BROADBAND OVER POWER LINE:
A REGULATORY ECONOMIC ANALYSIS

by
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Broadband over Power Line: A Regulatory Economic Analysis

Thesis directed by Dr. Patrick Ryan

Abstract

Broadband over Power Line (BPL) has gained recent notoriety as the technology that may finally allow universal access to broadband data services. Power lines reach virtually all corners of our nation; consequently, they hold the unique potential to provide ubiquitous broadband service without the cost of additional infrastructure build-out. However, BPL still faces significant stumbling blocks towards achieving market acceptance. BPL is a late entry into the broadband services market and faces a number of technical, regulatory and financial obstacles. This paper will examine the issues that BPL must overcome in order to position itself as a major player in the broadband market. It is only through achieving the necessary objectives in each of these issues that BPL will be able to successfully compete in the broadband services market.
This thesis work is dedicated to overcoming the obstacles of broadband internet delivery so that all people are able to realize the potential of the Information Age. May technological development of BPL and other similar services provide the means to overcome the “Digital Divide.”
ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Patrick Ryan, for his guidance; my colleague, Brian Goldhardt, for his knowledge of the thesis writing process; Vicki Darabcsek for her work as an editor; Vince Amman, Rich Sperduto, and Dalton Perras for their insight into the regulation of electric utilities; my parents, Kathy and Jim, for their devoted support; and finally my fiancé, Elizabeth, for her continued inspiration.
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Chapter 1 - Introduction

1.1 Background

The Internet of today is in the process of a dramatic change. As society becomes increasingly reliant on the Internet as a critical medium of communication, the bandwidth necessary to carry this information is also growing rapidly. The shift from 56 Kbps dial-up access to multi-megabit connectivity has been termed by many as “The Broadband Revolution”¹. Although the narrowband Internet is universally available to all homes over the public switched telephone network (PSTN), the infrastructure necessary for delivering ubiquitous broadband² access does not necessarily exist. Many new technologies are currently used to provide broadband access, including Digital Subscriber Lines (DSL), cable modems, fixed wireless, and broadcast satellite. However, none of these access technologies have the capability to reach every home in America such as the power utilities can. By utilizing the existing power line utility infrastructure, broadband over power line (BPL) presents the unique opportunity to provide truly universal broadband access.

1.2 Purpose and Scope

The purpose of this thesis is two-fold. The first objective is to assess the obstacles BPL faces to gaining widespread acceptance and address what role technology will play in addressing these obstacles. The second objective is to determine what objectives must be achieved to ensure the feasibility of BPL and conjecture how these objectives will allow BPL to serve as a competitive broadband access technology. This thesis will educate the reader with the fundamental background knowledge of BPL technology that is necessary to understand the capabilities and limitations of its services. We will consider the topic of

² The term broadband, while widely used, does not have a published definition. It is generally accepted to mean a connection rate of ISDN (128 Kbps) or better.
interference, its relation to the Federal Communications Commission (FCC)\textsuperscript{3} rulemaking process, and how the rules established for BPL will ultimately affect its ability to coexist. The reader will be introduced to the foundations of regulated industries and theorize how BPL will fair as a competitive service in a non-competitive industry. We will explain the economic principle of externalities and argue how the inherent positive externalities existing in BPL services may be properly accounted for. Finally, this thesis will argue what objectives BPL must achieve to gain widespread acceptance as a competitive broadband access technology.

1.3 Thesis Organization

Despite being heralded by FCC Chairman, Michael Powell, as the “ubiquitous third broadband pipe to the home,”\textsuperscript{4} BPL still faces significant obstacles in gaining market acceptance. This thesis hopes to address the three most significant issues for BPL acceptance:

1. The technical and regulatory obstacles caused by harmful interference.
2. The financial complications of a competitive service in a regulated industry.
3. The challenges associated with internalizing the positive externalities of BPL.

<table>
<thead>
<tr>
<th>Table 1 – Issues for BPL Acceptance</th>
</tr>
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<tbody>
<tr>
<td>Each main argument will be presented in a separate chapter. The first chapter is an introduction to the purpose and organization of this thesis. The second chapter will familiarize the reader with the necessary background information on BPL technologies. It will present a high level view of carrier current systems and describe their integration with the electric power grid. The third chapter will investigate the issue of interference. We will begin with an examination of the events of the BPL rulemaking process and finish with an</td>
</tr>
</tbody>
</table>

\textsuperscript{3} Federal Communications Commission. See http://www.fcc.gov/ (last visited March 10, 2005). The Federal Communications Commission (FCC) is an independent United States government agency, directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite and cable.

evaluation of what effect permanent rules will have the deployment of BPL. The fourth chapter will focus on the financial and regulatory issues of BPL. It will consider the market environment of a regulated utility and analyze the incentives that BPL presents to utilities and their customers. The fifth chapter will assess the role of externalities in BPL. We will examine the market incentive issues for BPL services, including ways to recover the costs of positive externalities. The sixth and final chapter will review the arguments made in this thesis and will conclude with our suggestions of how our research can be further applied to determining the market feasibility of BPL.
Chapter 2 - BPL Technology

2.1 Introduction

Broadband over power line is a method for sending high-speed communications information over electric utility lines. BPL achieves this goal by coupling radio frequency energy onto existing power lines in addition to the alternating electric current (AC). This technique allows high data rate communications in both the electric distribution grid of a utility company and within the in-wall wires of a customer facility. This is accomplished by using a number of devices to place the signal onto the wire, ensure it is transported with enough strength and integrity, and finally to receive and process the signal. This chapter will investigate the different types of BPL, the techniques and equipment used, and finally reviews the standards development process.

2.2 BPL Types

BPL is traditionally split into two types: In-house BPL and Access BPL. The two types are differentiated by their use and radiation characteristics. In-house BPL systems have been in use for many years without the need for a formal classification because their low emissions present minimal risk of interference. Since Access-BPL systems work over greater distances at a much higher power, they inherently have more radiated emissions than the in-house BPL systems. This trait combined with the open air characteristics of Access BPL presents a significantly higher potential for interference with licensed services which will be discussed further in later chapters. The FCC has ruled in favor of classifying the two systems individually. The following sections will describe the characteristics and usage of each system.
### 2.3 In-house BPL systems

The first widely used application of BPL was for home networking on the low voltage electricity lines within the household and was termed In-house BPL. In-house BPL systems directly compete with the coaxial cable, phone line, and wireless solutions. In-house BPL was once preferred over the phone and cable line systems because all areas of a household are wired for electric, whereas only certain locations in the house have phone and cable outlets. Several years ago, the In-house BPL solution also offered lower prices than wireless systems due to the expensive electronics need to modulate a wireless signal onto an RF carrier. However, in the past few years the wireless systems (WiFi)\(^5\) have dropped dramatically in price and have largely overtaken the in-house wired alternatives. The In-house BPL systems are now beginning to gain popularity because of their ability to interoperate with Access BPL systems to reach networks located outside the household such as the Internet.

The transmission standards for In-house BPL were developed by the HomePlug Powerline Alliance\(^6\). The HomePlug physical layer standards use Orthogonal Frequency Division Multiplexing (OFDM)\(^7\) much like the DSL standards, but use a burst mode rather than a continuous mode. The standard uses 84 carriers within the 4.5-21 MHz band and has

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\(^5\) The WiFi Alliance. See [http://www.wi-fi.org/OpenSection/index.asp](http://www.wi-fi.org/OpenSection/index.asp) (last visited March 9, 2005). The WiFi alliance is a nonprofit trade organization. The Wi-Fi Alliance has three purposes: To promote Wi-Fi worldwide by encouraging manufacturers to use standardized 802.11 technologies in their wireless networking products; to promote and market these technologies to consumers in the home, SOHO and enterprise markets; and last but certainly not least, to test and certify Wi-Fi product interoperability.


\(^7\) Orthogonal Frequency Division Multiplexing (OFDM). OFDM divides the high-speed data stream to be transmitted into multiple parallel bit streams, each of which has a relatively low bit rate. Each bit stream then modulates one of a series of closely spaced carriers. The property of orthogonality is a result of choosing the carrier spacing equal to the inverse of the bit rate on each carrier.
“notched out” allocations for amateur radio bands. Figure 1 compares the features of OFDM with similar modulation schemes.

<table>
<thead>
<tr>
<th></th>
<th>OFDM</th>
<th>Spread Spectrum Techniques (FH and DS)</th>
<th>Single Carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Efficiency</td>
<td>Good</td>
<td>Poor</td>
<td>Moderate</td>
</tr>
<tr>
<td>Robustness Against Channel Distortions</td>
<td>Excellent</td>
<td>Not Good</td>
<td>Good</td>
</tr>
<tr>
<td>Robustness Against Impulsive Noise</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Ability to adapt to channel changes</td>
<td>Excellent</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>EMC Aspects</td>
<td>Good</td>
<td>Good-Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Implementation Costs (Equalizers, etc.)</td>
<td>Fair</td>
<td>Poor</td>
<td>Poor (Equalizers required)</td>
</tr>
</tbody>
</table>

Figure 1 – OFDM Feature Comparison

The variable rate OFDM of in-house BPL allows raw throughput rates of 10-14 Mbps in the HomePlug 1.0 standard. Figure 2 shows a throughput comparison between the HomePlug standard and the other home networking competitors, all of which are suitable for sharing a broadband connection. In-house BPL devices have been in use for years and present minimal risk of interference because they have very low radiated emissions. The radiated emissions from an In-house system are almost always confined within the walls of the household and thus present a low risk of external interference with licensed services. The FCC has

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9 Ibid.

10 Gardner, Brian Markwalter, and Larry Yonge. “HomePlug Standard Brings Networking to the Home.” http://www.commsdesign.com/main/2000/12/0012feat5.htm (last visited March 10, 2005). Technical specifications were provided within the article. This article describes the technical details of the HomePlug Alliance standards and is directly referenced from the HomePlug Powerline Alliance website.
established a separate classification for In-house BPL systems, allowing the technology to continue to evolve free from the constraints of Access-BPL.

<table>
<thead>
<tr>
<th>Physical Layer</th>
<th>HomePlug</th>
<th>10 Mbps Ethernet</th>
<th>IEEE 802.11b</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC Layer</td>
<td>8.2</td>
<td>9.8</td>
<td>7.48</td>
</tr>
</tbody>
</table>

Figure 2 – HomePlug Data Throughput (Mbps)\(^{11}\)

### 2.4 Access BPL Systems

Recently, electric utility providers have been advocating the deployment of broadband Internet access on medium voltage power lines (Access BPL). These signals are capable of being carried throughout the utility power distribution grid. Since its existence, BPL has used several names according to its capabilities. In its earlier stages this technology was also referred to as Power Line Communications (PLC). PLC has been in use for over 25 years in a low data rate analog format.\(^{12}\) Recent advances in modulation techniques and technology have led to significant increases in the throughput of power line carriers. This new class of high data rate power line carriers is commonly referred to as BPL.\(^{13}\) Due to its greater potential to enter the broadband service market, this study will focus primarily on Access BPL, rather than In-house BPL. For the simplicity of this paper, I will be referring to Access BPL systems simply as BPL. Any further references to BPL will imply Access BPL unless specifically stated as In-house BPL.

### 2.5 Classification of BPL

Access BPL is regulated under Rule 15 of the FCC as an unregulated, low power service operating on a non-interference basis. Since the radio frequency (RF) energy of BPL

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\(^{13}\) The general distinction made between PLC and BPL is that BPL data rates are in the megabits.
is injected onto a medium voltage power line it is defined by FCC Part 15.3(ff) as a carrier current system:

“A carrier current system installed and operated on an electric utility service as an unintentional radiator that sends radio frequency energy on frequencies between 1.705 MHz and 80 MHz over medium voltage lines or over low voltage lines to provide broadband communications and is located on the supply side of the utility service’s points of interconnection with customer premises.”

This definition further implies that since BPL signals are taken directly off the wire rather than through the radiated signals, the radiation is neither wanted nor intentional and is thus classified and regulated as an unintentional radiator. All radiators, intentional or unintentional, are regulated to meet certain limits for both conducted and radiated emissions. Part 15.209 rules regulate the amount of conducted and radiated emissions that may be coupled to a carrier current system. Since almost all possible interference potential from BPL systems is radiated, not conducted, and the conduction measurements on 40,000 volt medium power line can be very dangerous, the FCC has ruled that primary enforcement will be through radiated emissions testing. The emission limits for radiation below 30 MHz are clearly defined and have traditionally been rigorously enforced. The strict enforcement of the lower frequencies is due to their long wavelengths, some up to 10 meters. A wave of that length has the characteristics that allow it to propagate for very long distances. The fear is that these very long wavelengths may radiate from the long open stretches of overhead wires which have the capability to act as a large antenna when carrying electric current.

2.6 BPL Technology

BPL is a method for sending high-speed communications information over electric utility lines. Since the alternating current of electricity is at 60 hertz and the BPL signal is

thousands of hertz, both signals can be carried across the same wire. There have been several enabling technologies recently created that have made BPL a viable technology. The most significant advancement has been in the methods of signal modulation. As stated in the earlier In-house BPL section, the signal modulation technique used in Access BPL is OFDM. The important characteristic of OFDM is its ability to spread the data signals over a much greater bandwidth allowing it to adaptively overcome noise in the communication system. The use of OFDM is also considered a critical feature allowing BPL to avoid certain frequencies.\textsuperscript{15} Since OFDM uses multiple simultaneous sub-carriers operating at different frequencies, these frequencies can be selectively chosen in order to avoid interference with licensed frequencies.

BPL has only recently become economically viable due to the creation of faster chipsets to perform signal encoding and decoding at a very high rate. A broadband signal carries a significant amount of data that must be digitally encoded and decoded with a very low processing delay. The cost of these chipsets has plummeted in the recent years and dramatically reduced the price of BPL equipment. Another enabling technology is the digital amplification techniques that allow the integrity of a signal to be kept during the regeneration process across the distribution network. The signal strength and integrity is reduced by attenuation of the signal over long stretches of distribution feeder. The signals are also degraded due to small impedance differentials at the interconnection of different media types. Using normal power line facilities in the US, the signal must be regenerated and repeated approximately every mile to ensure its integrity. Because of the number of repeaters needed for large distribution grids, the availability of low-loss digital amplification equipment significantly affects the economic viability of BPL systems.

\textsuperscript{15} The practice of “notching” certain frequency bands to avoid interference will be discussed in chapter 3.
The standard equipment consists of an injector to interface between the data services and the power line, repeaters to ensure the minimum signal strength and integrity, and extractors to interface between the medium voltage lines and the device serving the household. The lifecycle of electricity from generation to household use can be split into eight hops:\footnote{16}{“Broadband over Power Lines Part 1.” Bernstein Market Research Call Report 5 August 2004. This market report outlined the business prospects of BPL. It described the current state of technology, detailed a visit to a live trial of a Cinergy deployment in Cincinnati, and forecasted the business potential in the BPL segment.}

1. Generation - The Power Plant
2. High-voltage transmission lines – Regional transmission (100 - 700 kilovolts)
3. Substation for voltage step-down – Utility company
4. Medium-voltage transmission lines – Local distribution (10 - 40 kilovolts)
5. Low-voltage step down and transformer – Street distribution (220 volts)
6. Drop from transformer to customer premise – Single home feed
7. House meter - Distribution to internal wiring
8. Wall sockets

\begin{table}[h]
\centering
\caption{Electricity Lifecycle}
\begin{tabular}{|c|}
\hline
1. Generation - The Power Plant \\
2. High-voltage transmission lines – Regional transmission (100 - 700 kilovolts) \\
3. Substation for voltage step-down – Utility company \\
4. Medium-voltage transmission lines – Local distribution (10 - 40 kilovolts) \\
5. Low-voltage step down and transformer – Street distribution (220 volts) \\
6. Drop from transformer to customer premise – Single home feed \\
7. House meter - Distribution to internal wiring \\
8. Wall sockets \\
\hline
\end{tabular}
\end{table}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3}
\caption{End-to-end BPL Technology\footnote{17}{Tongia, Rahul. “Promises and False Promises of PowerLine Carrier (PLC) Broadband Communications.” Techno-Economic Analysis. Department of CS, Engineering, and Public Policy, Carnegie Mellon University.}}
\end{figure}
The BPL signal is injected into the medium voltage distribution lines using a coupler between steps 3 and 4. This is shown as the coupler that receives the datacenter uplink in Figure 3. This signal then propagates until it reaches the transformer for step-down. This is shown in Figure 3 as the distribution transformer located between the couplers on the final utility pole. The step-down process involves changing the medium voltage current to low voltage for secondary distribution into the household. At this point the power companies face a significant technological issue. Although low frequency signals, such as AC power at 60 Hz, can easily pass through the transformer, higher frequency signals are impaired. The BPL signal cannot step-down through the transmitter with the electric current because the attenuation in this process degrades the signal to below usable quality.

2.7 Voltage Step-down

Utility companies have chosen to solve the issue of transformer step-down using a variety of solutions. Two distinct methods have been chosen by the leading BPL technology providers, Amperion\(^\text{18}\) and Current Technologies\(^\text{19}\). In the first solution, the signal must be taken off the medium voltage lines and re-coupled onto the low voltage drop to the home with a device called a power line bridge. Using this method the signal is removed from the medium voltage line, avoids the transformation step down, and is re-coupled to the low

\(^{18}\) Amperion. See [http://www.amperion.com/default.asp](http://www.amperion.com/default.asp) (last visited March 10, 2005). This figure shows hops three through eight using the corresponding Amperion equipment. Amperion is a pioneering powerline communications company that develops networking hardware and software to enable the delivery of high-speed broadband data over the medium-voltage utility lines. Amperion's products allow service providers and utilities to use existing powerline infrastructures to provide high-speed data transport and enhance utility services economically and with minimal capital investment.

\(^{19}\) Current Technologies. See [http://www.currenttechnologies.com/](http://www.currenttechnologies.com/) (last visited March 10, 2005). Current Technologies is an industry leading provider of BPL solutions. Current is focused on building and delivering innovative BPL equipment and networks. Current Technologies BPL network equipment also enables utilities to offer new, enhanced power distribution services such as automated meter reading, automatic outage detection, and demand side management.
voltage line. The subscriber is then able to access the BPL signal using traditional in-house HomePlug devices. This method is chosen by Current Technologies as shown in Figure 4\textsuperscript{20}.

The second option is to pass the BPL signal from the medium voltage lines directly into a wireless device. This wireless device then delivers the signal to the customer devices using WiFi. This is the method utilized by Amperion shown in Figure 5\textsuperscript{21}.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{BPL_Power_Line_Bridge}
\caption{BPL Power Line Bridge}
\end{figure}


\textsuperscript{21} Amperion. http://www.amperion.com/uploadedfiles/Amperion%20Connect%20Brochure%202.pdf (last visited March 10, 2005). This figure shows hops three through eight using the corresponding Amperion equipment.
Although the problems associated with the voltage step-down process have been solved by the BPL technology providers, the equipment used in the solution adds a significant amount of cost and complexity to the BPL system.

### 2.8 Standards

The Institute of Electrical and Electronics Engineers (IEEE)\(^{22}\) has begun the development of a standard P1675, which address the installation and safety of BPL. Due to the volatile nature of electric lines, this standard hopes to describe best practices that ensure adherence to applicable codes. This standard limits its scope to the installation and testing of BPL services, and does not include hardware, data transmission, or any details on the communication systems. The inner workings of the BPL communication systems are generally proprietary and characteristic are highly dependant on the equipment provider. The

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\(^{22}\) The Institute of Electrical and Electronics Engineers (IEEE). See [www.ieee.org](http://www.ieee.org) (last visited March 10, 2005). The IEEE is a leading authority in technical areas including computer engineering, telecommunications, and electric power. It also serves as a standards setting body for technical specifications.
throughput provided by operational BPL systems is currently in the 2-24 Mbps range\textsuperscript{23}. The uplink bandwidth is split at the transformer, making it a shared medium much like cable.

BPL equipment providers are optimistic about the future bandwidth capabilities of BPL. The Home Plug Power Alliance has been developing a replacement for the HomePlug 1.0 specification called HomePlug AV that is capable of 200 Mbps. The regulatory stability that has recently been established in the BPL industry is likely to drive newer, faster, and cheaper BPL solutions.

2.9 Outlook for BPL Technology

The advances in BPL technology have led to a substantial reduction the cost of BPL equipment to a price level that is competitive with cable and DSL systems. The ability to offer broadband services in addition to operational communications differentiates the new developments in BPL from the existing power line communications. The advanced OFDM modulation techniques used in power line carriers are capable of overcoming noise and also offer the ability to notch out specific bands in the case of interference. Despite the challenges that the voltage step-down process presents at the transformer, several technology companies have devised innovative ways of circumventing this obstacle. As the interest in this new technology has grown, advances in BPL technology have led to increasingly higher data rates, decreasingly lower technology costs, and the continued development of standards.

\textsuperscript{23} Although the numbers have a very large range, the common trend is recent large jumps. The 24 Mbps is for Amperion.
Chapter 3 - Interference

3.1 Introduction

Although the BPL signal is coupled to the power lines, the signal still escapes the line and acts as an unintentional radiator, presenting a significant potential for interference with other licensed devices in its spectrum range. The issue of radiated emissions of BPL deployments has been debated in the United States and has led to a codification of rules for carrier current systems by the FCC. The process began in April of 2003, when the FCC initiated a public Notice of Inquiry (NOI) for the carrier current system of Broadband over Power Lines. As an unintentional radiator, BPL is required to abide by the rules of an unlicensed service defined in part 15 of the commission rules. Since the existing rules do not properly classify BPL services, the inquiry was created to outline proposed changes to the FCC rules governing unlicensed devices. This NOI resulted in over five thousand replies, many of which were dedicated to the measurement of harmful interference. Incumbent users of the licensed amateur radio spectrum expressed their guarantee of protection from all forms of interference that they are afforded by radio licenses. BPL technology providers responded by demonstrating interference mitigation techniques that would allow BPL to operate as an unlicensed service. The FCC stance was unclear as to whether interference from an unlicensed service must be avoided *ab initio* or mitigated *post hoc*. In an apparent victory by

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24 Federal Communications Commission public inquiry process. See [http://www.fcc.gov/](http://www.fcc.gov/) (last visited March 10, 2005). The FCC is based on a system of openness and seeks the comments of the public when ruling on any major issue. All information used in the decision making process is released to the public and all comments are submitted electronically so they can be viewed by others. All FCC documents referred to in this paper can be downloaded directly from the FCC e-filing system and website.

25 “FCC Notice of Inquiry, In the Matter of Carrier Current Systems, including Broadband over Power Line Systems.” ET Docket No. 03-104. 28 April 2003. When telecommunications laws are passed by congress, it is the responsibility of the FCC to establish rules enforcing these laws. The Commission actively seeks comments from the public while developing these rules. This involves a multiple step process of soliciting comments, proposing rules, and reporting the final order. The Notice of Inquiry (NOI) is the first of these three steps. All FCC documents are made available to the public on their website.

26 FCC Rules and Regulations. Title 47 of the Code of Federal Regulations, Office of Engineering and Technology. Section 15.3(m). Part 15 of the FCC Rules pertains to the operation of unlicensed services. The section in question defines interference in relation to licensed services.
proponents of BPL services, the FCC issued a final Report and Order in October of 2004, restating the views established within the FCC during the NOI and Notice of Proposed Rulemaking (NPRM)\(^\text{27}\) proceedings. This order established permanent rule changes in the classification of BPL technology as an unlicensed device and detailed the specifics for BPL interference measurement and avoidance techniques. This chapter will investigate the issues brought up in the proceedings, the motivations for the rule changes, and how the rule changes could affect the market feasibility of BPL services.

### 3.2 Experimental Licenses

After receiving the initial comments of the 2003 NOI, the FCC began granting experimental licenses for test deployments of Access BPL in the 1.7-80 MHz range. The stated purpose of the experimental trials was to investigate the interference and propagation environment of BPL, determine the types of interference mitigation techniques, develop an equipment authorization process, establish a method of registering BPL usage, and develop a standardized method for testing BPL signals.\(^\text{28}\) The current licenses in operation today represent each of the major players in the BPL technology provider space [Figure 6].\(^\text{29}\)

<table>
<thead>
<tr>
<th>BPL Applicant and Provider</th>
<th>Date</th>
<th>Status</th>
<th>File Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amperion, Inc.</td>
<td>3/7/2003</td>
<td>Granted</td>
<td>0046-EX-PL-2003</td>
</tr>
<tr>
<td>Hawaiian Electric Company, Inc.</td>
<td>5/2/2003</td>
<td>Granted</td>
<td>0089-EX-PL-2003</td>
</tr>
<tr>
<td>Ambient Corporation</td>
<td>8/7/2003</td>
<td>Granted</td>
<td>0050-EX-ML-2003</td>
</tr>
<tr>
<td>Current Technologies, LLC</td>
<td>1/30/2004</td>
<td>Granted</td>
<td>0025-EX-RR-2004</td>
</tr>
<tr>
<td>AT&amp;T Corporation</td>
<td>4/2/2004</td>
<td>Granted</td>
<td>0072-EX-PL-2004</td>
</tr>
<tr>
<td>Southern Telecom, Inc.</td>
<td>8/24/2004</td>
<td>Granted</td>
<td>0120-EX-RR-2004</td>
</tr>
<tr>
<td>Current Technologies, LLC</td>
<td>12/6/2004</td>
<td>Pending</td>
<td>0090-EX-ML-2004</td>
</tr>
</tbody>
</table>


\(^{28}\) “FCC Notice of Inquiry, In the Matter of Carrier Current Systems, including Broadband over Power Line Systems.” ET Docket No. 03-104. 28 April 2003. Experimental Deployment Trials gave utility companies the ability to test BPL services before the creation of the final rules.

\(^{29}\) Chart derived from BPL Deployment and Field Trials page on ARRL webpage. See http://www.arrl.org/tis/info/HTML/plc/deploy.html#Experimental (last visited March 10, 2005).
The experimental licenses were granted on the grounds that the BPL services will operate within the guidelines of Part 15 regulations. Despite these guidelines, hundreds of interference complaints were filed with the FCC. The interference concerns are a direct resultant of the fact that overhead electric power lines are not inherently or procedurally shielded and therefore radiate portions of any RF energy that they carry. The majority of the interference complaints were from licensed spectrum users such as Amateur radio operators operating within their assigned frequency. The next few sections will examine the licensed radio spectrum allocations that have been awarded within the private and public sector.

3.3 Incumbent Spectrum Users

Within the 1.7 to 80 MHz range utilized by BPL, incumbent licenses exist for the authorized use of many types of radio services that have been specifically allocated because of the inherent propagation characteristics within these particular frequencies. These services include fixed, land mobile, aeronautical mobile, maritime mobile, radiolocation, broadcast radio, amateur radio, and radio-astronomy. This band consists of the high end of the medium frequency band (MF), the high frequency band (HF), and the very low end of the very high frequency band (VHF). Many of these services exploit characteristics of propagation at particular wavelengths to accomplish their effectiveness and thus cannot be relocated to another spectrum band. The 1.7 – 80 MHz range consists of 157 frequency bands that are classified by the National Table of Frequency Allocations as exclusive federal, exclusive

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30 Comments and complaints for all FCC proceedings are filed to the e-filing system and are publicly accessible. Interference complaints for the experimental licenses can be found by searching ET Docket No. 03-104. See www.fcc.gov/e-file/ (last visited March 10, 2005).
31 “United States Frequency Allocations Table.” Department of Commerce, Office of Spectrum Management. This allocation table represents the licenses granted within the Radio Frequency (RF) spectrum of the United States. This table is established in cooperation between the Department of Commerce, FCC, and NTIA.
non-federal or shared. A total of 110 bands are shared, with the federal and non-federal users having 12 and 34 exclusive bands, respectively.

### 3.4 Frequency Protection

As a member of the International Telecommunication Union (ITU)\(^{32}\) the United States’ foremost obligation is to abide by international treaty, as set out in the ITU Radio Regulations. The ITU Radio Regulations, appendixes 13 and 15, list a set of specific frequencies that must be protected by all members of the Union. Of particular interest to the BPL community, ITU Radio Regulation RR 4.11 dictates:

> “Member states recognize that among frequencies which have long distance propagation characteristics, those in the bands between 5 MHz and 30 MHz are particularly useful for long-distance communications; they agree to make every possible effort to reserve these bands for such communications. Whenever frequencies in these bands are used for short-or medium-distance communications, the minimum power necessary shall be employed.”\(^{33}\)

This statement outlines the critical need to protect segments of the radio spectrum that utilize the characteristics of their assigned frequencies, and thus cannot be relocated. Because of the special propagation characteristics of the HF bands, the ITU recognizes their scarcity for long-distance communications, and requests that they be afforded special protections. The ITU makes no specification or recognition of secondary or unlicensed overlays as long as the primary licensed service has exclusive rights. Since BPL services operate within the 5 MHz to 30 MHz band, the FCC has an obligation to enforce regulation standards to prevent international corruption of these frequencies.

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32 International Telecommunication Union. See [www.itu.int/home/index.html](http://www.itu.int/home/index.html) (last visited March 10, 2005). The ITU is an international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services. The Union was established as an impartial, international organization where governments and the private sector could work together to advance the development of communications technology.

3.5 Spectrum Exclusions

The FCC, NTIA, and ITU are obligated to make special exclusions for spectrum ranges that host critical services that must be protected. These critical services include emergency services, law enforcement, military, scientific research, and long-distance communication. For the specific range in question, the FCC lists protected frequencies in the Rules and Regulations Part 15, 80, and 87. These protected bands are used for public safety, navigation, radio astronomy, and other critical services. In response to the FCC NOI and request for comments regarding the rules pertaining to BPL, the NTIA released Report 04-413, identifying several sources of concern regarding interference, and outlining studies they would perform to address those concerns. In this report, the NTIA declares that it has 41 bands in the 1.7 to 80 MHz range that will require additional protection beyond those provided by FCC Part 15. These 41 bands account for approximately 5.4% of the proposed BPL spectrum. The NTIA has suggested that BPL providers choose their operating frequencies with the NTIA services in mind and have advocated that requirements for frequency avoidance and notching capabilities be required for all commercial BPL deployments.

3.6 Definition of Interference

There are many different definitions of interference depending on the source and how narrowly it is defined to relate to BPL. The Institute for Telecommunication Sciences defines electromagnetic interference (EMI) as, “Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical

34 “Telecommunications and Information Administration Potential interference from broadband over Power Line systems to federal government radiocommunications at 1.7 – 80 MHz.” Phase 1 study, NTIA Report 04-413. April 2004.
35 Ibid.
36 Ibid.
equipment.” The FCC Rules and Regulations further narrow the definition to only apply to unlicensed services in Section 15.3(m). This section defines harmful interference as: “Any emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this Chapter.” The FCC definition narrows the interpretation to communication services, specifically to those which are licensed.

Although the book definition seems to be clear in theory, the reason that so many interference reports have been disputed lies in the extent to which the interference occurs in practice. The definition leaves inherent room for interpretation and does not specify whether non-harmful interference may exist in any part, or if there is zero-tolerance for interference. This definition is also unclear as to what amount or length of time of interference is considered acceptable. Due to the ambiguous nature of the interference definition, we will find that the de facto interpretation may be very different from the de jure definition. Later sections will investigate the de facto interpretation exhibited by the policy of enforcement in the FCC.

3.7 Measurement Standards

As an unlicensed service, BPL must operate on a non-interference basis. This requirement is to protect the incumbent license holders who have been granted exclusive use rights for certain segments of spectrum. The radiated emissions measurement principals were

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37 The Institute for Telecommunication Sciences (ITS). See http://www.its.bldrdoc.gov/ (last visited March 10, 2005). The ITS is the research and engineering branch of the NTIA. The ITS serves as a principal Federal resource for solving the telecommunications concerns of other Federal agencies, state and local Governments, private corporations and associations, and international organizations.

38 FCC Rules and Regulations. Title 47 of the Code of Federal Regulations, Office of Engineering and Technology. Section 15.3(m). Part 15 of the FCC Rules pertains to the operation of unlicensed services. The section in question defines interference in relation to licensed services.
codified and established into the FCC rules and regulations by the BPL Report and Order.

The radiated emission limits in that report are explicitly defined [Figure 7].

<table>
<thead>
<tr>
<th>Classification Category (Type)</th>
<th>Frequency Range (MHz)</th>
<th>Field Strength (uV/Meter)</th>
<th>Measurement Bandwidth (kHz)</th>
<th>Measurement Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Current Systems</td>
<td>1.705 - 30</td>
<td>30</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>Class A - Commercial</td>
<td>30 - 88</td>
<td>90</td>
<td>120</td>
<td>10</td>
</tr>
<tr>
<td>Class B - Residential</td>
<td>30 - 88</td>
<td>100</td>
<td>120</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 7 – FCC Radiated Emission Limits

This figure demonstrates that lower frequency signals are measured at a lower field strength and greater distance because of their propagation characteristics. The figure also shows that measurement distance for residential carrier current systems is much smaller due to the limited probability of it escaping the household. The procedure for measuring the radiated emissions is documented in the FCC rules and regulations. The FCC contends that they have taken the comments of all involved parties into consideration when establishing the rules and procedures.

### 3.8 Prevalent use of Licensed Spectrum

One of the reasons that resolving the interference complaints of the amateur radio groups has proven to be such a difficult challenge is the particular type of use for the licensed spectrum. Setting a discrete signal strength definition for interference that “seriously degrades” amateur radio would be prohibitively difficult since amateurs use varying strength amplifiers and often look for very weak signals. Licensed amateur radio operators, such as Gary Pierce, have written extensive documentation on their use of spectrum and how BPL signals present significant risk to their activities. Pierce and other licensed radio operators oppose BPL’s use of the HF, VHF, and ultra high frequency (UHF) bands and have e-filed

39 FCC Radiated Emission limits edited to reflect those relevant to BPL services.
40 Pearce, Gary (KN4AQ). Gary has been a licensed radio operator since 1965 and holds an Amateur Extra class license. He is the editor of the Repeater Journal Magazine and contributing editor to CQ VHF Magazine. On July 17, 2004, Gary e-filed a 20 page reply to the FCC NPRM documenting his direct experience with interference from Progress Energy Phase I+II BPL trials.
numerous reports to the FCC for consideration in the rulemaking process. In his comments
Gary Pierce explains the need for a clear signal:

“Amateur Radio operators roam the spectrum, looking for new and
interesting signals. Often those signals are weak – just above that low noise
floor, and the challenge is to understand the signal well enough to exchange
information.”41

He extends his definition in his reply to the FCC’s proposed amendment by saying,

“Can the harmful threshold be set where if I can hear it all day, every day,
it’s harmful, no matter how weak?…Remember, Part 15 devices seek to
share spectrum that is already in use by a primary, licensed service. They
should remain very much in the background, and should consider the needs
and existing practices of the incumbent.”42

These comments outline why the particular type of use in the amateur radio spectrum creates
a situation where there is an extremely low tolerance for interference. Although most uses of
the licensed spectrum have the ability to overcome a certain acceptable amount of
interference, amateur radio spectrum has the inherent need for an extremely low noise floor.
The actual amount of interference that the licensed service should be required to tolerate from
an unlicensed service, if any, falls into question when a “standard of communications” has not
been established or well-defined.

3.8 Interference Interpretation

From the outcomes of the BPL Report and Order we can make the assumption that
the FCC has ruled that there is a certain amount of flexibility in the definition of interference.
It could be argued that, in general, they believe a service should be allowed to progress given
that the public utility of the service outweighs the harm caused by harmful interference. In
paragraph 33 of the BPL NPRM the commission states, “On balance, we believe that the
benefits of Access BPL for bringing broadband services to the public are sufficiently

41 Pearce, Gary. “Reply comments on ET Docket No. 04-37, Amendment of Part 15.” FCC Electronic
42 Ibid.
important and significant as to outweigh the potential for increased harmful interference that
may arise."43 By advocating such a stance, the FCC alludes that the definitions existing in the
Rules and Regulations may be conditionally interpreted if they feel they are acting in favor of
the public good. This would seem to be consistent with the conditions of the FCC’s spectrum
goal: “To encourage the highest and best use of spectrum domestically and internationally in
order to encourage the growth and rapid deployment of innovative and efficient
communications technologies and services.”44 The question arises as to whether the FCC
retains this decision making jurisdiction in the powers that have been delegated to them by
congress. The FCC’s obligation and duty, as granted by congress, is to establish and enforce
the governing rules and regulations in the best interest of the public. However, the
responsibility for protection of the incumbent services’ exclusive rights to the spectrum
contradicts its duty of encouraging the growth of innovative technologies. The stance taken
by the FCC is ultimately reflected in the amendments to the rules, or even more subtly, in
their enforcement of the rules.

3.9 Proponent Interference Reports

The chief proponents of BPL deployment are the electrical utility providers and the
technology companies that have an invested interest in providing BPL services and
equipment. The United Power Line Council (UPLC)45 is an alliance of these utilities and
technology companies, with the unified goal of promoting the deployment and acceptance of
BPL. The UPLC represents virtually every utility that is actively deploying experimentally

43 “FCC Notice of Proposed Rulemaking.” ET Docket 04-29 (Regarding 03-104 and 04-37). 23
February 2004. This document proposes rule changes to Part 15 regarding the measurement and
definition of a new type of carrier current system that provides broadband services over utility power
lines (BPL).
Among the goals of the FCC is fair and judicious use of the RF spectrum. This duty has been
increasingly coming to the forefront because of the success of wireless technologies.
45 United Power Line Council (UPLC). See www.uplc.utc.org (last visited March 10, 2005). The
UPLC’s efforts are focused in three strategic areas: market awareness, regulatory and legislative
advocacy, and technical operability. They have been a very active proponent of BPL since the NOI
and have issued a number of comments to the FCC e-filing system.
licensed BPL. The UPLC claims that there have been few actual reports of interference, and that all reports have been resolved completely and swiftly. The UPLC has made claims that, “In all of these deployments, there have been virtually no reported instances of interference, and any interference that has occurred has been corrected quickly and easily, using some of the mitigation techniques recommended by the FCC in this very proceeding.” They allege that interference issues have been minimal as stated in the FCC NPRM and final ruling. They further argue that the ARRL and other BPL opponents have greatly overstated the interference potential, which has had a very limited effect on their licensed use of the spectrum. Similar claims have been made by many other utilities that are currently operating under the experimental BPL license. BPL providers suggest that either interference is minimal and meets the FCC Part 15 requirements, or that adaptive mitigation techniques such as notching or dynamic power adjustment are able to quickly and completely resolve interference issues.

3.10 Opponent Interference Reports

The largest private opposition to BPL has been from the amateur radio community. The National Association of Amateur Radio, also known as American Radio Relay League (ARRL), is a non-profit organization that promotes the interests of amateur radio. The ARRL has been very active in raising support for their cause. The main radio services that

46 United Power Line Council. “Reply comments on ET Docket No. 04-37, Amendment of Part 15.” FCC Electronic Comment Filing System. 3 May 2004. The UPLC shares the position held by many of the utility companies that the amateur radio community only represents a very vocal minority. They claim that the amateur interference reports are unscientific and contrary to the professionally administered measurement of the FCC and power companies.

47 PowerWAN. “Reply comments on ET Docket No. 03-104, Amendment of Part 15.” FCC Electronic Comment Filing System. 7 July 2003. Utility companies have proven on many occasions that they possess the capability to mitigate interference reports. They have stated that they can dynamically reduce power or even notch out the interfering bands.

48 The National Association of Amateur Radio (ARRL). See www.arrl.org/ (last visited March 10, 2005). The ARRL has represented the most vocal opposition to the BPL proceedings. With a very large base of loyal members, they have organized an opposition movement. As the license holders of the spectrum the amateur radio operators have the most to loose from a loose interpretation of interference or lackadaisical enforcement policy.
the ARRL hopes to protect are the Amateur Radio Service, Citizens' Band Radio Service, and the Maritime Mobile Service. The ARRL contends that

“There were more than 5,000 comments filed in Docket 03-104 by radio amateurs and other users of those bands which reflect their understanding of the serious radiated interference problems inherent in use of unshielded power lines elevated above ground level for conducting relatively strong RF signals. The technical exhibits filed by ARRL conclusively established that there is a significant interference potential from access BPL systems to Amateur Radio operation throughout the Amateur HF allocations.”

Although the claim of 5,000 comments has been disputed, many of the thousands of comments received by the FCC have been received from licensed amateurs, making them the most active community in the rulemaking process. The majority of the comments filed by this group have reported interference from the experimental BPL services in their local community or expressed their concern that future deployments may cause further interference. The members of ARRL continue to provide technical documentation of interference, and continue to garner support, both technically and financially, from other amateur radio operators across the country and world.

3.11 International Opponents

As more BPL systems go into operation there is a growing fear that BPL deployments may have international, inter-continental, or even global consequences. Due to the possibility of ionospheric aggregation, amateur radio operators around the world believe that any type of large scale BPL deployment would inherently lead to an elevation of the noise floor. The long-distance propagation characteristics of HF radio signals allow them to extend to vast geographical areas through ionospheric propagation. There is a fear that the interference strength of signals radiated on the same frequency, but from different areas, will begin to aggregate into a single large source of interference. Because BPL providers operate independently and without mandated collaboration, BPL opponents argue that this phenomenon becomes increasingly likely as more systems come into operation. Since this
phenomenon is likely to only take effect after a large number of geographically dispersed and co-channeled BPL systems become operational, the true interference potential is unknown. In the first report issued by the NTIA they reported that BPL aggregation and ionospheric propagation is not a potential near-term problem, but they do plan to address its long-term potential in the research of Phase 2.

### 3.12 NTIA Interference Suggestions

The issue of interference has been carefully evaluated within the federal government spectrum management offices. The Telecommunications and Information Administration (NTIA)\(^{49}\), an agent of the US Department of Commerce, is responsible for the management and use of federal RF spectrum. In response to the NOI and NPRM regarding BPL, the NTIA began the process of conducting a two-part research study to evaluate the effects of BPL on government spectrum licenses. The comments filed by the NTIA in the first of the two studies reported that they believe they would receive interference within certain critical services, but the interference could be adequately avoided or properly mitigated. The NTIA also reported that the actual amount of interference potential was quite subjective and highly dependant on the measurement technique.

As an advocate of BPL services, the NTIA proactively provided suggestions that may reduce the harmful interference to an acceptable level, rather than documenting the interference levels themselves. They also proposed methods for effectively measuring radiated emissions in a way that would be more consistent to actual interference potential. The NTIA has recommended that BPL operators be obligated to register the parameters of

\(^{49}\) Telecommunications and Information Administration (NTIA). See [www.ntia.doc.gov](http://www.ntia.doc.gov) (last visited March 10, 2005). The NTIA is a governmental agency which receives its jurisdiction from the U.S. Department of Commerce. Much like the FCC it represents the US government in the information technology area. It is the Executive Branch’s principal voice on domestic and international telecommunications issues. The NTIA encourages competition, promotes innovation and works to provide consumers with the most choices, best quality, and lowest prices on telecommunications products and services.
planned and actual implementations so that all possible attempts can be made to avoid and eradicate interference. The federal government suggests that all BPL devices be approved and installed by qualified electric utility providers only. They request that all BPL systems be capable of frequency avoidance and notching to accommodate local radio frequencies. They advise that BPL operators have the capability to remotely decrease power emissions and terminate BPL services on power lines segments in order to immediately respond to interference issues. The NTIA also suggests that BPL operators chose signal frequencies that minimize radiated emissions and interference with active licenses in the local spectrum.

### 3.13 Enforcement Policy

Enforcement of the regulations for unlicensed Part 15 devices lies with the FCC enforcement bureau. As licensed services, the incumbents have exclusive rights to their assigned spectrum and are entitled to protection from unlicensed devices. The general conditions of operation of Part 15.5(c) state, “The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference. Operation shall not resume until the condition causing the harmful interference has been corrected.” However, the statements made by the commission in the 2004 Report and Order suggest that BPL operators be given due process and the opportunity to mitigate the interference before ceasing operation. Paragraph 33 of the proposed rules reads: “In addition, as discussed in the next section herein, we are proposing that Access BPL devices include technical capabilities and administrative procedures to ensure that the potential for harmful interference is minimized and that any instances of harmful interference are quickly resolved.” Further complications arise in attempting to define what the actual process of mitigation involves and how long the mitigation process should be allowed to proceed. Since the definition and action of mitigation both lie with the BPL provider, they are given the right of choosing the speed or completeness of the process.
3.14 Complaint Enforcement

One of the largest debates in the interference issue centers on the resolution of interference complaints. A large majority of the BPL interference complaints have been filed by amateur radio operators. Commission staff members in the Enforcement Bureau have indicated to the ARRL that all complaints about BPL interference are being forwarded to the Office of Engineering and Technology for resolution. Few of these complaints have led to the termination of BPL operations. Since the BPL operators continue to make claims that they have yet to experience any interference, all of the documented cases are still pending. Therefore, the ARRL states, “since these complaints are pending and unadjudicated, the BPL providers are taking the position that there is no interference, or no documented interference from the test sites, and that therefore there is not an interference problem.” The ARRL contends that utility companies must be required to take a more active role in mitigating interference.

The proposed solution from the FCC Enforcement Bureau is interference mitigation techniques such as frequency band selection, notching, or judicious device placement. The UPLC has further commented that they suggest the FCC impose a reciprocal obligation of good faith on both licensed and unlicensed users to discourage frivolous complaints and ensure timely resolution of interference issues. This view parallels the FCC’s stance that the 0 dBµV/m noise floor suggested by the ARRL is typically below the noise floor of the HF/VHF bands and that such a restriction is unnecessary and prohibitively restrictive for BPL operators. Although mitigation techniques may often be successful, this solution results in licensed users forfeiting their claim to exclusive rights while allowing the secondary services the right of mandated self-enforcement.

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3.15 Interference Avoidance and Mitigation

The rule changes enacted by the FCC Report and Order may have lasting effects for the future of unlicensed services acting on a condition of non-interference. The BPL rulings have transferred the onus of interference avoidance to the licensed service. The ARRL points out that “The Part 15 rules were developed, however, upon the fundamental premise, and on the condition, that interference is to be avoided ab initio, not remedied post hoc. Were it otherwise, the Commission would have no statutory jurisdiction to permit unlicensed operation of devices or systems.”\(^{51}\) BPL services are a secondary service and were established on a condition of non-interference. A BPL device does not actually have the right to employ mitigation techniques because the rules and regulations dictate that it must cease operation upon the first existence of harmful interference.

The freedom to mitigate, rather than avoid, interference will create the opportunity for faster BPL deployments. The act of mitigation places the responsibility of enforcement action upon the licensed spectrum owners. Although the incumbent services have the exclusive right to the 1.7 – 80 MHz range, the responsibility to report BPL interference now falls upon the license owner. Despite operating as a secondary service, BPL operators no longer have the responsibility of policing encroachment of the primary services. The process of mitigation frees the BPL providers from their duty to avoid interference and only requires them to take action when interference is reported by the primary service.

The Report and Order also specifies that an Access BPL database will be created to track deployments and serve as a point-of-contact directory for interference mitigation. The

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intent of this database is to make it easier to resolve interference claims. The database shall contain: 52

1. The name of the Access BPL provider
2. The frequencies of the Access BPL operation
3. The postal zip codes served by the specific Access BPL operation
4. The manufacturer and type of Access BPL equipment and its associated FCC ID number, or, in the case of Access BPL equipment that has been subject to verification, the Trade Name and Model Number, as specified on the equipment label
5. The contact information, including both phone number and email address of a person at, or associated with, the BPL operator’s company, to facilitate the resolution of any interference complaint
6. The proposed date of Access BPL operation.

Table 3 – Access BPL Deployment Database Requirements

By having this database publicly available the FCC hopes to allow complaints to be quickly and efficiently resolved without intervention of the Enforcement Bureau. Since the database contains all the details of proposed deployments it can be used to proactively avoid interference issues. The development cost and maintenance requirements shall be borne by the BPL providers.

3.16 The Final Ruling

The FCC Report and Order of October 2004 finalized the discussion on many of the regulatory obstacles that BPL has faced. This document achieved the following objectives in accordance with the intent of ET Docket 03-104 and 04-37. 53

- Defined Access BPL in the Rules and Regulations
- Maintains the existing emission limits for carrier current systems for BPL
- Requires Access BPL devices employ adaptive interference mitigation techniques
- Requires Access BPL system operators provide an information database on the areas where their systems are installed and other technical parameters
- Adopts specific measurement guidelines for both Access BPL and other carrier current systems to ensure that measurements are made in a consistent manner and provide for repeatable results in determining compliance with our rules

Table 4 – BPL Report and Order Achievements

By codifying these rules the FCC has established certainty in the BPL market. They have established that they, along with the NTIA and Department of Commerce, are committed to removing obstacles to emerging technologies. By establishing such confidence and stability in the BPL technology they have paved the road for further deployments and investment.

### 3.17 Impact on BPL

The issue of harmful interference has been the single largest barrier to acceptance of BPL. The threat of interruptions in broadband services due to strict interference enforcement has kept many prospective BPL players on the sideline. The opponents of BPL have been very vocal about their concerns of interference and appear to have a very convincing argument. However, the Phase One report of the NTIA and the Report and Order of the FCC suggest that the policymakers are optimistic about the possibilities of BPL services and are willing to take exceptional measures to ensure that the technology has an opportunity to succeed. The decision makers within the regulatory environment have taken the stance that they are willing to embrace BPL services and are hopeful for continued investment. The decisive stance articulated in the BPL rulings sends a signal to BPL community that they have established stability in the sector and that BPL ventures will be allowed to thrive free of regulation in the future. With the recent success of several of the experimental deployments and the stability established in the regulatory environment, the BPL market is in a position for significant future growth.
Chapter 4 – The financial aspects

4.1 Introduction

In achieving widespread acceptance, possibly the largest obstacle that BPL will face is financial justification. It is only through the creation of a viable business plan that BPL has any possibility of large scale success. The challenge is to create a model by which a company in a partially regulated industry is able to financially benefit from a competitive service.54 The financial incentives of offering BPL services in the competitive broadband market are much less than would be expected. The reason is that virtually all electric distribution companies’ rates are regulated. In a purely cost-based regulatory environment, the risks associated with a new technology far outweigh the potential to expand customer base.55 However, in a performance based regulatory environment the intelligent network capabilities that are made available by BPL services will allow a company to cut costs, increase efficiency, and improve reliability.56 This chapter will detail the regulatory aspects of the utility industry to explain why a utility company would consider the deployment of BPL technologies. It will seek to address the changes in the regulatory environment and how that affects the financial feasibility of BPL services. It will also investigate the financial benefits that enhanced BPL capabilities may provide as an internal efficiency mechanism within the electric utility industry.

54 Public utilities are universally provided for all households meaning that only one set of power lines run to each house. A utility customer generally does not have the choice to pick their utility provider. In exchange for these exclusive rights a utility must agree to be regulated. Broadband internet access, however, is not provided universally. Broadband providers must compete for customers in a competitive market and do not have the same regulations that a public utility does.

55 Ammann, Vincent. Interview by Author. 16 September 2004. Vince Ammann is the Chief Financial Officer at Washington Gas and Electric. Although his company is not currently involved in BPL trials, he was willing to help me understand the economic and regulatory principles of the electric utility industry.

4.2 State and Federal Regulation

Most public utility companies are granted exclusive monopoly franchises within their service areas. As a government granted monopoly, the companies are regulated in attempt to a maximum economic efficiency and public utility. Regulation is handled by both the state and federal regulatory agencies. At the national level, power utilities are regulated primarily by the US Federal Energy Regulatory Commission (FERC)\(^57\). FERC’s responsibilities include the approval of wholesale generation rates, oversight of energy securities, review of the federal power market, and certification of generation facilities. FERC’s influence typically only extends over the nationwide issues such as the national energy infrastructure and energy markets. Regional and local issues are left to the state commissions.

Despite a regulatory agency within the federal system, almost all electric distribution regulation is performed at the state level by a state designated regulatory authority. These state agencies are headed by an appointed panel of commissioners, commonly referred to as the public utility commission (PUC). These panels are typically supported by a staff of regulators with various legal, financial, and operating backgrounds in the energy industry. PUC staff and Commissioners are loosely affiliated through their voluntary memberships in regulatory associations, such as the National Association of Regulatory Utility Commissioners (NARUC)\(^58\). The NARUC serves as an alliance of independent agencies; however, NARUC Committee meetings and publications serve as forums for debate and policy guidance that members utilize in forming opinions and developing direction for their

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\(^58\) The National Association of Regulatory Utility Commissioners (NARUC). See [http://www.naruc.org/index.cfm](http://www.naruc.org/index.cfm) (last visited March 10, 2005). NARUC’s mission is to serve the public interest by improving the quality and effectiveness of public utility regulation. Since utility regulatory law is established at the state level by the PUCs, the NARUC provides an advisory role.
own state regulatory process. Ultimately, each PUC establishes its own regulatory rules that apply at the state level. Since the purpose of this paper is to investigate the market feasibility of BPL services, its focus will be narrowed to the regulation of reliability and rates.

4.3 Regulation Methodology

The most common regulatory scheme in use today is cost-based or rate-of-return regulation. This type of regulation is premised upon the 1944 Supreme Court case of Federal Power Commission v. Hope Natural Gas Company.\textsuperscript{59} This ruling established the method for determining fair market value for utility rates. The decision ruled that the intent of regulation is to provide a utility provider with a rate of return that is adequate for a utility company to attract investors, ensure the long-term integrity of investments, and earn dividends comparable to those in other ventures with similar risks. Although there are regulatory reform movements that will be discussed later in this chapter, all current regulatory practices rely upon the foundation of cost-based regulation.

Under the established rate of return methodology, utility companies propose a rate that will allow them to recover all of their operating costs, plus an additional return on their invested capital.\textsuperscript{60} This revenue requirement must be collected from all customers in order for the utility to recover its costs and also allow an opportunity to earn an investment return for its shareholders. If the rate were to be set below this level, there would be no incentive to invest in a utility venture. Likewise, any excessive revenue beyond this amount would be considered an exploitation of monopoly status. The balance between these two factors is one challenge of rate regulation. Theoretically, strictly applying cost-based regulatory principles gives no incentive for a utility to efficiently make capital investments because as capital

\textsuperscript{59} “Federal Power Commission v. Hope Natural Gas Company.” 320 US 591, 1944. This landmark case established the rate of return regulation methodology that is still in use today. In this case Hope was ordered to adjust its natural gas rates in the state of Ohio because they were taking unreasonable levels of profit. This ruling now serves as the foundation for public utility rate regulation.

\textsuperscript{60} Ammann, Vincent. Interview by Author. 5 October 2004. My second interview with Vince Ammann revolved around regulation methodology in electric utilities.
investments increase a greater return can be justified. Through its oversight role, regulators are charged with providing utilities with enough revenue to cover prudently incurred costs, while challenging practices and procedures with sufficient scrutiny to assure that utilities do not spend excessively.\textsuperscript{61} The difficulty of establishing this balance is one of the reasons that certain regulatory reforms have been suggested.

4.4 BPL Regulation

When looking at the viability of BPL it is critical to investigate where BPL services fit into the regulatory model. Since power rates are set by a regulatory entity, the addition of a competitive service creates problems for establishing the correct rate. The first situation that must be investigated exists when BPL services fall under regulatory control as a non-competitive service. In this situation, capital investment in BPL technology will be passed onto the customer and reflected in the utility rates for that service.

All other things being equal, if a utility company is permitted to offer a value-added service to its customers from the same level of invested assets, utility regulators would argue that the only aspect changed in the revenue requirement formula is the customer base or the denominator. In this situation, the utility would not be allowed to recover the cost of the capital invested twice, reducing rates to electric customers by the amount of revenue collected from BPL customers. However, in the case of BPL services, the utility would incur significant additional capital costs in order to offer this optional service to its customer.\textsuperscript{62} Using a simple cost-based rate structure, the utility would be able to pass the cost of incremental capital costs for BPL services onto its customers by increasing the per capita rates. Under either scenario, a difficulty arises related to the allocation of the established infrastructure costs. The incremental capital costs associated with BPL service should be

\textsuperscript{61} Ibid.
\textsuperscript{62} Sperduto, Rich. Interview by Author. 7 September 2004. Rich Sperduto is an engineer for Rochester Gas & Electric Company, a subsidiary of Energy East Corporation. Rich was able to explain the cost justification process that was under investigation for BPL technologies.
allocated to the rates charged to customers who elect this service; however, it is not so clear how the cost of the pre-existing distribution assets should be allocated. If BPL customer rates are designed to only recover the incremental cost of this service, the electric commodity customer would be partially subsidizing this service.\textsuperscript{63} This is because the customer would be bearing the full allocation of the rate of return on the distribution infrastructure costs that make BPL service possible. This creates a challenge because some customers have their utility prices set upon a rate-of-return that includes BPL infrastructure costs despite having opted out of the service. This creates a cross-subsidization dilemma with characteristics similar to the formerly regulated telephone industry.

The incentives a utility might have for adding non-commodity services must be examined in the context of a regulated market. The economic assumption can be made that a company would hope to gain additional revenue from BPL services through a monthly subscription fee.\textsuperscript{64} However, once a utility is able to start earning increased revenue from the invested BPL capital, the allowed rate of return on equity would likely be changed by the regulators.\textsuperscript{65} Any extra revenue that is generated by a utility company can be recaptured by the regulators through a reduction in other rates that the utility may charge. In addition, if the capital investment is made into non-traditional assets the regulator may challenge the utility to produce financial and operating models that justify that this new capital investment was prudently incurred. The introduction and reliance upon new technologies naturally draws increased regulatory scrutiny to protect consumers from wasteful spending by the utility. The utility company does not have the capability to offer increased returns to its shareholders by offering additional services provided it is gained from the same set of invested capital.

\textsuperscript{63} Ammann, Vincent. Interview by Author. 14 February 2005. My third interview with Vince Amman focused on the methods that utility companies could employ to integrate a competitive service into their otherwise regulated business.

\textsuperscript{64} [Sperduto] 7 October 2004.

infrastructure under a cost-based regulation methodology. Given the prospects of rate reductions and additional regulatory scrutiny, most utility companies have little incentive to act in an entrepreneurial manner.

4.5 Unregulated Affiliates

A remedy for the financial disincentives inherent in a utility offering BPL services through its regulated utility entity would be to offer the services through a non-regulated affiliate. The unregulated affiliate would then collect the revenue from the additional services. Since the affiliate is not rate regulated on a cost basis, the utility rates will remain the same while the utility company is able to offer additional services to customers and is given the opportunity to expand their base. However, the financial links between a regulated industry and a non-regulated affiliate become very complicated. Similar attempts involving other services have been fraught with regulatory problems and legal debates over the allocation of the infrastructure costs that the services require. In the case of BPL, both the regulated and the unregulated services stand to benefit from the capital investment. In this situation there would be pressure or tacit acceptance by the parent company of the combined entity to shift costs from the competitive industry to the regulated industry in order to make the unregulated service more attractive to consumers. The practice is well known as a cross-subsidization and is a typical focal point of regulatory investigations when non-regulated affiliates compete in the regulated utility’s market. The financial intricacies involved with the introduction of non-regulated affiliate services in a regulated industry is beyond the scope of this paper. The time involved with making such a regulatory change puts it outside the limited timeframe that this paper hopes to examine. However, it should be noted that some utilities have chosen to pursue this option.

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66 Ibid.
67 Cross-subsidization, as defined by The Student web site for Economics 3rd Edition: When the costs of one product are assigned to or absorbed by another product.
4.6 Competitive BPL

As a regulated industry, utility companies have little to gain by offering a competitive service such as BPL to their consumers. The risks associated with additional services far outweigh the potential to increase customer base.\(^{68}\) However, there is a recent trend to migrate from a purely cost based regulatory environment to a regulatory model based both on cost and efficiency. One of the largest drawbacks to a government granted monopoly is economic inefficiency from the lack of competition. Since competition in the utility industry is inherently limited because of the single right-of-way for electric lines to a customer premises, the regulatory reform movement has chosen to seek ways to improve operating efficiency of the utility providers.

Taking a purely cost-based view of the current regulatory market would overlook some of the new regulatory trends that may significantly affect the feasibility of BPL services. In many markets the regulators have been moving away from strict rate-of-return regulation towards an incentive-based regulation.\(^{69}\) The regulators goal is to align the customers and shareholders interests by achieving low cost services through promoting efficiency. The US Congressional Budget Office clearly states,

“The proper objective of policy is neither the promotion nor discouragement of electric energy use. Rather, it should be the provision of energy-based services at the lowest real cost to the economy when all external effects are considered.”\(^{70}\)

Notice that the Congressional Budget Office recognizes that externalities may exist and should be accounted for when minimizing economic cost. Traditional rate of return

\(^{68}\) [Ammann] 16 September 2004.
regulation has come under strong criticism from both consumer interest groups and utilities seeking opportunities to earn returns that are not kept artificially low by regulation inefficacies. Its opponents site the following issues: the lack of incentives to minimize cost, the lack of productivity improvement, costs of regulation, and the associated problems with mixing competitive services with a regulated industry. Because of these flaws, new regulatory models have developed to address these problems.\textsuperscript{71} By layering incentive mechanisms on top of a traditionally regulated market, the price is still largely determined according to the investment and operating costs. However, the profit margins that are realized by the utility may be changed through efficiency or reliability factors.

\section*{4.7 Performance Based Regulation}

Performance-based regulation is a regulatory methodology that rewards economic efficiency and promotes competitive behaviors. The incentives for adopting a service such as BPL are strengthened because of its competitive nature. In this regulation model the link between a utilities cost and its regulated rate is disconnected. A division is created between the costs of capital investment and the costs of operation.\textsuperscript{72} Since the rate is only partially dependant on sunk costs, a company is able to earn higher profits by lowering operating costs. In performance based regulation a utility is rewarded by accomplishing more with less, such as keeping generation and delivery rates constant while reducing the number of workers or amount of lines. For a traditionally uncompetitive utility, lowering operating costs could be accomplished in a number of ways, including better organizational flow, increased productivity, or even innovation. This chapter will discuss the opportunity for utilities to utilize BPL technology as a way of reducing operating costs.

\textsuperscript{71} [Ammann] 5 October 2004.
\textsuperscript{72} Ibid.
Under performance-based regulation, a utility is allowed to keep a partial share of additional profit that is generated by increasing operational efficiency. The customers are also given a rate reduction, allowing both parties to benefit from the efficiencies. Performance based regulation creates the possibility of increased economic efficiency and more competitive behavior in a regulated industry because the interests of consumers and shareholders are more appropriately aligned. It also presents significant incentives for utilities to adopt a cost-reduction investment such as BPL technology. Many companies have begun investigating the advantages of performance based regulation plans (PBR) [Figure 8].

### Table ES-1. Sample of Electric Utility Performance-Based Regulation Plans

<table>
<thead>
<tr>
<th>Company</th>
<th>Plan Type</th>
<th>Term (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Maine Power Co. (CMP)</td>
<td>Price Cap</td>
<td>5</td>
</tr>
<tr>
<td>NY State Electric &amp; Gas (NYSEG)</td>
<td>Price Cap</td>
<td>3</td>
</tr>
<tr>
<td>Niagara Mohawk Power Co. (NMPC)</td>
<td>Price Cap</td>
<td>5</td>
</tr>
<tr>
<td>Pacificorp</td>
<td>Price Cap</td>
<td>3</td>
</tr>
<tr>
<td>Tucson Electric Power (TEP)</td>
<td>Price Cap (freeze)</td>
<td>5</td>
</tr>
<tr>
<td>Consolidated Edison of New York (ConEd)</td>
<td>Revenue per-Customer Cap</td>
<td>3</td>
</tr>
<tr>
<td>Pacific Gas &amp; Electric Co. (PG&amp;E)</td>
<td>Base-Rate Revenue Cap</td>
<td>6</td>
</tr>
<tr>
<td>San Diego Gas &amp; Electric Co (SDG&amp;E)</td>
<td>Base-Rate Revenue Cap &amp; Modified Price Cap</td>
<td>5</td>
</tr>
<tr>
<td>Southern California Edison (SCE)</td>
<td>T&amp;D Revenue Cap &amp; Modified Price Cap</td>
<td>6</td>
</tr>
<tr>
<td>Alabama Power</td>
<td>Sliding Scale</td>
<td>Indef.</td>
</tr>
<tr>
<td>Mississippi Power</td>
<td>Modified Sliding Scale</td>
<td>Indef</td>
</tr>
</tbody>
</table>

**Figure 8 – Performance Based Regulation**

### 4.8 BPL Performance Enhancement

This section will investigate the impact that the introduction of BPL services might have on the operating efficiency of a utility company. As discussed earlier, a utility company is able to keep a higher margin of their rates by reducing operating costs and achieving

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73 Ibid.
greater efficiency. This fundamental shift in competitive policy creates a need to investigate the incentives that may influence a utility’s decision to deploy BPL services. The focus shifts to the efficiency mechanisms realized by BPL technologies rather than revenue generated by broadband services.

Power companies are now beginning to weigh the benefits of increased revenue from broadband versus the performance enhancement efficiencies that an intelligent network may provide. The profit margin in a highly competitive broadband market with established competitors such as DSL and cable is razor thin. However, the advantages of a smart distribution grid may outweigh the value of broadband. By integrating data services into their distribution network, the utility companies have the potential to achieve the following benefits:

- Real-time monitoring of load distribution and power flows
- Remote power management and switching services
- Automated power reading and real-time pricing
- Outage notification and tracking
- Long-term trending with system state tracking

| Table 5 – Intelligent Network Benefits |

These benefits create the potential for a significant impact on operational efficiency and cost savings. The decision to implement BPL services on the power distribution grid will only be partially dependant on the ability to provide broadband services. It is really the long term effects of an intelligent network that are likely to influence the decision to make an investment in a BPL infrastructure. If deploying BPL can be cost-justified from the viewpoint of operating efficiencies or savings shared with shareholders, then any incremental revenue opportunities in the future from providing BPL services to end users will be a pure

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75 Perras, Dalton. Interview by Author. 8 October 2004. My second interview with Dalton Perras focused on the benefits that BPL technology will provided to utility companies in addition to increased revenue from broadband services.

76 Ibid.
The details of an intelligent distribution grid and how a utility company may be able to capitalize on its technological advantages will prove critical in the acceptance of BPL technologies.

4.9 Transmission Network Intelligence

The national electric transmission grid already has some intelligence in place on its high voltage transmission lines. The transmission lines carry energy from the generation plants to the distribution station. Since the distribution station is billed according to the amount of power received, a monitoring system is needed to track the energy flows. System control and data acquisition systems (SCADA) and distribution management systems (DMS) allow monitoring and distribution management on power networks. These systems allow utilities to control flow, locate faults, preempt failures, and engage in a real-time energy market. These systems work at low data rates using non-standard protocols and are usually very application specific. The intelligence functions across the transmission grid and is then removed from the current at the power distribution station during the step-down to medium voltage. As discussed in the earlier sections, network intelligence loses its integrity during the step-down transformation process. The low and medium voltage distribution networks do not currently have any built in intelligence. A study performed by the Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) evaluated the business case for an intelligent network meter called the EnergyPort. The findings from this study indicate that investment in a communications system that enables energy and network management could

78 Sciacca and Block. “Advanced SCADA Topics.” IEEE Computer Applications in Power, January 1995. This article explores some of the SCADA system concepts and suggests technology and business issues involved with this topic.
79 Ibid.
80 The Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) See http://www.ceids.com/ceids/About/About.html (last visited March 10, 2005). CEIDS provides the science and technology to ensure an adequate supply of high-quality, reliable electricity to a digital economy and integrate energy users and markets.
81 EnergyPort: A meter, device, or a set of devices that serves as the communications and control hub for the customer.
be worth roughly seven times the initial expenditure. Figure 9 illustrates many of the added capability that intelligent network services allow. The lack of network intelligence on the distribution and access grids prevents utilities from realizing the potential benefits of real-time monitoring capabilities.

![Utility Power Network Diagram](image)

**Figure 9 – Network Intelligence Capability**

**4.10 Reliability**

In addition to the performance based mechanisms of the regulatory environment that reward operating efficiency, regulation also bears the capability to ensure reliability. For many customers the measure of reliability is as great, if not greater, than the cost. Since utilities are granted non-competitive monopolies the regulatory model must also contain protections to ensure a certain level of reliability is met. BPL presents the opportunity to create intelligence within the network to enhance monitoring capabilities. The lack of real-

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time visibility in the distribution grid greatly reduces their ability to provide reliability. The first indication of a power failure is often a call from the customer.

The rate a utility company can charge for service is closely tied to their ability to provide reliability. Reliability is measured in the utility industry through two well known indices:

The first is the system average interruption frequency index (SAIFI) [Equation 1].

\[
SAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}}
\]

Equation 1 – SAIFI Index

The second is the system average interruption duration index (SAIDI) [Equation 2].

\[
SAIDI = \frac{\text{Sum of all customer interruption durations}}{\text{Total number of customers served}}
\]

Equation 2 – SAIDI Index

These reliability indices are often used by regulators when determining rates. Average indices generally average less than two interruptions, accounting for a duration of three hours per year, excluding storms [Figure 10].

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83 Short, Tom. “Reliability Indices.” T&D World Expo. 2002. Outlines the different reliability indices in use and how they are calculated.

84 Ibid.

85 Ibid.
Table of Reliability Indices

<table>
<thead>
<tr>
<th></th>
<th>SAIFF number of interruptions per year</th>
<th>SAIDI, hours of interruption per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%  50%  75%</td>
<td>25%  50%  75%</td>
</tr>
<tr>
<td>[IEEE Std. 1366-1998]</td>
<td>0.60  1.10  1.45</td>
<td>0.80  1.50  2.30</td>
</tr>
<tr>
<td>[EEI, 1999] (excludes storms)</td>
<td>0.80  1.32  1.71</td>
<td>1.16  1.74  2.33</td>
</tr>
<tr>
<td>[EEI, 1999] (with storms)</td>
<td>1.11  1.83  2.15</td>
<td>1.38  3.00  4.38</td>
</tr>
<tr>
<td>[CEA, 2001] (with storms)</td>
<td>1.08  1.95  3.16</td>
<td>0.73  2.28  3.35</td>
</tr>
<tr>
<td>[PA Consulting, 2002] (with storms)</td>
<td>1.65  3.05  5.56</td>
<td>1.65  3.05  5.56</td>
</tr>
<tr>
<td>Large City Survey [IP&amp;L, 2000]</td>
<td>0.72  0.95  1.15</td>
<td>1.02  1.64  2.41</td>
</tr>
</tbody>
</table>

A, B, C represent the lower quartile A, the median B, and the upper quartile C of utility indices.

**Figure 10 – Reliability Indices**

Given the losses that accompany power outages, regulators have begun working to ensure the integrity of the power grid. Shortly after the North Eastern grid blackout of August 2003, FERC established a reliability team within its office of markets, tariffs, and rates. The purpose of this team is to address the reliability issues facing the industry.

Failure to meet reliability standards often results in costly fines and rate changes. An example was made of Jersey Central Power & Light (JCP&E) in July of 2003 after a 63 hour blackout on the Jersey Shore. The State of New Jersey Board of Public Utilities (BPU) ordered the rate of return on electrical utilities lowered from 10% to 9.5%, resulting in revenue losses of over $50 million dollars annually. As a result of this decision, New Jersey BPU retained the right to make further adjustments to the JCP&E rate of return in the future. Since utility consumers lack the ability to choose an alternate electric provider, the regulators have taken steps to ensure that reliability standards are observed. They achieve these

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In the matter of JCP&L’s emergency management of the seaside heights July 5-8 event and pertaining to reliability, security, and customer assistance. This document is the order adopting the staff’s final report, Docket No. EO04050373.
standards by adjusting the revenue of utilities that fail to meet these standards. Since BPL adds the capability to monitor real-time network statistics, it presents the opportunity to significantly increase the reliability of the low and medium voltage distribution grid.

### 4.11 Load Distribution

The medium voltage power grid lacks the intelligence of the SCADA systems found in the high voltage networks. The distribution network has the capability to allow SCADA systems; however, the scope of the grid is so much greater than the transmission lines that technology costs of enabling network intelligence were prohibitive. Due to this limitation, the utility companies do not have real-time monitoring capabilities and are often unsure of the actual power distribution characteristics. The power supply and current load must be constantly balanced to ensure the customers receive the proper voltages. If the power in reserve and the current load are not in equilibrium, the power supplied to customers will continuously fluctuate and cause electrical devices to malfunction. In the current system a large surge of customer load will require the utility to “shed load”, selectively causing area blackouts to prevent a system wide brownout. These provisions for system reliability and security are provided over the high voltage transmission grid by ancillary services. However, ancillary services do not extend to the distribution grid nor provide the responsiveness and granularity that is necessary. A system is needed to effectively identify and react to dynamic changes in load so that the reliability of the system can be increased. By monitoring the system supply at the distribution center and the current draw at the customer transformers with BPL, the utilities have the capability to dynamically adjust to load conditions.

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88 [Sciaccia and Block] 1995.
89 Ancillary services, defined as: “those functions necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system.” Federal Energy Regulatory Commission. Ancillary services include frequency regulation, voltage control, scheduling and dispatch.
In the present situation, the utility companies are uncertain of real-time load conditions and must have the capability to surge to meet expectations in high load situations. This means that they must either have a large amount of power in reserve or the capability to exceed normal draws from the generation companies in times of need. Both of these options are temporary solutions and very expensive to implement. The third option is to increase the capacity of your network and over budget the energy needs of your customers to ensure that you will always be able to meet the demand. Conversely, if utility companies implemented BPL system-wide they would have the capability to monitor and control the energy flows. This enables more efficient load distribution and reduces the need to over budget the capacity.

4.12 Network Redundancy and Preventative Maintenance

A significant portion of the invested capital in the electric grid is allocated to redundancy and fault tolerance. This is compounded by the fact that an equally significant section of operating costs is devoted to preventative maintenance. The reliability standards for the continent of North America are set by the North American Electric Reliability Council (NERC). Since the medium voltage grid does not have any self-diagnostic facilities, the accepted solution has become fault tolerant systems. These redundant solutions must be constructed so that the system is resilient in the case of failure. If the grid had intelligence built in, it would have the capability to track deterioration of the facilities and warn the grid operators of impending failures. Self-diagnostic figures from BPL enabled devices will allow for long term trending of facility performance to isolate the areas that require attention. This will save maintenance costs by allowing the utilities to perform preventative maintenance in those areas that need it most. BPL enabled intelligence would not only decrease the amount

90 The North American Electric Reliability Council (NERC). See http://www.nerc.com/ (last visited March 10, 2005). NERC's mission is to ensure that the bulk electric system in North America is reliable, adequate and secure. The standards set by NERC are voluntary and relying on reciprocity and mutual self-interest of all involved parties.
of redundant network facilities needed to provide reliability, but it would also ensure optimal network health, preventing future outages.

### 4.13 Customer Usage Statistics

One of the largest incentives for distribution grid intelligence is the ability to collect real time usage statistics at the individual customer level. This type of capability is used by the major generation companies with the SCADA system. Real-time pricing information allows them to create individualized pricing plans for each downstream distribution facility. The utility companies would like to have these capabilities for each of their individual customers.\(^91\)

Today utility companies charge the customer a flat rate for power usage. They monitor power usage through a meter at the point where the distribution facility interfaces with the customer facilities. Utility companies send agents out to manually collect usage statistics from these meters over a given billing interval. Since the meter reading process is labor intensive and requires human intervention, it becomes quite costly. The estimate for meter reads ranges from $0.31 – $0.71 per household,\(^92\) depending on the density of customer locations. This process has additional costs because the meter reads must then be manually entered into the billing system and cross-checked for correctness. These billing costs are passed onto the consumer without receiving any actual services in return. If BPL services were integrated into the medium voltage distribution grid system-wide, the meter reads could flow back to the utility company as BPL data and completely automate the meter reading process. Automated meter reading (AMR) presents the opportunity for utility companies to not only reduce operating costs, but also increase the reliability of the information.

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Additionally, we will find that the capability to monitor the meter in real time allows for enhanced capabilities.

4.14 Automated Meter Reading

A traditional utility meter collects long term usage over a given period without capturing any statistics on rate or time of usage. A parallel can be drawn to the odometer on a vehicle that keeps track of miles driven without any statistics on when or how quickly those miles were driven. The manual system also means that customers are unable to receive timely information about their recent usage statistics. The idea of AMR has been in existence for over 40 years but has not been widely deployed because of cost and lack of technical feasibility. There has been increased interest in ultra narrow band PLC systems for AMR capabilities, such as the TWACS system from DCSI\textsuperscript{93}, but the cost advantages have not been realized. Utility industry research firm Chartwell\textsuperscript{94} predicts that all new meter deployments will incorporate some type of AMR capabilities and that existing meters will soon be replaced to achieve uniformity and cost savings [Figure 11].

<table>
<thead>
<tr>
<th>Eventual AMR Deployments by Customer Type\textsuperscript{95}</th>
<th>% projected</th>
<th>% projected</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP meters</td>
<td>65%</td>
<td>22.8 million</td>
</tr>
<tr>
<td>Residential meters</td>
<td>56%</td>
<td>138.3 million</td>
</tr>
<tr>
<td>All</td>
<td>57%</td>
<td>140.7 million</td>
</tr>
</tbody>
</table>

\*Based on Chartwell’s recent survey of 110 utilities. Because customer responses varied drastically, Chartwell could not provide an estimated time period.

Figure 11 – AMR Deployments

\textsuperscript{93} Distribution Control Systems Inc. (DCSI). See \url{http://www.twacs.com/} (last visited March 10, 2005). DCSI is a power line communications company that manufactures the Two-Way Automatic Communication System (TWACS). This system that was created in 1978, provides two-way data communications between utility providers and utility companies. Although very low bandwidth, this system is capable of capturing real time statistics on usage and load with AMR capabilities.

\textsuperscript{94} Chartwell Inc. See \url{http://www.chartwellinc.com/} (last visited March 10, 2005). Chartwell is a market research firm that specializes in the utility industry. Their goal is to provide utility and retail energy decision makers with accurate and up-to-date information on issues facing the industry.
4.15 Demand Side Management

Previous methods have approached solving the reliability and load distribution problems from the supply side (the utility company), but BPL enabled network intelligence would also allow these problems to be resolved from the demand side (the consumer). Network outages are most often caused by sudden surges in customer demand. Since storing power is prohibitively expensive, the only option for utility companies to meet excess demand is to purchase additional power through dynamic power generation companies. However, since these power generation facilities are only used as needed they charge a much higher price. As a regulated entity the utility has a set price for power rates and must make up for the excess costs involved with purchasing power as needed from a generation company. The utility companies would prefer to have the ability to pass the cost of excessive load onto the customer who is demanding the power.

4.16 Peak Load Pricing

A BPL system with integrated metering would create the infrastructure necessary to capture real time usage statistics at the individual customer level. The ability to capture real time statistics creates the opportunity for the utility companies to create differentiated pricing options. The overall efficiency of a commodity market has been shown to increase by instituting differentiated pricing options. Given the network capacity structure of electric utilities, differentiated pricing is likely to result in a Pareto improvement.95

A good example would be the cellular phone market. In a given cellular plan you are given a lower rate for night or weekend minutes because this is the time that the cellular network is under capacity. Under a single rate, everyone is likely to make their calls during the same peak hours. By implementing differentiated pricing, the market is segmented and

95 Varian, Hal. Market Structure in the Network Age. University of California, Berkeley. 30 August 1999. This paper discusses some of the various aspects of competition in a commodity markets, such as the aggregate welfare of differentiated pricing.
those who are cost sensitive will make calls during the less expensive hours. Since the calls are more evenly distributed, the network capacity does not have to be so overbuilt for the times of peak usage. This example also demonstrates a further classification of differentiated pricing called peak load pricing\(^9^6\). Although not quite as elastic as cellular usage, peak load pricing will most likely result in a smoothing of electricity usage patterns by sending the appropriate pricing signals to customers.

Peak load pricing presents the opportunity to create lower operating costs for the utility company while still offering the same level of service to its customers. By invoking a differentiated pricing plan in which customers pay more for the power that costs the utility company more to provide, the customers’ usage will more properly reflect their cost adjusted demand. This leads to greater market efficiency and recaptures some of the efficiencies lost in a regulated utility.

### 4.17 Impact on BPL

BPL services have the ability to create a significant financial impact on the electric utility industry. When viewed strictly in the sense of entering the broadband services market, the utility industry appears to have very little incentive. This is coupled by the fact that rate of return regulation markets are very risk adverse. However, the regulation methodology appears to be making fundamental changes, pushing in the direction of performance based regulation. Given the developing progressive regulatory structure of the utility industry, the ability to offer broadband services may only be a small factor when making the decision to adopt BPL technologies. The true potential of BPL actually lies in its ability to add intelligence to the power distribution grid. Network intelligence creates the opportunity for utilities to cut operational costs while also improving reliability. BPL capabilities must be  

implemented system-wide to achieve full potential. Given this requirement, broadband services is just one of many enhancements found in BPL. Once the technology is in place and cost-justified for both consumers and shareholders, utilities would act in their own self-interest, offering revenue-generating competitive BPL service to end-use customers in an incentive regulation paradigm. The greatest financial incentive to deploy this technology will potentially come from deploying the operating efficiency uses of this technology under a performance-based incentive regulation.
Chapter 5 – Positive Externalities

5.1 Introduction

One of the most important, yet difficult to analyze, aspects of the viability of BPL services is the ability to capitalize monetarily on the positive externalities of BPL. It is well understood that BPL will have a difficult time matching the dollar for dollar capital investment returns of cable and DSL services. However, this fails to recognize several positive externalities that exist only within a BPL infrastructure. This chapter will begin by introducing the topic of externalities and how they can be internalized. It will then examine several positive externalities created as a result of BPL services. The next section will describe the political and regulatory environment for broadband services and how BPL could affect that environment. The chapter will then examine what role BPL can play in the establishment of universal broadband services and the creation of a more competitive broadband market. The focus then shifts to the security and reliability enhancements that BPL offers to the national power grid. This chapter will conclude by investigating how the positive externalities of BPL can be internalized and properly considered.

5.2 Positive Externalities

When investigating the utility provided by BPL services three positive externalities arise:

- Universal broadband access
- Introduction of competition
- Security and reliability enhancements to the national power grid

Table 6 – BPL Positive Externalities

5.3 Defining Externalities

The economic definition of externality is defined as:

“A situation in which the private costs or benefits to the producers or purchasers of a good or service differs from the total social costs or benefits entailed in its production and consumption. An externality exists whenever one individual's actions affect the well-being of another individual -- whether
for the better or for the worse -- in ways that need not be paid for according to the existing definition of property rights in the society.  

Many such definitions can be found, this particular definition was chosen because of its relation between social costs and property rights within society. Since the cost of an externality is normally not directly accounted for during the production of a good or service, its economic influence is under-exaggerated. This is true because under rational price-maximization a market entrant will only account for the costs or benefits that they are required to bear. In a market economy the most efficient decision is made when all factors are properly considered. However, we find that externalities create situations where non-optimal decisions are made.

Externalities pose a significant problem for regulators since a regulator hopes to maximize the overall utility to society, but only has limited tools to affect the price of the supplier. The problem associated with social externalities is the challenge of assessing such a large number of individual utility values. The positive externalities in BPL possess a wide scope of relative value and utility. Some of the externalities, such as national security, affect everyone in the country. When the utility for each additional citizen is marginalized, the costs associated with calculating and accounting for such externalities is prohibitive. However, without properly including externalities into economic utility calculations, demand is either under or over represented.

5.4 Internalizing Externalities

The challenges associated with calculating externalities result in difficulties accounting for them. In the case of externalities, society benefits from a good or service without actually engaging in any type of payment or ownership of that good or service. The act of accounting for the externalities is called “internalizing”. There is evidence that both

the consumers and the producers will gain utility from properly reconciling externalities. However, the accounting associated with these reconciliation agreements is very complicated. Since the transaction costs of an agreement between all parties affected would be prohibitively costly, society often resolves these issues through taxation, regulation, or legal adjunction. The scope of BPL specific externalities primarily extends to the state or national level and is most likely to be handled by taxation or regulation. In competitive markets such as broadband, tariffs are commonly used for reconciliation because the markets react to economic indicators. In the non-competitive utility service markets, rates are already regulated so it would make sense that externalities would be rectified through further regulation.

5.5 Penetration of Broadband Services

Broadband services offer the unique capability to create social and economic benefits at the national level. The advent of affordable, accessible, and timely communications are changing the way society interacts. The ability of broadband to make communication and information available is making businesses and workers more productive and more efficient. Access to information is creating educational opportunities and increased awareness of the world around us. The proliferation of broadband services can be seen as a worldwide goal. Many of the industrialized nations view broadband services as imperative to national growth. While the United States leads the world in the pure number of broadband customers, a 2003 report by the Office of Strategic Planning and Policy Analysis and International Bureau shows the United States as eleventh in the percentage of broadband subscribers per 100 people [Figure 12].

The figure clearly illustrates that the United States has been surpassed by other nations in the percentage of high speed data connections. In a world economy that is increasingly dependent on information and communication services, the US government hopes to assure that the US will not fall behind. The FCC has taken steps to improve this percentage and has released a fourth report to Congress on how they can speed the adoption of broadband services in the United States. Availability of broadband services is a top goal for both the US government and the FCC.

5.6 Political Broadband Initiatives

The United States government and the Bush Administration have shown that they believe broadband services are vital to the growth and international competitiveness of the US economy. The current administration has made it clear that they see the proliferation of broadband...
broadband access as a means for encouraging economic growth. They believe that to achieve this goal the country must remove regulatory obstacles for new technologies such as BPL. In an April speech to the American Association of Community Colleges, Bush stated,

“And we're going to continue to support the Federal Communications Commission. Chairman Michael Powell, under his leadership, his decision to eliminate burdensome regulations on new broadband networks availability to homes. In other words, clearing out the underbrush of regulation, and we'll get the spread of broadband technology, and America will be better for it.”

The Bush administration has shown that they believe the United States must take immediate action to prevent falling behind the rest of the world in broadband services. The development of BPL technologies has been advocated at many political levels from the leaders of underserved rural communities all the way to the White House. In June of 2004 Bush further restated the potential of BPL to provide these broadband capabilities when he said,

“We need to get broadband to more Americans…one great opportunity is to spread broadband throughout America via our power lines.”

President Bush sees universal broadband access as a goal for the United States and believes that BPL may help make that vision a reality.

5.7 Universal Service

The Telecom Act of 1996 included rules for universal service in communication services. Traditionally this meant for plain old telephone service (POTS), but the recent shifts towards an information based society seem to indicate that the internet is the new model of communication. Universal service is mandated for POTS lines, but the use of high data rate latency sensitive applications is creating a need for broadband services. Congress has ordered a hastening of the rate of market penetration and has given the goal of universal broadband access by the year 2007. Although DSL and Cable services are capable of providing broadband access in most areas, there are some areas, such as rural and geographically

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103 Congressional Declaration of Universal broadband access by 2007. Primary source unknown.
isolated areas, that they are unable to serve. Despite the universal service protections of the public switched telephone network (PSTN), only those customers within a certain distance of the provider’s central office can subscribe to DSL services. The only other governmentally mandated service is the public utilities. Since electric power is available at all consumer locations, only the electric distribution lines offer truly ubiquitous “last mile” services. Because of the existence of electric lines to every household, BPL presents the unique capability of providing universal broadband access.

5.8 FCC Broadband Promotion

The US congress has delegated the authority of interstate and international communication regulation to the FCC. One of the many responsibilities that falls within this duty is the regulation and promotion of broadband services. By creating a regulatory environment that fosters innovation, encourages investment, and promotes competition, the FCC is able to provide more options at a lower cost for the consumer. The FCC has chosen to remove regulatory obstacles for innovative technologies such as BPL. In a statement from a study on broadband capabilities for the United States\textsuperscript{104}, FCC Chairman, Michael Powell states,

“The Commission’s role—and my mission—is to continue to champion and facilitate higher-speed, more capable platforms that can run the applications of tomorrow. As regulators, we must embrace the reality that the torrent of change from new broadband technologies has arrived, is unstoppable, and will accelerate over the years ahead.”

The statement shows that Chairman Powell is very optimistic of the potential for BPL to provide universal access to broadband while also creating more competition in that space. After seeing a demonstration by Pacific Gas and Electric\textsuperscript{105}, Powell explained,

“Powerline technology holds the great promise to bring high-speed Internet access to every power outlet in America. What I saw today has the potential

to play a key role in meeting our goals to expand the availability and affordability of broadband…The future is bright for powerline broadband.”

The FCC believes that BPL will allow broadband services for those who had previously been unable to get cable or DSL services. Since the data rates of BPL are comparable to that of DSL and Cable Modems, BPL will serve as an alternate technology and promote additional competition within the broadband marketplace. The FCC is confident that the competition that BPL will bring to the market will result in lower prices for the consumer.

5.9 Promoting Broadband Competition

A duopoly exists in the current broadband services market. In this study cable operators had 60% of the market, DSL providers had 39%, and the remaining 1% was shared by Fiber to the Household (FTHH), wireless, and satellite. One of the greatest accomplishments of the Telecom Act of 1996 was the establishment of competition in the telecommunications sector. The responsibility of promoting telecommunication competition falls under the jurisdiction of the FCC. The promotion of competitive technologies such as Access BPL is outlined in the FCC's broadband strategic goal:

“To establish regulatory policies that promote competition, innovation, and investment in broadband services and facilities while monitoring progress toward the deployment of broadband services in the United States and abroad.”

However, the current broadband market has been segmented with each side of the duopoly taking their respective shares. The market has been split into the cost-sensitive, low data rate users and the more inelastic, high data rate users. Cable providers, with inherently more bandwidth, have gone after the high data rate users by charging a premium price, while the DSL providers have chosen to go after the cost-sensitive users. With both members of the duopoly apparently satisfied with their respective segments, they have less incentive to reduce prices than they would if they were in a more competitive market. The introduction of

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a third player in BPL would likely upset the market segmentation that the cable/DSL duopoly has today. The results of this added competition would be better service at a lower cost to the consumers.

5.10 Reliability Benefits of BPL Infrastructure

In addition to the benefits that the consumer may receive from broadband services, BPL also provides additional infrastructure monitoring and management capabilities to secure the integrity of the national power grid. As discussed earlier in chapter four, reliability is one of the most important factors for electric consumers. The earlier investigation looked at the importance of reliability at the utility level, but this issue must be considered at the regional and national level also.

The reliability of the United States power grid has been called into question by the Northeast power outage of August 2003. In that event, power was lost in the entire Northeastern transmission grid for over 2 days. The losses associated with a long term power loss in a major metropolitan area are catastrophic. According to the US Department of Energy, the economic costs of the 2003 blackout exceeded six billion dollars. BPL services can increase the reliability of the power distribution networks, adding intelligent network capabilities that allow increased outage awareness and avoidance. Features available in BPL will give the utilities increased system management capabilities such as load management and flow balancing to ensure that power outages will not occur. BPL will also add capabilities to track power outages in real-time, allowing better response times.


108 Ibid. The August 14, 2004 Blackout caused a reported loss of $6 Billion dollars according to the US Department of Energy.
5.11 Benefits to National Security

BPL services also offer the opportunity to increase the security of our nation’s power grid, in addition to providing broadband capabilities. The deployment of BPL services has been advocated by political parties and the Office of Homeland Security109, who believe that additional, redundant information networks make the nation more resistant to terrorist threats. Homeland Security officials believe that our national reliance on electric power creates an opportunity for terrorism. The proposed Energy Policy Act of 2003 will accomplish the following key Administration priorities to help secure our Nation’s energy future:

“Modernize our electricity grid by reforming outdated laws, promoting open access to the transmission grid, promoting regional planning and coordination, protecting consumers, and developing and deploying new technology.”110

The current administration views the deployment of new technology as one of the ways to secure the electric grid. The national power grid is vulnerable to terrorist attack because of its inability to dynamically respond to system failures. In a February 2005 report on cyber security by the President’s Information Technology Advisory Committee (PITAC), the importance of network intelligence was emphasized:

“The electric power generation industry, for example, relies on a range of IT systems and capabilities. It relies on supervisory control and data acquisition (SCADA) systems to collect information about system operation, help regulate and control power generation, optimize power production, respond to changing power demands and system parameters, control distribution, and coordinate among the various generation and storage facilities within a power company system. Increasingly, SCADA systems are also used to integrate electric companies into regional or national power grids to optimize power production, minimize production and distribution costs, and provide backup services.”111

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109 The Office of Homeland Security. See http://www.whitehouse.gov/homeland/ (last visited March 10, 2005). One of the primary roles is developing national strategy to help secure cyberspace and the infrastructures and assets vital to our public health, safety, political institutions, and economy.


As discussed in the previous chapter, BPL technology allows the benefits of SCADA systems to extend from the transmission lines to the medium voltage distribution lines. The cascading nature of the failures that have led to the major power outages in recent years demonstrate the need for a more reactive solution utilizing the features that BPL technology can provide. Lefteri Tsoukalas, head of the Purdue School of Nuclear Engineering, believes intelligence must be built into the power grid that will allow us to quickly and effectively respond to faults. “We need to begin developing a system to protect against such events by embedding the grid with monitoring devices that alert us not only to accidental events but also terrorist attacks,”112 Tsoukas says. “This system could automatically isolate the affected areas while routing electricity to the rest of the grid.”113 An intelligent BPL enabled network would be capable of monitoring the power grid for indications of a fault and dynamically respond to address the situations, whether they are accidental or terrorist related.

5.12 Internalizing BPL Externalities

Traditionally, positive externalities were made to affect a company’s profit structure only through intervention of a governmental agency. In the case of a negative externality such as pollution, a corporation will only comply when given an incentive. Government policy for market correction of externalities usually involves levying a fee in the case of a negative externality and a subsidy in the case of a positive externality. In the case of BPL, the positive externalities must be carefully examined. Investigating positive externalities requires a closer look at subsidization. A subsidy is defined as:

“A special money payment by a government to one or more firms in a favored industry, usually for the purpose of enabling them to sell one or more of their products at a price below their costs of production. Subsidies are typically advocated either to promote more widespread consumption of some good deemed to be especially essential or meritorious by the government, or to boost the levels of production of goods whose manufacture or

112 “Purdue faculty working to protect the homeland.” Purdue University News, 14 February 2005.
113 Ibid.
consumption involves sizable positive externalities or partake of the nature of public goods.\textsuperscript{114} This definition of subsidy was chosen because it describes how one might be used in the case of “sizable positive externalities.” The compensation of positive externalities through subsidy is often the case in agriculture. The government realizes that the cost of producing agricultural items is higher than the market is willing to bear, so they award subsidies to farmers to ensure that the level of production matches the optimal society utility. By offering these subsidies, the government assures that the supply curve shifts to the right and the product or service is created in larger amounts. If BPL produces positive externalities, particularly those that benefit society utility as a whole, the argument can be made that the government should offer some type of BPL subsidy. To assess the amount of subsidy that should be awarded, the overall utility given to society must be established.

The public utility of added competition in the current duopoly of broadband services is fairly substantial. Cable and DSL providers have experienced significant first-mover advantage and will likely engage in price wars to prevent the onset of competition. A market correction in the form of a subsidy for the deployment of BPL services would help to increase the rate of broadband penetration. Unfortunately, the subsidy would send inaccurate signals to a competitive market and may not result in utility improvement. Rather than provide financial incentives for BPL deployments, the FCC has decided to pave the way for BPL ventures by removing all regulatory obstacles that would prevent investment in BPL technology. By internalizing the positive externality of BPL competition through regulatory means rather than rate adjustment, there is less chance that the balance of the competitive market will be thrown off.

The argument for providing universal broadband service through BPL may stand as the strongest justification for financial subsidies. BPL is the only truly ubiquitous last mile

\textsuperscript{114} Johnson, Paul M. A Glossary of Political Economic Terms. Auburn University Political Science Department. \url{http://www.auburn.edu/~johnspm/gloss/index.html}. 63
solution that is capable of providing low latency, high data rate bandwidth to all households. The current administration sees universal broadband as a method for encouraging economic growth and has established a goal of 2007. However, a small but significant portion of the nation’s households are so geographically isolated that the infrastructure costs associated with broadband services will never be made in a competitive market. In these situations a government subsidy is necessary to offset the infrastructure costs. These subsidies can be funded by tariffs on competitive services as they currently are for the telephone universal service. By using universal service funds to establish BPL service on all existing power grids, the consumers not only gain broadband availability, but also gain the benefits of improved reliability and security as discussed in the next section.

Although BPL deployments for national power grid reliability and security could theoretically be subsidized economically, these positive externalities would most likely be internalized through regulation. Since the electric utility market is a regulated market, unlike the competitive broadband services market, regulation appears to be the most efficient method of establishing the proper market indicators. Rates in the utility market are regulated and set according to rate of return and performance, making the calculation of the proper subsidies difficult, given that the utilities are not engaged in competition and use different rate bases. In the regulated markets, a positive externality can be reconciled by allowing the utilities to offset some portion of the BPL infrastructure costs to the customers. Essentially, if a company is using cost-based regulation, nothing has changed except the capital expenditures. This allows the additional cost of improving the national infrastructure to be properly reflected in the consumer’s rates.

5.13 Impact on BPL

BPL services will face formidable competitors from established cable and DSL broadband offerings and is unlikely to create the same per dollar returns on infrastructure
costs. However, despite the first-mover advantages of cable and DSL, BPL offers several distinct advantages outside of broadband revenues alone. Many of these additional services provide significant utility benefits to society as a whole in the form of positive externalities. The competition from BPL has the ability to break the duopoly of broadband services and lead to better service and lower prices. This political goal is in addition to the reliability and security enhancements in the power grid that are enabled through the use of BPL technology. Political support for competition in broadband services is likely to lead to a favorable legislative stance towards BPL technologies. BPL also has the unique capability to provide ubiquitous broadband service to the underserved communities. Given this capability, BPL has the potential to be the enabling technology for the extension of traditional universal service to include broadband data services. Since each of these market externalities fall outside the economic influence of a single company, it is only through regulatory and political efforts that a competitive market will be able to internalize these factors. The ultimate challenge that the BPL industry will face is to garner political support for a method of regulatory reconciliation that will allow them to capitalize monetarily on positive externalities.
Chapter 6 - Conclusion

6.1 Recommendations

As stated in the introduction, BPL must be able to achieve three distinct objectives to successfully gain market acceptance:

1. The technical and regulatory obstacles of harmful interference must be adequately addressed to allow the necessary stability for investment in BPL.
2. A financial method for incorporating competitive BPL services into the unregulated industry must be established. This method must consider the efficiency enhancement features of an intelligent power grid to create revenue beyond that of broadband access services alone.
3. The positive externalities of BPL must be properly accounted for by achieving the removal of regulatory obstacles, establishing additional revenue through subsidies, and securing universal service funding.

Table 7 – BPL Market Acceptance Requirements

Through my research I have established a set of recommendations for how each of these objectives can be achieved.

This thesis has provided evidence that BPL will prove itself capable of overcoming the technological obstacles that it will encounter over the next few years. Innovators within the telecommunications field have proven themselves fully capable of solving technical challenges that face the industry. BPL systems have already demonstrated their ability to notch-out bands for incumbent spectrum users and a number of solutions have been presented to solve the issue of transformer voltage step-down. Companies such as Amperion and Current Technologies are dedicated to solving these problems and have increased the number of live BPL deployments. Since the manufacturing process and market has already been established by DSL and cable modems, BPL technology will be able achieve returns to scale much quicker and have an existing competitive landscape among the manufacturers. The cost of BPL technologies such as processing chips for modulation and line injectors will continue to drop at a rate as great, if not greater, than their competitor’s.
The BPL industry must recognize the FCC as a strong advocate and use this advantage to establish stability in the BPL regulatory environment. The FCC has removed the primary regulatory obstacles existing in BPL with the codification of the rules and regulations regarding emissions measurement and interference mitigation in the October 2004 Report and Order, generating market security and paving the way for further investment in BPL. The FCC will remain dedicated to pushing BPL as a competitive entrant into the broadband services sector as long as it is able to retain its position as the ubiquitous “third wire” in last-mile access technologies. However, we must suggest that BPL avoid any delay in capitalizing on this favorable regulatory stance to avoid the potential risk of being overshadowed by the fixed wireless technologies such as WiMAX.\(^{115}\)

The greatest financial challenge facing the electric utility industry is the integration of BPL technology into their physical and operational infrastructure. The potential benefits of increased efficiency and additional revenue that are realized through BPL services is primarily dependant upon the regulatory methodology that is mandated by the state public utility commission. Utility markets are undergoing a fundamental shift from rate-of-return regulation to performance-based regulation. This shift to performance-based regulation will create incentives for the reduction of operating costs and lead to competition in the utility markets. Competition will be good for both the consumers and the enterprising utilities because only those utilities that are able to increase reliability and provide better service through an intelligent network will be able to survive. By using BPL capabilities to increase their rate-of-return, electric utility companies have the opportunity to offset a large portion of the cost of the BPL infrastructure while also delivering enhanced services to the customer.

\(^{115}\) WiMAX Forum. See [http://www.wimaxforum.org/home](http://www.wimaxforum.org/home) (Last visited March 10, 2005). WiMAX is an IEEE 802.16 standards-based technology created to deliver last mile broadband services through wireless technologies. WiMAX provides fixed and mobile broadband connectivity through wireless technology similar to WiFi. Typical range is 3 - 10 km and has up to 40 Mbps bandwidth per channel. WiMAX has been touted as the solution to universal broadband access and high bandwidth mobile services.
Given the benefit to society from increased competition and the value-added services created by the incentives found in new regulatory methodologies, public utility regulators will continue to move towards the performance-based regulatory model, clearing the path for efficiency enhancement technologies such as BPL.

The BPL industry must find methods for internalizing the positive externalities that are inherently created through BPL services. There are significantly large economic utility benefits that BPL services provide to society, but these benefits will become unrealized if BPL providers are unable to find a way to capture them financially. BPL providers must continue to work with political supporters at clearing legislative obstacles to ensure that BPL will be capable of providing a competitive alternative to DSL and cable. Utility companies must actively seek government subsidies from the Department of Homeland Security in exchange for the increased reliability, security, and resiliency to terrorism created within the national power grid. As our society moves toward an information based economy, the definition of universal service will be extended to include broadband internet services. BPL is in the position to benefit from universal broadband service funds as the only truly ubiquitous last-mile broadband technology. Although capturing these positive externalities presents a difficult challenge, the financial benefits will be great enough to make BPL services a formidable competitor to the cable and DSL duopoly.

6.2 Final Analysis

Broadband over power lines presents a unique opportunity to provide universal broadband access using the existing power distribution grid. Despite a precarious start in the regulatory area, BPL has been able to largely overcome the issue of harmful interference. Although the optimal price setting methodology a regulated utility should employ when entering the competitive broadband services market remains uncertain, the utilities have found added incentives for the deployment of BPL in the efficiency improvements created in
the power distribution grid. Although BPL may have a difficult time competing with cable and DSL in the established broadband services market on price alone, the performance enhancements provided by intelligent network capabilities will make tremendous headway towards defraying the cost of the infrastructure. BPL has also shown to be in a favorable position to capture significant benefits from the positive externalities that BPL technologies create for the general public. The greatest near-term challenge that BPL will face is the financial realization of the indirect incentives that BPL technology can offer. This thesis has shown that if this financial realization can be achieved, BPL is fully capable of becoming the “ubiquitous third broadband pipe to the home.”
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# APPENDIX A – ACRONYMS

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>Alternating Electric Current</td>
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<tr>
<td>AMR</td>
<td>Automated Meter Reading</td>
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<td>ARRL</td>
<td>American Radio Relay League</td>
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<td>BPL</td>
<td>Broadband over Power Line</td>
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<tr>
<td>BPU</td>
<td>Board of Public Utilities</td>
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<td>CEIDS</td>
<td>Consortium for Electric Infrastructure to Support a Digital Society</td>
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<td>Digital Subscriber Line</td>
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<td>Distribution Management Systems</td>
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<td>Electromagnetic Interference</td>
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<td>Orthogonal Frequency Division Multiplexing</td>
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<td>Performance Based Regulation</td>
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