AT&T bought TCI and began trying to modernize and upgrade its systems. This job turned out to be a poor fit for AT&T, which was struggling to define itself in a rapidly changing industry. Following the dot-com and telecommunications crash in 2000-2001, AT&T sold its cable business to Comcast in 2002. Comcast began to take over operations in 2003 and was fully competing against APT by 2005.

During that same period (2001 to 2005), APT built out its own HFC cable television system, which it also used to provide Internet service (but not telephone service). In the process, the City of Alameda borrowed $33 million and began an aggressive marketing campaign to win subscribers.

In 2003, APT commissioned a study that formed the basis for its operations and financing going forward. The City of Palo Alto had a similar study done during the same time frame, by the same consulting company. Although these two studies were separate and differed in many respects, similar conclusions were reached.

The APT business plan assumed it would sell television service to about 39% of Alameda households (versus 38% for Palo Alto) and Internet service to 24% (versus 51% for Palo Alto). It predicted the system would be financially viable at that point. It also made assumptions about programming costs and the effectiveness of its primary competitor (initially TCI and finally Comcast) based on history and experience.
Though well-founded, those assumptions proved incorrect. Market share topped out at about 30%, programming costs skyrocketed and Comcast proved to be a very aggressive competitor. APT could not meet its financial obligations, and eventually sold the cable system to Comcast in 2008 for about fifty cents on the dollar. It is currently in litigation with its debtholders, who are trying to recover the millions of dollars they lost.

7.4. Conclusions

The City of Palo Alto has been exploring FTTH service for more than ten years. The financial prospects have not proven compelling to prospective private sector partners. Its original FTTH pilot project demonstrated technical feasibility but did not address the business case.

Municipalities with successful FTTH stories bear little resemblance to Palo Alto. Bristol and Cedar Falls are relatively isolated communities in rural areas, with second tier video service providers. As a university town with Comcast as the incumbent cable operator, Provo has marginally more in common with Palo Alto, and its FTTH venture has been a financial failure for the city.

Private sector FTTH overbuilders have had some successes, but not in the Bay Area. Surewest is doing reasonably well in Sacramento, but only after buying its principal fiber network there out of bankruptcy at a steep discount. RCN pulled out of the Bay Area in 2007. Both companies are more bullish on providing middle mile service and/or serving more isolated regions.

Although there are significant differences between Palo Alto and Alameda, the failure of the APT project should be accepted as a legitimate, real world test of Palo Alto’s current FTTH business case. Both cities operate their own electric utilities, are urban communities in the San Francisco Bay Area and are served by the same two highly competitive broadband system operators.

The factors that caused the failure of APT’s system – for example, rising programming costs and intense competition – would be equally problematic for Palo Alto. Until solutions are found or, more likely, there are structural changes in the telecommunications industry, the financial prospects for FTTH in Palo Alto are dim.

Broadband system operators face an uncertain future. The standard, video-supported business model is under increasing pressure as consumers access programming directly over the Internet. In the long run, revenue from Internet services is likely to increase and dependence on video revenues is likely to decrease.
This shift in the broadband business model could eventually make FTTH systems economically viable in markets such as Palo Alto. Considering the possibility of future services such as FTTH when evaluating network extensions, as Columbia Telecommunications Corporation did in its April 2011 report for the City of Palo Alto, makes sense.

For the present though, the broadband sector’s turmoil and uncertainty make FTTH system investments less attractive. The current state of the broadband market does not support a business case for a third, overbuild residential broadband system in Palo Alto.
8. Findings and Recommendations

In summary, the following conclusions have been reached:

1. CPAU’s core competency is providing reliable and relatively inexpensive dark fiber connectivity through much of the City.

2. CPAU’s dark fiber services are effectively marketed to organizations that need a correspondingly high level of bandwidth. CPAU’s market share and brand awareness are high within this segment. Stanford Research Park and downtown Palo Alto are two specific areas where CPAU has been very successful.

3. The entrepreneurial nature of the high technology and biomedical industries means there is steady turnover amongst staff and companies as a whole. A modest, highly targeted and ongoing advertising and promotion program will help maintain CPAU’s market position over time. Examples include:

   • Develop a fiber-specific, search engine optimized website so prospective customers can quickly learn about services.
   • Periodically do keyword-based advertising on major search engines.
   • Occasionally buy sponsorships for local information technology networking events, particularly in downtown Palo Alto and Stanford Research Park.
   • Work with economic development agencies and organizations to provide information about CPAU fiber services to newly arrived and prospective business.

4. Telecommunications services resellers are CPAU’s best customers, and are already positioned to provide higher-value added services such as Layer 2 support and Internet connectivity. CPAU should consider initiatives that would encourage and enable resellers to make services available to a wider range of businesses, rather than competing against resellers’ core competencies.

5. Mobile telephone companies are a category of telecommunications service provider that could also be addressed. CPAU should consider developing a comprehensive approach to this market segment, including extensions of the existing network and other facilities to better serve it.

6. Flat rate service pricing and amortizing construction costs via a flat or cost-recovery based increase in the monthly drop fee would simplify CPAU’s selling proposition and make the service more attractive to customers at the edges of the network. A revised pricing policy would also make CPAU’s dark fiber services more understandable and affordable for
potential customers who lack a high level of internal information technology support, for example commercial property owners.

7. A wider range of commercial properties could be served if CPAU worked with resellers and property owners to extend fiber connectivity to unserved office complexes, via a “Fiber to the Basement” business model, particularly one that created a mechanism for financing and contracting out pre-engineering and construction work when necessary. An RFP for such a program should be considered.

8. There are areas of the City that have concentrations of businesses and institutions that are not reached by the CPAU network. East Meadow Circle should be considered a high priority for network extension. The Sand Hill Road/Welch Road area is another good candidate for network extension, particularly if Stanford Medical Center and its affiliates have an interest. El Camino Real should also be considered generally on the basis of the economic development potential of fiber availability and specifically in terms of supporting mobile telephone companies and large commercial properties. An East Bayshore Road extension should be considered on the same basis.

9. The public schools in Palo Alto are within reach of the current network, and all can be reached via extensions.

10. There is no compelling case for providing fiber service directly to residences at this time. Palo Alto is served by large incumbent retail video and broadband service providers that enjoy decisive competitive advantages resulting from economies of scale. Comparable municipal broadband ventures have failed. It is unlikely that a City-run or supported residential fiber service would be able to achieve enough market penetration or subscriber revenue to support itself in the near term. Long term, the broadband business environment is very likely to change and might do so in a way that makes FTTH service financially viable. It makes sense to treat it as one of the many factors that should be considered when evaluating network extensions.
9. Appendix A - Tables and Spreadsheets

9.1. Prospective Network Extensions

<table>
<thead>
<tr>
<th>Segment</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>From Stanford Ave. and El Camino Real, south along El Camino Real to El Camino Real and Del Medio Ave.</td>
</tr>
<tr>
<td>2</td>
<td>From western termination (designated point AU by CPAU) on Quarry Road west to Welch Road.</td>
</tr>
<tr>
<td>A</td>
<td>From El Camino Real and Sand Hill Road, west on Sand Hill Road to Stock Farm Road.</td>
</tr>
<tr>
<td>B</td>
<td>From Sand Hill Road and Arboretum Road, south along Arboretum to Arboretum and Quarry Road.</td>
</tr>
<tr>
<td>C</td>
<td>From Quarry Road and Welch Road north on Welch and then curving west on Welch to Pasteur Dr.</td>
</tr>
<tr>
<td>D</td>
<td>From Sand Hill Road and Pasteur Road south on Pasteur to Welch and Pasteur (taking the westernmost leg of Pasteur).</td>
</tr>
<tr>
<td>E</td>
<td>From termination point designated AF by CPAU south of Alma Street and Fern Ave., south on Alma to northern leg of San Antonio Ave., then east on San Antonio Ave. to San Antonio and Middlefield Road.</td>
</tr>
<tr>
<td>3</td>
<td>From termination point designated CN by CPAU on East Bayshore Road, north to last parcel within city limits.</td>
</tr>
<tr>
<td>4</td>
<td>From East Meadow Drive (pole 3637) south on East Meadow Drive to pole 3706.</td>
</tr>
<tr>
<td>A</td>
<td>From East Meadow Drive and East Meadow Circle, around East Meadow Circle, forming, a complete loop around East Meadow Circle.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segment</th>
<th>Route</th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>From termination on Coulombe Drive north on Coulombe Drive to Maybell Avenue.</td>
</tr>
<tr>
<td>7</td>
<td>From El Camino Real and Barron Ave., west on Barron Ave. to Barron and El Centro Street.</td>
</tr>
<tr>
<td>8</td>
<td>From Heather Lane and Embarcadero, northeast on Heather to Channing Ave.</td>
</tr>
<tr>
<td>9</td>
<td>From Louis Road and Amarillo Ave., east on Amarillo for 200 meters.</td>
</tr>
<tr>
<td>10</td>
<td>From Louis Road and East Meadow Drive, south on Louis to 200 meters north of Greer Road.</td>
</tr>
</tbody>
</table>
## 9.2. Fiber to the Basement Business Model Scenarios

### Fiber to the Basement - Low Case
- Median CPAU installation fee: $7,619
- On-premises capital costs: $5,000
- Total: $12,619

<table>
<thead>
<tr>
<th>CPAU flat rate</th>
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<tbody>
<tr>
<td>Monthly opex per tenant</td>
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<tr>
<td>Monthly fixed opex</td>
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<td>Monthly fee per tenant</td>
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<td>Number of subscribing tenants</td>
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</table>

<table>
<thead>
<tr>
<th>Business Model (000s)</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<td>$43</td>
<td>$43</td>
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<td>CPAU fees</td>
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<td>$21</td>
<td>$21</td>
<td>$21</td>
<td>$21</td>
<td>$21</td>
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<tr>
<td>Building opex</td>
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<td>$19</td>
<td>$19</td>
<td>$19</td>
<td>$19</td>
<td>$19</td>
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<td>$3</td>
<td>$3</td>
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### Fiber to the Basement - High Case
- Median CPAU installation fee: $7,619
- On-premises capital costs: $20,000
- Total: $27,619

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<tr>
<th>CPAU flat rate</th>
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<tr>
<td>Monthly fixed opex</td>
<td>$1,000</td>
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<tr>
<td>Monthly fee per tenant</td>
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</tr>
<tr>
<td>Number of subscribing tenants</td>
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</table>

<table>
<thead>
<tr>
<th>Business Model (000s)</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
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<td>Tenant revenue</td>
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<td>$60</td>
<td>$60</td>
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</tr>
<tr>
<td>CPAU fees</td>
<td>$22</td>
<td>$22</td>
<td>$22</td>
<td>$22</td>
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<tr>
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<td>$23</td>
<td>$23</td>
<td>$23</td>
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</table>
10. Appendix B - List of Maps

1. Business Partner Parcel 100m Proposed Network
2. Business Partner Parcels 200m Proposed Network
3. Business Partners 50m COPA Data Connections
4. Business Partners 50m
5. Business Partners 100m COPA Data Connections
6. Business Partners 100m
7. Business Partners 200m COPA Data Connections
8. Business Partners 200m
9. Business Partners Greater Than 100m COPA Data Connections INDEX ALL
10. Business Partners Greater Than 100m COPA Data Connections INDEX
11. Business Partners Greater Than 100m INDEX ALL
12. Business Partners Greater Than 100m INDEX
13. Business Partners Greater Than 100m
14. Business Partners Greater Than 200m COPA Data Connections INDEX ALL
15. Business Partners Greater Than 200m COPA Data Connections INDEX
16. Business Partners Greater Than 200m COPA Data Connections
17. Business Partners Greater Than 200m INDEX ALL
18. Business Partners Greater Than 200m INDEX
19. Business Partners Greater Than 200m
20. New Business Partners ALL INDEX
21. New Business Partners ALL
22. New Business Partners INDEX
23. New Business Partners
**Active Ethernet or Active Optical Network (AON)**
Active Ethernet or Active Optical Network (AON) is a dedicated medium in which each user has a home gateway directly connected to the Ethernet router in the central office or street cabinet by a direct fiber. Between the central office and the end user, there can also be an aggregation Ethernet router. The AON dedicates a fiber from each user to the electronics. This means that each customer has a dedicated path to the electronics and does not share bandwidth directly with another customer in the neighborhood. An AON network has many more field lasers than a passive network since there is a 1:1 ratio between lasers and customers.

In an AON network, everything is encoded as data between the electronics and the customer. This means all services must be digitized and delivered as an IP data stream to the user. The AON uses only 2 wavelengths on each fiber – one for transmittal of data to the users and one for transmittal of data from the users.

Since everything on an AON is data, the only possible video product is IPTV. IPTV delivers one channel at a time to customers all of the time. IPTV delivers one channel at a time to customers as they request it. This is a different model than normal broadcast TV, where almost all channels are delivered to a customer all of the time. With IPTV, a customer must have a set-top box for each TV that wants to receive its own channel.

**Advanced Metering Infrastructure (AMI)**
AMI systems measure, collect and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters and water meters. Systems include hardware and software communications, consumer energy displays and controllers, customer associated systems, Meter Data Management (MDM) software and supplier business systems.

**Backhaul**
A term used to describe the transmission of customer usage data from a collection point back to a central point or network backbone.

**Dark Fiber**
Dark fiber is unused fiber through which no light is transmitted or installed. Fiber optic cable not carrying a signal. Sometimes dark fiber is licensed or sold by a carrier without the accompanying transmission service. It’s “dark” because it’s provided without light communications transmission. The customer is expected to put his/her own electronics and signals on the fiber and make it “light.”

**Distributed Antenna Systems (DAS)**
A DAS employs antennas placed atop utility poles approximately every half mile alongside a road to provide cellular coverage to vehicles and nearby neighborhoods.

**Ethernet-based Services**
Ethernet as a service (EaaS) is the use of high-bandwidth, fiber optic media such as Packet over SONET (PoS) to deliver 10 Mbps, 100 Mbps or even 1000 Mbps Ethernet service to one or more customers across a common bidirectional broadband infrastructure. Ethernet, a networking
technology defined in IEEE 802.3 and related specifications, is best understood as a carrier sense multiple access/collision detect (CSMA/CD) form of baseband networking. The service arrives to the recipient via a broadband channel that it must accommodate, manage, and service within its overall infrastructure.

(4G) Fourth-Generation
4G is the short name for fourth-generation wireless. The 4G stage of broadband mobile communications that will supersede third-generation (3G) wireless technology.

4.9 GHz Public Safety Band
The 4.9 GHz band is a licensed band available for use by public safety agencies. Any agency qualified for a 700 MHz license qualifies for a 4.9 GHz license. Generally, this covers all government entities, private companies sponsored by a government entity (such as private ambulance services) and any organization with critical infrastructure (power companies, pipelines, etc.).

Geographic Information System (GIS)
GIS is a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data. Practitioners also regard the total GIS as including the operating personnel and the data that go into the system. Spatial features are stored in a coordinate system (latitude/longitude, state plane, UTM, etc.), which references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. GIS can be used for scientific investigations, resource management, and development planning.

Layer-2
The data link layer in the Open Systems Interconnection (OSI) 7-layer model of the networking suite. Describes the logical organization of data bits transmitted on a particular medium. For example, layer-2 defines the framing, addressing and check-summing of Ethernet packets.

Long Term Evolution (LTE)
The next generation of 4G technology for both GSM and CDMA cellular carriers. Approved in 2008 with download speeds up to 173 Mbps, LTE was defined by the 3G Partnership Project in 3GPP Release 8 specification. LTE uses a different air interface and packet structure than previous 3G systems, which are GSM, UMTS, and CDMA’s EV-DO. However, it is envisioned that all GSM and CDMA2000 carriers will eventually migrate to LTE to provide an interoperable cellular system worldwide.

Node
A node is a point of connection into a communications network.

Passive Optical Network (PON)
PON is a shared medium in which a fiber is “passively” split into many end user connections. The term passive refers only to the optical splitter, which does not require external electrical power to function. Each end user has an Optical Network Unit (ONU) while the fiber terminates at a central office (CO) in an Optical Line Transmitter (OLT), which requires electrical power. Between the OLT and the ONU may be one or two stages of passive splitters which split the
connection to multiple end points. The Passive Optical Network (PON) uses passive hardware to “split” the signals so that a single high-powered laser can be shared by up to 64 customers (more typically 32 customers). This technology requires less fiber than an Active Optical Network (AON) since many customers in a row or in an areas share the same single fiber over which the information carried on the fiber is ‘split” into 32 individual fiber drop paths for delivery to homes or businesses. In construction, one feeder fiber “feeds” a passive splitter that takes the information that is transmitted onto the feeder fiber and distributes across 32 or 64 individual fiber drops similar to the way water in a single pipe can be sent to 32 individual locations by placing a 1-to-multiple pipe junction on a single feeder water pipe.

**Synchronous Optical Network (SONET)**
SONET is a standard for connecting fiber optic transmission systems. SONET defines interface standards at the physical layer of the OSI (Open System Interconnection) seven-layer model. The standard defines a hierarchy of interface rates that allow data streams of different rates to be multiplexed. SONET established Optical Carrier (OC) levels from 51.8 Mbps (OC-1) to 9.95 Gbps (OC-192). Prior rate standards used by different countries specified rates that were not compatible for multiplexing. With the implementation of SONET, communication carriers throughout the world can interconnect their existing digital carrier and fiber optic systems.

**Virtual Private LAN Services (VPLS)**
VPLS – Ethernet-based services which allow multi-point businesses to operate as a single meshed network.

**Wave Division Multiplexing (WDM)**
WDM technology is a technology that increases the capacity of an optical fiber by simultaneously operating at more than one wavelength, and at as many as four wavelengths within a single strand of fiber. With WDM you can multiplex signals by transmitting them at different wavelengths through the same fiber. Variations of WDM technology are Coarse Wavelength Division Multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM).

**White Space Spectrum**
White space refers to locally unused portions of the broadcast television spectrum, which the FCC has opened up for unlicensed use.

**Wireless Fidelity (Wi-Fi)**
A wireless networking technology that uses radio waves to provide network connections and access to high-speed Internet.

**Worldwide Interoperability for Microwave Access (Wi-MAX)**
Wi-MAX is a telecommunications protocol that provides fixed and mobile Internet access. Wi-MAX uses licensed spectrum and is a wireless technology that is being used for 4G networks.