OECDpublishing

Please cite this paper as:

Kwon, B. (2009-06-04), “Broadband over Power Lines (BPL): Developments and Policy Issues”, *OECD Digital Economy Papers*, No. 157, OECD Publishing, Paris.
http://dx.doi.org/10.1787/222266878856

OECD Digital Economy Papers No. 157

Broadband over Power Lines (BPL)

DEVELOPMENTS AND POLICY ISSUES

Byung-Wook Kwon

OECD

Unclassified **DSTI/ICCP/CISP(2008)3/FINAL**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

04-Jun-2009

English - Or. English

DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY
COMMITTEE FOR INFORMATION, COMPUTER AND COMMUNICATIONS POLICY

DSTI/ICCP/CISP(2008)3/FINAL
Unclassified

Cancels & replaces the same document of 02 June 2009

Working Party on Communication Infrastructures and Services Policy

BROADBAND OVER POWER LINES (BPL): DEVELOPMENTS AND POLICY ISSUES

English - Or. English

JT03266053

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

FOREWORD

The Working Party on Communication Infrastructures and Services Policy discussed this paper at its meeting in December 2008. The Working Party agreed to recommend the paper for declassification to the ICCP Committee. The ICCP Committee agreed to the declassification of the paper in March 2009.

The paper was drafted by Byung-Wook Kwon of the OECD Science, Technology and Industry Directorate. It is published under the responsibility of the Secretary-General.

TABLE OF CONTENTS

MAIN POINTS

At first glance Broadband Power Line (BPL) technology seems to have a high potential to provide ubiquitous broadband access to households and businesses across a country. The fact that electricity is provided on a nationwide basis seemingly gives BPL an advantage. The commercialisation of BPL could also be important from a competition perspective providing a second or third wire to the home in competition with digital subscriber line technology and cable modem technology. It also has the potential to be a shared technology, given its use in developing smart grids and monitoring consumption of electric power to share costs. BPL also has unique features such as the possibility of in-home access for broadband from any power socket in the room without the need for further in-house wiring.

Thus, while BPL has all the features of a promising technology, it has not, as yet, fulfilled earlier expectations. The extremely slow growth in the number of BPL service providers, and customer base, and the fact that a number of BPL service providers have been withdrawing from the market concentrating instead on developing smart-grid technology to monitor energy consumption, seems to indicate that service providers face problems.

There are a number of technological and, to a lesser extent, regulatory issues which need to be overcome in order to facilitate the take-off of BPL technology in the market. The electrical grid provides a harsh environment for data transmission, issues regarding radio frequency interference are both technological and regulatory, and international standardisation is incomplete. BPL requires investment, in particular where power grids are old, and BPL also requires investment to send data over long distances. Furthermore as broadband over DSL migrates to fibre and cable modem speeds increase as a result of new technology, the competitive environment facing BPL becomes more difficult.

In short, while there may be a potential for BPL to further competition in the broadband market, there is little evidence to indicate that this will take place soon and that it can be counted on to provide a competitive alternative in the near term to xDSL (or fibre to the home) and cable modem technologies. Nevertheless, a technology neutral policy would argue in favour of regulators ensuring that no unnecessary barriers are in place for the eventual commercial diffusion of this technology as well as ensuring that interference with other licensed wireless services is minimised.

I. INTRODUCTION: GOAL AND SCOPE

The focus of this paper is to provide an overview of developments in broadband power line technologies and related policy issues. The electric power grid is a hostile environment for high-speed data transmission, but after years of development, the technology to deliver high-speed data over the existing electric power delivery network has emerged, somewhat tentatively, in the marketplace. This technology, referred to as *Broadband over Power Lines* (BPL), uses medium- and low-voltage power lines to provide broadband Internet access to residential users and businesses and is considered by some as a third access technology offering potential competition to xDSL telecommunication lines and cable modems. Recent trends, however, indicate that the focus of BPL technology is shifting from providing broadband connectivity to smart meter usage allowing households to reduce energy costs and allow energy companies to better manage their networks by developing a “smart grid”.

BPL technology is relevant to a variety of public policy issues, such as energy, communications, environmental policy, and national security policies. For example, BPL can promote energy policy by enabling advanced metering initiatives for time-of-use pricing, load management and outage detection, but it can also enhance communications policy by providing broadband access and promoting competition for broadband services to rural and under-served areas. Furthermore, it is relevant for environmental policies through conservation and energy management that reduce greenhouse gases, and for national security through network redundancy and video surveillance applications that are being used for public safety and critical infrastructure protection.

There are several reasons why BPL can be attractive as a third wire to the home. From the perspective of electrical utility companies the basic infrastructure is already in place (electric grid) and there is no requirement to obtain rights of way or construct ducts, nor is there a need for business or household wiring to deploy BPL. This enhances the cost-effectiveness of rolling out BPL. Only the sub-station server equipment and customer conditioning service units need to be installed in order to establish a digital power line network. Another important benefit from the perspective of providers is that the power grid is virtually ubiquitous in most countries providing an already existing network infrastructure covering private customers as well as businesses.

From the perspective of end users, the equipment needed to set up BPL in the home is cheaper on average than that of other broadband solutions such as DSL and cable modems. The equipment uses existing power outlets in the home making it easier to set-up and there is no need for additional wiring or installations.[1] For end users in rural areas, who cannot receive DSL or cable modem services, BPL could have the potential to provide a broadband access which can support triple play services and automation of a smart network controlling electrical consumption.

Despite the potential advantages of BPL, it faces a number of serious challenges. Technologically, BPL has floundered over the last few years because it can generate radio frequency interference with amateur and emergency radio. The slow rate of growth in BPL, with less than 30 000 subscribers in 15 OECD countries as of 2007, and the lack of international standardisation, has also meant that there have been insufficient scale economies in the manufacture of equipment. Many BPL trials and/or commercial networks are being abandoned or are being reconverted for use in smart-electrical grid monitoring.

This paper reviews the main challenges facing BPL, focusing on three variables, namely, technology, markets, and public policy.

II. BPL: AN OVERVIEW

1. What is BPL?

Broadband over Power Lines (BPL), also known as Power Line Communication/or Carrier (PLC) or Power Line Telecommunication (PLT), is a technology that allows voice and Internet data to be transmitted over utility power lines.[2] BPL transmits high frequency data signals through the same power cable network used in carrying electrical power to household/or business subscribers. In order to make use of BPL, subscribers install a modem that plugs into an ordinary electrical wall outlet and pay a subscription fee similar to those paid for other types of Internet service.[3]

BPL is based on PLC technology developed in 1928 by AT&T Bell Telephone Laboratories, and which has been used for internal and low-speed data communication applications since that time by the electric power utilities.[4] Based on PLC technology, some customer premises equipment (CPE) such as intercom systems, have used the embedded electrical wire to avoid the cost of special wiring. In Europe and most of the rest of the world, PLC standards allow for communications over the 220-240 volt power grid at frequencies of 30 KHz to 150 KHz. In the United States, the standards for the 120 volt power grid allow the use of frequencies above 150 KHz as well. Power utilities use the frequencies below 490 KHz for internal applications such as telemetry and monitoring and control of equipment at remote sub-stations. In the 1990s, development began on broadband over power line (BPL), which has since then been regionally standardised.[5]

2. How does it work?

In order to provide data communication, the initial BPL systems coupled radio frequency (RF) data signals into the existing electric power lines. The high frequency data signals are transmitted through the same power lines that carry low frequency electricity to the household or business. This enables both signals to coexist on the same wire.[6]

From the specific technological perspective, the basic idea of BPL technology is to modulate a radio signal with data and send it through power lines in a band of frequencies which are not used for supplying electricity. The frequencies used and the encoding scheme have a significant influence on the efficiency and the speed of BPL service. The encoding scheme which is used by most of the BPL providers is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a technique used for transmitting large amounts of digital data over a radio wave. OFDM splits the radio signals into multiple smaller sub-signals that are then transmitted at different frequencies to the receiver. The transmission of data by OFDM along several of the carrier frequencies simultaneously increases speed and reliability. Data loss occurs when electrical distribution is interrupted by electrical devices turned on and off. OFDM uses small packets to deliver data within the home, losing only small amounts of data rather than the whole signal.[7]

Another encoding scheme which is used in BPL is Direct Sequence Spread Spectrum (DSSS). DSSS is one of two types of “spread spectrum techniques”[8] wherein a data signal at the transmitter is combined with a higher data rate bit sequence, or chipping code, that divides the user data according to a spreading ratio. The chipping code is a redundant bit pattern for each bit that is transmitted, which increases the signal’s resistance to interference. The redundancy of data helps in recovering the bits that are corrupted during data transmission.[9]

From the system engineering perspective, BPL provides effective data communication through a combination of the electric network within the home or office, the power distribution grid, and the backbone network which transfers the data signal from the Internet Service Provider (ISP) to the power lines. BPL systems take advantage of one of the largest and the most pervasive networks, the power distribution grid.

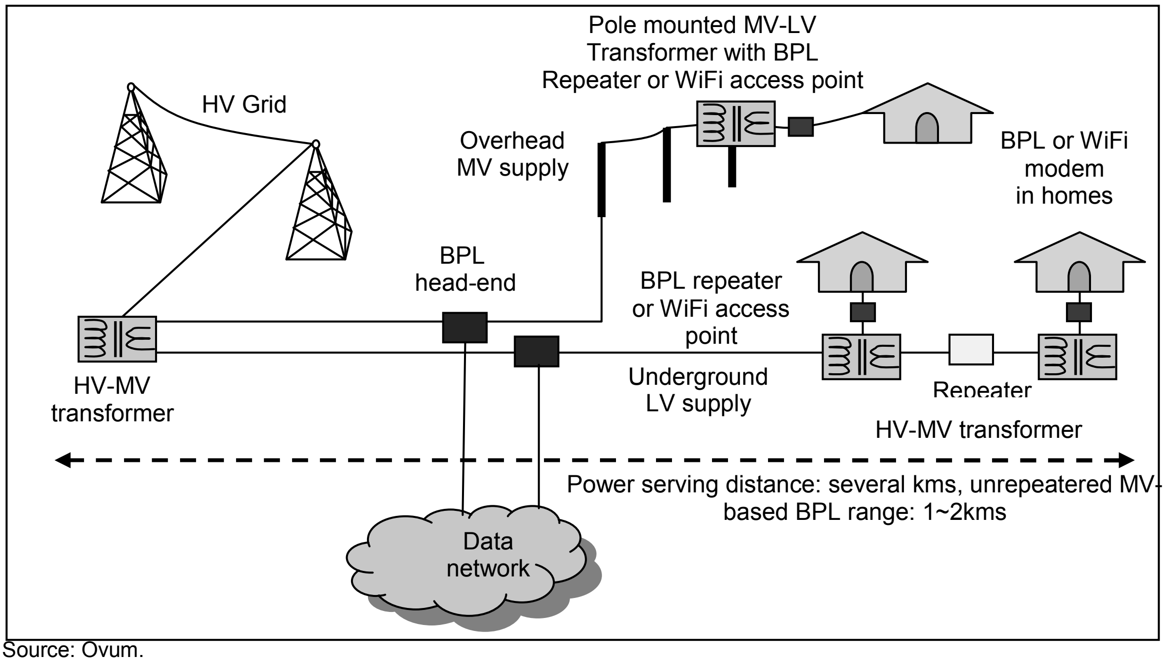
The power distribution grid is made up of a number of components aimed at delivering electricity to customers, and includes overhead and underground Medium Voltage (MV) and Low Voltage (LV) power lines and associated transformers. First, power is generated at power stations and distributed around a medium to large geographical area via High Voltage (HV) lines. Second, in areas where power needs to be distributed to consumers, transformers will be used to convert this high voltage into a lower voltage to transport over MV power lines. These transformers are generally located at electrical sub-stations operated by the utility or power supplier. Such MV power lines will be used to transport electricity around smaller geographical areas such as small towns. Finally, for the purposes of using electricity in the home or business a transformer is used to reduce the voltage down to safer and more manageable voltages at the customer's house or business premises. This power is usually transported over LV power lines. These LV power lines include the lines that traverse a customer's home or business.[10]

Over the existing power distribution grid, recent technological advancements have led to the development of new systems that make it possible to deliver broadband services. These systems are comprised of *access BPL*, *in-house BPL*, or a combination of both technologies.[11] Access BPL uses electrical transmission lines to deliver broadband to the home, and uses injectors, repeaters, and extractors to deliver high-speed broadband services to the customer. Injectors/or concentrator are devices that aggregate the end user Customer Premises Equipment (CPE) data onto the MV grid. Injectors are tied to the Internet backbone via fibre lines and interface to the MV power lines feeding the BPL service area. A repeater is a physical-layer hardware device used on a network to extend the length, topology, or interconnectivity of the physical medium beyond that imposed by a single segment. Extractors provide the interface between the MV power lines carrying the signals to the customers in the service area. BPL extractors are usually located at LV distribution transformers that service groups of households. Since the BPL signal loses strength as it passes through the LV transformer, extractors are required to retransmit the signal. In other cases, couplers on the MV and LV lines are used to bypass the LV transformers and deliver the signal to the customer. One company, Corridor System, has designed a third type of extractor transmitting a wireless signal directly from the MV power line to the customer.[12]

In-house BPL is broadband access within a building or structure using the electric lines of the structure to provide the network infrastructure. In-house BPL will network machines within a building. Unlike access BPL, in-house BPL utilises the electric wiring in a privately owned building and not the electric power lines owned, operated or controlled by an electricity service provider. Broadband devices are connected to the in-building wiring and use electrical sockets as access points. In-house BPL technologies are largely designed to provide short-distance communication solutions which compete with other in-home interconnection technologies. Product applications include networking and sharing common resources such as printers.[13]

Figure 1 shows the simplified Medium Voltage (MV) BPL access network. The BPL signal in this network is transmitted over the MV system from a head-end[14] in the local network, and for the purpose of final distribution of BPL service to the end user, either a local repeater to counter the signal-blocking effect of the local transformer, or alternatively a WiFi wireless LAN access point can be used. In such countries as the United States where the local electricity supply is 120V, medium voltage (MV) systems deliver power very close to many premises with a very localised transformer providing the final 120V supply to relatively few premises, which can be as low as between one and six homes in rural areas.[15]

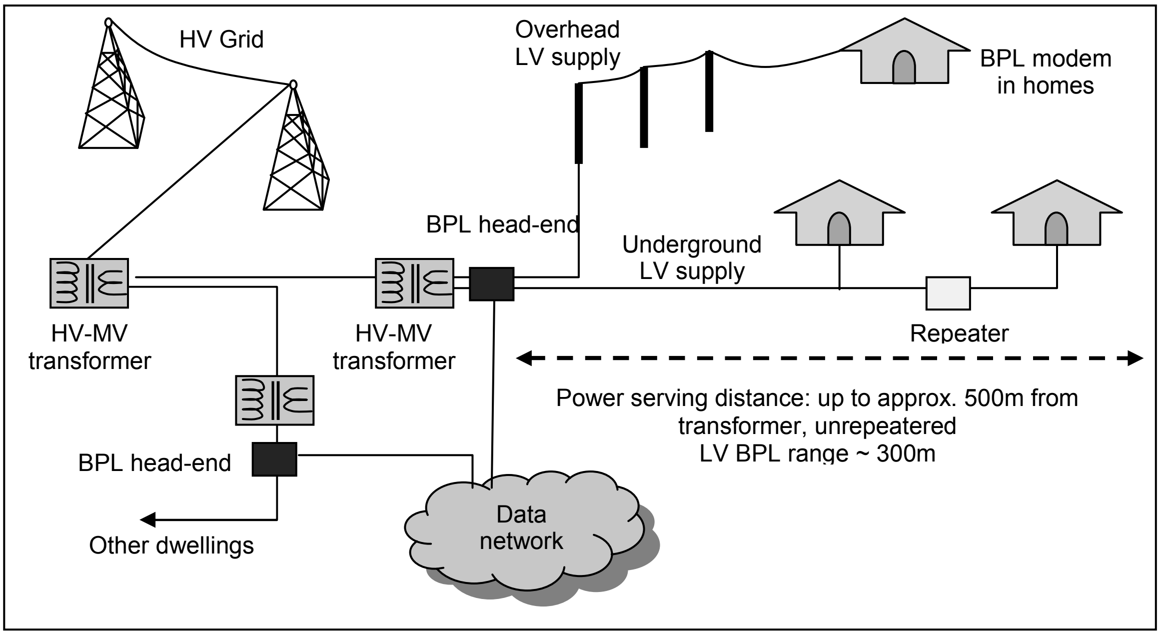
Figure 1. Medium voltage BPL Access Network



Source: Ovum.

Figure 2 shows the Low Voltage (LV) BPL access network, common in Europe and parts of Asia-Pacific. In this case, the system head-end is the local step-down transformer,[16] and the LV wire is used for the broadband data distribution. In countries where the local electricity supply is 220-240V, the local step-down transformer is usually located further from the final customer, and can distribute power to typically tens of hundreds of customers.[17]

Figure 2. Low-Voltage BPL Access Network



Source: Ovum.

3. Why BPL?

Inherently BPL would appear to have a very high potential in terms of its market reach, given the ubiquity of electricity service in countries, and the fact that it is a shared medium, potentially allowing for more cost sharing than certain other technologies. The fact that electrical utilities have virtual nationwide rights of way also makes them attractive partners for companies providing backhaul and backbone communication networks. BPL is also attractive as utility companies own more paths directly into the home than most telecommunication companies, especially in rural and remote areas. For end users in rural areas, who cannot receive DSL or cable modem services, BPL could potentially provide an all-in-one service providing telephone, television and high-speed data access.

It also has a unique feature providing the possibility of in-home access for broadband from any power socket in the room, as well as the fact that customers will be able to get the same speed both ways (upload speed is slower than down-load speed for both DSL and cable services). Electrical cabling in the home can be used to network PCs, printers, telephones and fax machines. Equipment needed to set-up BPL in the home is as cheap as that of other broadband solutions such as DSL and cable modem.

Potentially BPL can be a third access technology providing a range of extra advantages that the other technologies do not have. These range from a simple Automatic Meter Reader (AMR) facility that reduces costs for the utility, to a number of other home automation and home management services that can be of benefit both to the utility and the end-user. In addition, from the perspective of network security, BPL can be a third wire at the national level safeguarding communications in case of outages of the telephone or cable systems.

The extra services that BPL could provide would also be a key element of a business model allowing BPL service providers to differentiate their quadruple play services from xDSL and cable modem service providers.

The potential list of customer services can include the following:[18]

- Voice over Internet telephony.
- Automated monitoring and control of end-use equipment, including demand response and load shedding.
- Billing data and energy consumption data.
- Real-time building security monitoring/reporting.
- Automated inventory tracking of various goods such as fuel stocks.
- Dynamic price information.
- Video on demand.
- Streaming audio.
- Real-time, interconnected Internet-based games.
- Transmission of data/telephone/fax without multiple fixed lines.
- Triple play services; voice/data/video.
- Quadruple play facilities; triple play services and home automation network.

III. TECHNOLOGICAL DEVELOPMENTS AND CHALLENGES

1. Historical overview

Because of low speed, low functionality and high development cost, BPL technology was never seriously considered as a communication medium, even though it has been operational since the 1930s. Historically, BPL was not only a control mechanism for electrical utilities, but also was originally designed to send simple commands over power lines at such low frequencies as 100-180 kHz. Such a mechanism makes both remote monitoring and diagnostics possible even over long distances. More recently, BPL has been used in "smart homes". Smart homes can provide such automated applications as entry, entertainment, and comfort systems, and can be networked and controlled from a central location. A simple form of BPL also provides the basis for intercom systems.[19]

The first technique to make use of power lines to control messages was the method called "Ripple Control."[20] Ripple control generally refers to systems that are applied to electrical networks for demand side management purposes. They offer a means of communication from a central point to any point on the LV network for action at end-users' premises. Ripple control is mainly dedicated to mass applications but individual and specific applications can also be addressed. This system does not only provide one-way communication technology, but also can support such applications as the management of street lights and load control.

In the mid 1980s, experiments on higher frequencies were carried out to analyze the technological characteristics of the electric power grid as a medium for data transfer. Frequencies especially in the range of 5-500 kHz were tested. In these tests, both the signal to noise levels and the attenuation of the signal by the power grid were important topics for measurements. These tests were undertaken both in Europe and in the United States.

In the late 80s and early 90s, two-way communication was developed using power grid networks. The main difference of those networks compared to modern networks is that today's networks use much higher frequencies and there is a substantial reduction of the signal levels. Since 1997, the various experiments conducted focused on data transfer via power grid networks with higher bandwidth in both Europe and the United States.[21]

2. Technological complexity and its challenges

Until recently high-speed, long-distance data transmission over power lines has been hampered by the characteristics of the electric environment. These include radio frequency interference, the presence of electric noise, attenuation of data signal, and the complexity of sending data through or around distribution system transformers. The technological characteristics of the electric power lines act as a hostile environment, and create complexities to ensure effective power line communication.[22]

In this context the ITU undertook a study of the three types of wired broadband transmission which focused on the fundamental differences of the systems. Table 1 shows the characteristics of the three wired broadband media, identifying BPL as least suitable in all aspects.

Table 1. The Characteristics of the three wired broadband media

Nature	Coaxial Cable	DSL	BPL
Suitability of the transmission medium to carry broadband data	Very Good	Medium	Poor
Inherent electromagnetic compatibility (EMC) features of the cable system	Screened	Balanced	Indeterminate
Available bandwidth and potential for expansion	Very Good	Fair	Poor
Practicality of applying mitigating measures	Good	Medium	Very Poor

Source: ITU.

The most significant challenge for BPL technology appears to be radio frequency interference (RFI). Ham radio operators have claimed that BPL makes it difficult to operate their devices. According to the American Radio Relay League (ARRL), BPL systems produce RFI within 75 meters for mobile radio and 150 meters for fixed radio.[23] To reduce the potential RFI, BPL providers need to reduce the transmission power which consequently increases the number of required repeaters and the cost of the system.[24] Nevertheless, this issue has subsided somewhat since the FCC in the United States established testing requirements for equipment, and in Europe, the European Commission recommended how to apply provisions of the electromagnetic compatibility directive.

Another concern is that due to high attenuation (a reduction in the intensity of the signal) that occurs during transmission it is necessary to use repeaters at regular intervals. BPL is vulnerable to noise and furthermore, it is likely that an increased noise floor could occur across the high frequency (HF) bands due to the propagation characteristics of HF. Such problems are hard to narrow down to a particular system and a cumulative effect could be made by hundreds of these systems operating across a country.[25]

Scalability can become an issue, considering that the more subscribers are added, the more bandwidth is needed, which will lead to more network segmentation needs. This means that much wider HF spectrum will be needed as the BPL system is further deployed throughout a given area. In an extreme case, a BPL provider will inevitably face local interference as the entire HF spectrum will be needed to operate the BPL system.[26]

Security can also be a concern when using BPL technology. Power line cables are not twisted and use no shielding. These technological characteristics of BPL as a medium for data transfer mean that power lines cannot only produce a fair amount of Electro Magnetic Interference (EMI), but such EMI can also easily be received via radio receivers. Thus, encryption must be used to prevent the interception of sensitive data by unauthorised persons.[27]

3. Developments Enabling BPL Technology

Prior to recent developments of BPL technology, technological obstacles have hindered high-speed and long-distance data transmission over power lines. But the newly developed digital circuits have made it possible to help manage noise, attenuation, and help circumvent and/or bypass transformers. Sending broadband signals over high-voltage, long-haul lines may still be too difficult, but to create a communications connection to the end users over power lines, equipments can be placed at critical locations along MV distribution power lines. This communications network is connected to fibre, or backhaul that connects the BPL network to the Internet.

Foremost among the technical advances enabling BPL technology is how data signals are coded and modulated. As noted earlier, methods such as OFDM and DSSS rely on adaptive algorithms to cope with noise on the BPL system and reduce radio interference, and enable BPL to become a realistic and practical medium of communication. Repeaters or other amplification equipment are available that can boost and stabilise data signals. Placed at intervals of between 1000 feet and 1 mile, these signal boosters can minimise signal deterioration.[28]

Furthermore, various methods can be used to avoid attenuation at the distribution transformer. The first method is by-passing the transformer instead of going through it. The United States company, Amperion, uses this approach by extracting incoming data signals, converting them to a radio signal, and finally sending it to the premises of a customer. A second method is used by Current Technologies whereby signals can be extracted from the medium-voltage side and converted to a different power line signal and sent to the customer site over a secondary line. The last one is the method of equipment supplier Main.net by which the signal can be moved through the transformer.

In order to reduce the potential radio frequency interference (RFI), some vendors, like DS2, claim that they can alleviate RFI problems by filtering out frequencies that are interfering, and using other techniques to eliminate signal interference in power lines, while others, like Corridor Systems, propose to use microwaves instead of the lower frequency bands to transmit the data. On the other hand, Motorola uses BPL only on LV power lines and provides the backhaul wirelessly to overcome RFI which, according to them, results in less interference because it uses only low voltage power lines.[29]

Faster chip sets, or digital signal processors, enable high-speed data transmission through a noisy path by encoding the data into a signal, sending it, and then receiving the signal and decoding it for extraction. The high speeds of the latest integrated circuits are essential to the high data-transfer rates. This allows BPL to keep pace with the improving performance of other broadband access technologies.

IV. MARKET DEVELOPMENTS AND ITS LIMITS

1. Vendors and utility companies

Vendors/technology companies

There are numerous BPL vendors/or BPL technology companies in the marketplace. Among the various BPL companies, Table 2, 3, and 4 summarise four integrated BPL solution providers, six BPL equipment suppliers, and two BPL IC chip makers respectively. Notably among the others, companies such as Current Technologies and Ambient bypass the power transformer with special couplers to provide high-speed data access to the customer premises via a standard electrical outlet using existing standard consumer devices such as those promoted by Homeplug or EIA (CEbus). MainNet Communications relies on OFDM techniques to go through a transformer. Amperion uses Wi-Fi technologies to bring the Internet signal to the customer from the medium voltage lines before it gets to the transformer.

Table 2. Integrated BPL solution providers

Grindline Communications · Provides one stop shop for broadband & content solution · Uses following technologies - LV& MV couplers - integrated distributed BPL for last mile broadband access - integrated SoHo networking product · has relationship with Broadband Horizons, Allterra Holding LLC, UK-based eXstream Networks	**Current Communications** · Provides Smart Grid & BPL products & services · Specializes in end-to-end solution · Consists of three subsidiaries - Current Communications - Current Technologies - Current Technologies International GmBH · Acquisition of Kreiss Johnson Technologies(KJT), a developer of analytic software for electric utilities
IBEC (International Broadband Electric Comm. Inc.) · Full service provider of BPL solution, security, utility management &solution · Specialized in BPL coupling technology · Uses HomePlug modem · Has relationship with Cooper System Inc., a producer of MV & HV distribution solution and HV applications	**Utility.net** · Network operator & BPL full-service providers · Focuses on signing up IOUs in remote or hard-to-reach areas · Uses Three-step program - BPL equipment certification - BPL test agreement - BPL deployment Agreement

Source: Paul Budde Communication Pty Ltd, 2008.

Table 3. BPL equipment suppliers

Ambient

- Bypasses transformer
- Network layer products: S-Node (at the substation), X-node (bypassing the transformers), R-node(repeater, strengthening the signal along the line), GW-node(gateway, connection to the home), U-node(user, a low-cost GW option)
- Physical layer components: coupler and the nodes will provide high-speed data access to the premises via a standard electrical outlet
- Lists relationships with Ameren, PPL, Telecom LLC, Southern Telecom, etc
- Lists operating speeds at 1.5-4Mbps
- has relationship with Con Ed of NY, DS2, Earthlink

Amperion

- Pairs medium-voltage connect power line technology with WiFi
- Designed to serve multiple customers per transformer
- Delivers data at WiFi speeds
- Uses an injector, a repeater and an extractor. The devices clamp onto an electric line
- High-speed access to homes within 600 feet of transformer
- Has relationship with AEP and Cisco System, Inc.

Corinex

- Provides in-house BPL IP distribution equipment
- Utilizes the frequency division domain together with Ethernet
- provides the BPL regenerator designed with 200Mbps technology and operates at real speeds of up to 85Mbps
- provides AV200 Powerline Ethernet adapter which is currently in deployments, tests and field trials with over 40 operators worldwide for IPTV over powerlines
- Develops new Noise Resistant (NR) medium-voltage (MV) gateway

Corridor System

- Demonstrates the fastest communications over medium-voltage (MV) powerline at 216Mbps in Santa Rosa, California
- Develop a system for extending outdoor mobile wireless coverage efficiently and at a significantly lower cost through the use of the existing electric grid
  - transport spectrum across MV powerline
  - multiple applications including mobile wireless, Internet access, and transport of dedicated data/voice circuits is possible by using this system

Current Technologies

- Bypasses transformer
- Uses the following elements :
  - CT backhaul point to connect traditional networks to the distribution network – uses coupler
  - Coupler – interfaces the signal between the power line and the bridge or backhaul point
  - Bridge – gateway between the MV and LV distribution network(handles security, routing of IP packets, admission control, service monitoring , modulation of signal over low voltage
- Lists operating speeds at 2-6Mbps today
- Uses HomePug standard

MainNet Communications

- Goes through the transformer using OFDM (Orthogonal Frequency Division Multiplexing)
- Provides standard data rate of 2.5Mbps at user level
- Uses a modem, specially designed to operate in noisy powerline environments
- Uses a concentration head end unit., RF repeating units at the transformers, in-home network terminator devices
- Technology is FCC Part 15 verified
- They cite that have customers in 40 countries using this solution on a commercial basis

Source: IBM Corporation 2005 & Paul Budde Communication Pty Ltd, 2008

Table 4. BPL IC chip makers

DS2	Intellon
· Global supplier of silicon chips & software · specializes in 200Mbps chip and in-home powerline networking analogue chip · Provides a special mitigation technique called 'notching' technique · Adopted by Universal Powerline Association (UPA) and Open PLC European Research Alliance (OPERA) consortium · Launches a new powerline adapter reference design like one-touch set-up to create High Definition TV (HDTV) speed home network	· Maker of Intellon HomePlug 1.0 chip(14Mbps), HomePlug AV chip(85Mbps) · Focuses on research & developmnet - 18 US patents - 15 pending US patents - 5 foreign patents - 39 pending foreign patents · Its PowerPacket technology* was selected by HomePlug Powerline Alliance · a major contributors to the baseline technology for the new 200Mbps Homeplug Audio/Video standard

Source: Paul Budde Communication Pty Ltd,2008.

* : Intellon's PowerPacket technology is home networking technology, making it possible to network a home through ordinary powerlines at speeds up to 11 Mbps.

Notable utility companies

There are a wide range of energy companies in the United States that have shown interest in BPL or are currently using BPL on a trial basis. Cinergy is the first to go commercial. At least four other major United States utility companies decided in 2005 to go commercial. In Europe, energy market liberalisation has created new opportunities for power utility companies to exploit their existing power supply cables to create an alternative broadband supply route. In particular, the EC's recommendation that member states remove unjustified regulatory obstacles, in particular from utility companies, to the deployment of BPL systems facilitated the BPL market entry of power utility companies. Table 5 summarises the past and current major electric utility companies pursuing BPL in the OECD countries.

Table 5. Past and current utilities pursuing BPL

Country	Utilities
Austria	EVN (Ascom), TIWAG (Ascom), SSW, Linz AG
Czech Republic	PRE
Denmark	NESA (Ascom)
Finland	Energi Randers, SENER, Pori Energia, Sonera, Turku Energia
France	EDF (Ascom), Evicom, DefiDev
Germany	MVV (PPC), EnBW (Ascom), Avacon (Oneline), Offenbach, GEW, GWS, Stadtwerke Solingen, Stadt Werke Dresden, Schools Online Project, Drewag, Stadtwerke Hameln
Hungary	Novacom
Iceland	Reykjeviken
Italy	Enel (Ascom), ACEA
Luxembourg	CEGECOM
Netherlands	Nuon
Norway	Viken Energinetti (Ascom), BKK, Lyse
Poland	Gdansk, Pattern, Stoen, ZKE
Portugal	EDP (Ascom), Oni220
Spain	Endesa (Ascom), Iberdrola (NAMS, Mitsubishi), Union Fenosa
Sweden	Birka Energi, Elforsk, Graninge, Skanska, Sydkraft, Vattenfall (Ilevo, MainNet)
Switzerland	Sunrise EFF, Groupe E (Formerly EEF)
UK	SSE Telecom
US	Duke Energy, Entergy Corporation, Cinergy, Alliant Energy, Progress Energy Corporation (PEC), IOU FirstEnergy, TXU Electric Delivery, etc

Source: BuddeComm based on bmp Telecommunications Consultants and Bender IS Technology, 2006.

2. BPL tests and market developments: Trials and subscribers

Since 1995 when customer BPL trials, using a prototype system, began in Manchester in the United Kingdom, there have been over 100 trials and early stage commercial deployments of BPL in OECD countries. A number of OECD countries, including Australia, Austria, Canada, Finland, Ireland, Italy, Korea, Japan, the Netherlands, and Switzerland have examined BPL technology or have permitted BPL equipment trials.[30] The results have been mixed and have led to some administrations banning BPL systems while others have allowed deployment under various conditions. A number of administrations have suspended BPL trials pending international developments.

In Australia, several trials of BPL technology have been conducted in recent years, however none of them have progressed to on-going commercial offerings.

In Austria, there have been four BPL trials conducted by utility companies in different cities. Three trials were put on hold because of problems such as the financial uncertainties of suppliers and complaints of radio users relating to interference. The only commercially successful BPL service is operated by Linz AG, which offers BPL through its Linz AG Strom subsidiary, in the Linz region.[31] In 2007, regulators reported 5 500 BPL subscribers in Austria.

In Canada, BPL is still in its early exploratory stages with few trials and fewer commercial deployments available. By late 2007, city-wide BPL deployments were rare and most commercial BPL deployment were in the form of low-voltage BPL solutions within hotels.[32]

In Denmark, there are a number of municipal initiatives covering the rollout of broadband services by power utility companies. In the past two decades fibre optic networks have been laid down to monitor utility companies' power grids, and in many cases, more capacity than needed to support their electrical operations has been installed. Following a severe hurricane in December 1999 which caused significant damage to low voltage power lines, some Powerline Utilities Companies (PUCs) entered the broadband market by converting low voltage systems to ground cables.[33] In 2007, the regulator reported 96 BPL subscribers.[34]

In Finland, research into BPL technology is continuing, but a central hurdle to its adoption is the risk of radio frequency interference (RFI) as in other OECD countries. In 2001, the Finnish Communications Regulatory Authority (FICORA) measured disturbance levels in its BPL test network and concluded that the technology can only be adopted once the interference and information security problems have been solved.[35] The pioneer in BPL in Finland was Turku Energia, which launched BPL service in early 2003, but in October 2006 announced that it was discontinuing BPL service completely. Another BPL company, Vattidata Oy in Pori, has also terminated its service. At the moment, Kuopion Energia is the only company offering a BPL service.[36] In 2005 regulators reported 800 BPL subscribers.

In France, EDEV CPL technologies, which was created as a wholly-owned subsidiary of the French energy company EDF, undertook a BPL network test in Paris with MainNet Communications and its PLUS system in 2003. In addition, France Telecom is testing potential services and customer acceptance, but for indoor systems only.[37]

In Germany, to protect the rights of existing frequency users the law setting out the conditions for power line operations was enacted in July 2001. Utilities and BPL providers must either use low power spread spectrum systems or apply for national approval if they intend to use high power systems. The two principal BPL providers in Germany are EnBW and the utility MVV Energie. EnBW provides BPL solutions to some 350 schools and a number of universities for internal networking. MVV Energie has operated in Mannheim since 2001, and has 4 500 BPL subscribers.[38] According to regulators the total BPL number of subscribers in 2007 was 9 500, that is the largest customer base among the 15 OECD countries which provided data on BPL.

In Iceland, Reykjavik Energy has developed BPL technology as a part of a fibre cable network by using the energy utility’s distribution station and power grid to connect to metropolitan fibre networks. In 2001, Lina.net, an Internet Service Provider (ISP) of Reykjavik Energy, started to provide BPL services, but in 2004 the company dropped BPL in favour of fibre.[39] In 2004, regulators reported 1 020 BPL subscribers.

In Ireland, the government has been actively involved in BPL trials and its development. In 2003, the government invested in a BPL trial in partnership with the electricity provider ESB. In 2004, powerline technology was provided to 16 Dubin schools by Ascom under contract to the government.[40]

In Italy, a system for Automatic Meter Reading (AMR) had been developed by Ericsson and Acea, the second largest electricity distributor, from late 2005 to early 2006, to better manage water and electricity usage of Rome’s households, rather than as a third wire providing broadband connectivity.[41]

In Japan, in October 2006, regulations were changed so that only indoor services with a BPL system using a High Frequency (HF) band of 2 MHz – 30 MHz could be used. The services with a BPL system are confined to indoor use. However, it is possible to construct a network without LAN cables inside homes as well as in hotels or companies where it is difficult to introduce new LAN systems.

In Korea, Xeline and the Korea Electric Power Corporation (KEPCO) commercialised a 24Mbps BPL chip and developed a 200Mbps trial chip in 2006. The KEPCO deployed systems to 6 500 houses using BPL chips including metropolitan, rural and seashore areas, by means of pilot project in 2007. KEPCO is planning to diffuse telemetering based on BPL technology nationwide by 2015. Major research institutes and companies including the Korea Electrotechnology Research Institute, KEPCO, and the Research Institute of Automation at Seoul National University were involved in developing this technology.

Powercom, LG Electronics, and other private companies are also involved in the research. The potential for broadband access through powerlines gained attention in 2004 when the government sought to ease regulations for the provision of such services. The Ministry decided in June 2004 that it would allow use of high-voltage BPL. The Radio Waves Act was revised by the National Assembly in 2005 to allow BPL.[42]

In the Netherlands, a BPL pilot testing for technical and commercial viability was launched in 2002 in Antwerp by the utility company Nuon, but ceased in August 2003.[43] In New Zealand, the trial in Auckland by UnitedNetworks and Vector ceased after it failed to produce commercial results.[44] In Norway, the first field trial was made in late 2001 by Lyse Tele, a division of a Norwegian electricity utility. With a successful six-month field trial Lyse Tele rolled out a commercial system with the Swiss vendor Ascom equipment in Stavanger. It was reported that 300 users were connected in 2003. Another BPL tests using Ascom equipment were also completed in Oslo by Viken Eneriginett AS.[45]

In Spain deployment of BPL is minimal. After BPL trials using Medium Voltage power lines to transmit voice and data between sub-stations were conducted by the electricity utility Endessa at Seville and Barcelona in 2000 and at Zaragoza in 2001, the commercial BPL network with the OFDM standard used in the DS2 chip technology was deployed by Endessa in partnership with Auna at Zaragoza and Barcelona in October 2003. In late 2006, Endessa suspended its BPL service because of technical difficulties with the technology. Iberdrola, Spain's second largest electric company, suspended its BPL service as well in late 2006 due to technical difficulties. Previously the commercial BPL service of Iberdrola was provided by its telco Neo-sky in Mardrid.[46]

In Sweden, BPL trials were conducted by the Swedish Energy Industries Body, Elforsk, at Danderyd, Stockholm in 2001. In 2004 regulators reported 100 BPL subscribers.[47] In Switzerland, a BPL network was installed in Fribourg in 2002. The Swiss Federal Office of Communication (OFCOM) undertook extensive noise measurements on site, which showed that interference below 10MHz was of low impact in urban areas because of existing noise pollution, though at frequencies above 10MHz BPL interference was more notable, and at the 2.4MHz and 25.4MHz frequencies the noise interference exceeded the German standard NB30. In addition, in 2004 OFCOM carried out a measurement program in Solothurn to make an assessment of the interference level emitted inside buildings by BPL equipment, and its result was that the modem of the HomePlug standard was, at that time, not in conformity with the European Directive on Electromagnetic Compatibility (EMC). Considering the existing DSL and cable infrastructure in Switzerland, BPL remains a niche market with 3 903 subscribers in September 2008.[48]

In the United Kingdom, BPL service is currently not available although there were a few isolated commercial BPL trial networks in operation after BPL was developed by Norweb, a Manchester-based regional electricity company, from 1993. One reason for this was concern over leakage emission levels. In 1995 the first BPL customer trials of telephony services delivered by BPL were conducted in Manchester by using a prototype system supplied by Nortel. The company reported that its technology interfered with radio signals of emergency services and was affected by street lights. In March 2003, Scottish and Southern Energy began BPL trials in Winchester.[49] Currently, BPL development in the United Kingdom is headed by Scottish Hydro-Electric (part of the Scottish and Southern Energy Group), a Scotland-based utility that has run BPL trials in Crieff and Stonehaven. Another trial by the BBC's Research Lab reported that high interference inside buildings was caused by internal wiring and acted as a mast antenna, similar to the Norweb trial in Manchester.[50]

In the United States, several notable BPL deployments are planned or in progress, with some providing residential services (ISP, VoIP), while others are purely supporting utility applications (AMI, Intelligent Grid, etc.). By March 2007, 9 power utilities had commercial BPL deployments while 26 utilities were conducting ongoing BPL trials throughout the United States.[51] Table 6 and Table 7 summarise BPL trials and commercial deployments in the United States respectively.[52] In June 2007 regulators reported 5 420 BPL subscribers, most of them trial participants.

Table 6. BPL Trials in the United States

Pennsylvania	One of the first large-scale deployments of BPL was by PPL Telecom, a subsidiary of PPL Corporation, which provides power to some 1.3 million customers in Pennsylvania. The company launched its fourth trial in 2004, and experimented with both direct to outlet and WiFi solutions. In October 2005 its last BPL trial was ended by dint of the short of significant scale.
North Carolina	Progress Energy Corporation (PEC) finished the technological phase of its trial in mid-2003 and completed the second phase of its field trial in the Raleigh area in August 2004. However, by end-2004 PEC had shut down its BPL field trial after pronouncing the test a success.
Boise, Idaho	In 2004, as a part of Idacomm's ongoing BPL pilot project, the Amperion Connect solution was deployed in Boise by Amperion Inc and Idacomm. By establishing overhead network segments in several Boise locations, IdaComm planned to provide residences and businesses with high-speed wireless Internet access. However, in January 2006 IdaComm announced that it discontinued BPL services due to limited interest in the technology from other utilities.
Westchester County, NY	Ambient Corporation and Consolidated Edison Company commenced a BPL pilot with funding from the New York State Energy Research and Development Authority.
New York	BPL trial using Data Ventures Inc technology started at Penn Yan village in late 2003. However, the trial was dropped in mid-2004 after Data Ventures decided BPL was not commercially deployable.
Washington DC and Maryland	Pepco, a utility serving 700 000 Washington DC and Maryland customers, started its six-month BPL trial in Maryland in mid-2002, resulting in discontinuing its investment on BPL. However it still operates a BPL pilot in around 500 homes in Potomac, Maryland.
Cedar Rapids, Iowa	Alliant Energy launched its six-month trial at Cedar Rapids, Iowa in March 2004, resulting in shutting down only three months later due to unresolved radio spectrum interference.
Alabama, Indiana, Virginia	IBEC commenced BPL trials in partnership with: first, Central Virginia Electric Cooperative in Nelson County, Virginia; second, South Central Indiana Rural Electric Membership Cooperative in Martinsville, Indiana; third, Cullman Electric Cooperative in Cullman, Alabama. By late 2005 the market trials in Virginia and Indiana were complete and IBEC had started serving customers in those areas. Recently, IBM was hired by IBEC to manage the installation of BPL systems at electric co-operatives throughout the eastern United States.
Baton Rouge, LA	In January 2007 Entergy Corporation, one of the largest electric utilities in the United States with over 2.7 million customers, announced a one-year BPL trial with PowerGrid Communications Inc. The second phase of this trial involving new applications for the broadband network was planned to start in Little Rock, Arkansas.
Ohio	In 2007 IOU FirstEnergy planned to conduct a BPL trial using Ambient equipments in Ohio, and to negotiate the commencement of commercial deployment if the trial proved successful.

Source: UPLC (www.bpldatabase.org) and Paul Budde Communication 2008.

Table 7. Commercial deployments of BPL in the United States

Texas	In 2006, Current Communications Group LLC and TXU Electric Delivery announced a plan to offer high-speed Internet over electric power lines to more than 2 million customers in Texas. In May 2008, Oncor Electric Delivery Co., the Dallas-based distribution arm of former TXU Corp., announced that it will buy the BPL network of Current Communications Group to use the data capabilities of the network to monitor the electric grid.
Virginia	In February 2004 Manassas in Virginia was the first in the country to commence a BPL Internet service citywide. Communication Technologies (ComTek) owns and operates the BPL service for the Department of Public Works of the city of Manassas. it was announced that 900 residential and business customers had signed up by March 2006, but it was also noted that Manassas was a particular hotbed of interference debate in the United States.[53] It is reported that Manassas BPL system is going to cease provision of services to consumers and will remain in operation only for management of the electric system.
Ohio, Kentucky and Indiana	In March 2004, a major deployment of BPL was launched in Ohio, Kentucky, and Indiana by a joint venture between Current Communications Group, a BPL vendor, and Cinergy Broadband, a subsidiary of multi-utility Cinergy. In early 2006 Current Communications began offering commercial VoIP services at its deployment in Cincinnati with Cinergy Corp.
Syracuse, New York	In January 2007 National Grid and New Visions Powerline Communications, Inc announced an agreement to deploy BPL in three suburbs near Syracuse with a possible expansion across National Grid's upstate service territory. New Visions has already deployed BPL in the City of Solvay and began offering BPL services there in 2007.
Chicago, Illinois	In November 2006 Midwest Competitive Local Exchange Carrier (CLEC), First Communications announced the deployment of its FirstSpeed In-building BPL product which was marketed towards multi-tenant and multi-dwelling units such as schools, hospitals, apartments, condos, offices and airports. First Communications currently operates an In-building BPL deployment at Columbia College in Chicago, Illinois. In March 2007 following several control tests, First Communications was also in the early-stage deployment of its FirstSpeed Access BPL product which offered high-speed broadband to residential homes.
Southeastern States	Ambient Corporation announced in January 2006 that one of the largest investor-owned utilities, Duke Energy, successfully deployed Ambient's BPL solutions on its electrical distribution system. In September 2006 Duke signalled its decision to move to a commercial phase of BPL deployment when Ambient announced that it had entered into an Expanded Deployment Agreement with Duke Energy. The agreement will include building connectivity using Ambient's latest access BPL gear to around 6,000 homes in Charlotte, North Carolina.

Source: UPLC (www.bpldatabase.org) and Paul Budde Communication 2008

3. Business models

There are basically three business models that can be used by the BPL industry based on the amount the utility wants to invest and the level of risk they are willing to accept:[54]

- A landlord arrangement, leasing the wires to a third party, probably with a maintenance arrangement.
- A partnership or contract with an Internet service provider (ISP); the utility builds and owns the infrastructure, and the ISP handles all aspects of selling to and servicing the customer.
- The utility handles all aspects of the system, including serving as the Internet service provider.

With the landlord model a utility company leases infrastructure to a third party, usually to an existing communications company which will operate and service the BPL network. This model allows for small returns for small investment on the part of the utility company.

From the utility's perspective this model avoids the need to:[55]

- Invest funds in deploying BPL infrastructure.

- Run a BPL operation.

A second model is the developer/or wholesale model in which a utility company builds and owns the infrastructure and offers wholesale access to a communication company, acting as an ISP. Utilities having core competencies in building and maintaining networks will be suited for this model. Based on this model a utility company will be involved in network construction.[56]

This model could be used if:

- There are no regulations preventing opportunities to leverage the utility's position in the market.
- The utility has the internal skills to construct a BPL network that is economically and able to compete with other players.
- There are viable candidates to serve the BPL service providers in the market.
- The utility has no interest or capability in running the network and service operations.

The third model is one in which a utility company, as a service provider, provides BPL services to the customer. In extreme cases, the utilities can offer retail BPL services based on this model. This model involves the highest risk, but the highest returns.

To use this model a utility needs to ensure that:

- Regulations allow for joint marketing (electricity and broadband).
- Internal skills are available for constructing and maintaining a network.
- The utility has skills supporting marketing, operations, and network management.

4. Limited BPL developments

The nature of BPL technology and the power grid system seem to indicate that its economics are less compelling than its proponents seem to argue. As virtually all the technologies operate at MHz ranges, the signals cannot easily operate through transformers. The need for bypassing (coupling) or amplification or regeneration devices can raise costs significantly. Furthermore, BPL might be a late entrant to the broadband access market, and could face stiff competition from several alternatives – such as DSL and cable modem services, fibre-based offerings, and wireless broadband. So, whether BPL becomes a niche or mainstream technology for broadband Internet access will depend on successful trial and commercialisation of BPL technology in the marketplace.

The record of trials listed in previous sections of this paper indicates the slow pace of BPL deployment and the setbacks that have occurred in Europe and the United States. Trials have been suspended for a range of reasons. In the United States, 5 BPL trials in Pennsylvania, Boise in Idaho, New York, Washington, DC and Maryland, and Cedar Rapids in Iowa ceased for a variety of reasons including limited interest in the technology from other utilities, unresolved HF interference in the system, and difficulties in the commercial deployment of BPL. [57] In the United Kingdom, Nortel withdrew from the BPL project in 2000 following problems with the rebroadcasting of data and radio interference. In Iceland, Reykjavik Energy dropped BPL in 2004 in favour of fibre. In Finland, Turku Energia and Vattidata Oy in

Pori terminated BPL services in 2006. In Spain, the two largest utilities, Iberdrola and Endesa, both ceased new deployment of BPL services in late 2006. Both companies found it virtually impossible to compete with ADSL services and in addition, Endesa battled with interference issues from the BPL system.

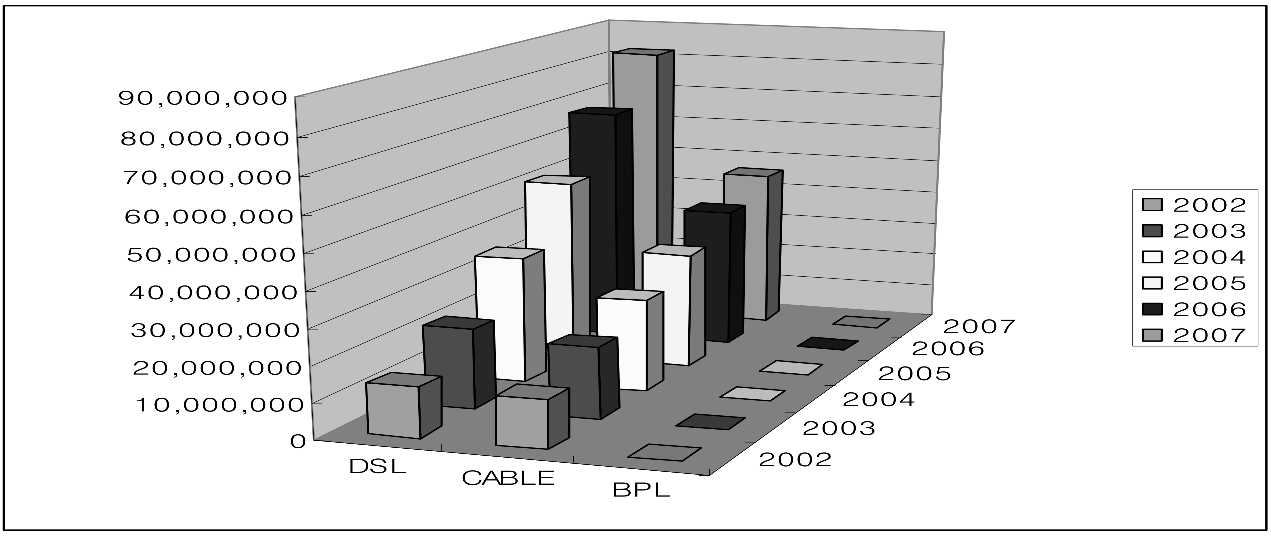
Table 8 shows the number of BPL subscribers in the 15 OECD countries providing data. As of 2007, total BPL subscribers were below 30 000. Figure 3 compares the limited development of BPL as a third wire to the home with DSL and cable.

Table 8. Number of BPL subscribers in 15 OECD countries

	2002	2003	2004	2005	2006	2007	
Austria			4,194	4,777	5,307	5,500	
Czech Repubic					430	350	
Denmark				92	99	96	
Finland				800			
Germany		8,200	9,300	9,600	9,500	9,500	
Iceland		859	1,020				
Italy			0	0	0	0	
Luxembourg				0	0	0	
Netherlands				0	0	0	
New Zealand		0	0	0	0	0	
Slovak Republic					0	0	
Sweden	400	300	100				
Switzerland		2,190	2,956	3,805	4,779	3,903	Sep. 08 res. prov.
UK						0	Service not available
US				4,571	4,776	5,420	07 data is for June 07
Total	400	11,549	17,570	23,645	24,891	24,769	

Source: OECD Broadband Portal.

Figure 3. Comparison of DSL, cable, and BPL: Total subscribers of 15 OECD countries, 2002 – 2007



Source: OECD Broadband Portal, OECD analysis.

V. POLICY ISSUES

1. Policy challenges and issues

Although BPL has shown some promise as a technology, it has not been attractive to most utility companies, despite their need for new revenue streams as deregulation and competition lower their margins.

Technically, two key issues that need to be dealt with are interference and the lack of existing international standards. Socio-economically, two main issues are how to secure a competitive advantage for BPL as a third wire to the home, having the potential for BPL to reach previously underserved and rural populations by exploiting BPL market opportunities. Some analysts have expressed concern that from a policy perspective cross-subsidies could be an issue if revenue from electricity service was used to lower BPL prices. However, if this does occur, regulatory experience from the communications sector and other utilities is sufficient to be able to resolve any concerns. From a regulatory perspective, it is important that there are no barriers to electrical utility companies entering the BPL market. Table 9 summarises the main policy issues:

Table 9. BPL policy issues

BPL Policy Issues		
Technological Issues	Socio-economic Issues	Regulatory Issues
• Interference	• Competition & Societal Issues	• Industry Governance Issues
• Standards & Specifications	• Cross Subsidies	• Regulatory Classification & Treatment Issues

2. BPL regulation in the United States and the European Commission

In order to establish a clear and balanced regulatory environment to attract new players and new investment to the power line broadband communications market, most governments in the OECD have tried to clarify the rules and regulations for using electric power cables to carry electronic communication data. There are differences in the power grid system between the United States and Europe which have led to some differences in how BPL is treated.

United States

In order to stimulate facility-based competition in the United States, the Federal Communications Commission (FCC) has endorsed BPL as an acceptable broadband technology providing a “third wire” to homes. This endorsement was viewed as important in providing the electric utility industry with regulatory security at the federal level so as to encourage investment in BPL.[58] In FCC 04-245 new rules for broadband over power lines aimed at facilitating investment in BPL technology.[59] These rules included a requirement that BPL devices use techniques to reduce interference - BPL systems in the United States, must comply with rules for license-free spectrum that deals with emission and interference (FCC Part 15 rules). In addition BPL operators were required to provide information on where their systems are installed and other technical parameters which would be available to the public, and to adopt specific measurement guidelines to ensure consistency across the industry in measurements undertaken so as to ensure compliance with rules on interference.

Aside from the federal regulatory environment, state regulation may also affect BPL. Many state utility regulators in the United States are in the process of deciding whether, and if so how, to regulate BPL. In August 2005, the Texas House of Representatives passed legislation providing various incentives for utilities to deploy BPL networks.[60] The legislation allowed the utility affiliate to retain revenues and allowed the utility itself to recover the capital and operational expenses associated with BPL. This law specified that BPL operators must pay a standard pole attachment fee to the telecommunications utility if its poles are used for BPL systems, and any municipal rights-of-way charges should not be greater than the lowest charge imposed on other broadband service providers.[61]

In April 2006 the California Public Utilities Commission (CPUC) decided to adopt a regulatory policy regarding BPL deployment by electric utilities. This policy was formulated to accelerate the rollout of BPL deployment in California. Specifically, the CPUC ruling included the following:[62]

- Allowing third-parties or affiliates of electrical utility companies to invest in and operate BPL systems.
- Requiring utilities to follow affiliate transaction rules for transactions between a utility and a BPL affiliate.
- Maintaining the safety and reliability of the electrical distribution system.
- Requiring companies installing BPL equipment on utilities’ infrastructure to pay pole-attachment fees.
- Aligning investor’s risks and rewards; and
- Exempting certain types of BPL-related transactions from regulatory review.

In October 2006, the New York Public Service Commission (NYSC) adopted a policy statement supporting the deployment of BPL technology throughout the state.[63] This statement emphasised that BPL services may not be offered by regulated electric utilities, but can be provided by a structurally separated utility affiliate, subject to acceptable cost allocation, affiliate transactions and related business rules designed to prevent subsidisation and support of the competitive BPL service provider. The commission ultimately prefers a landlord business model in which an independent third party uses a utility network to provide BPL service to the public.

In January 2007, the Indiana legislature introduced a bill entitled the Broadband over Power Lines Deployment Act designed to create incentives for utility companies to deploy BPL networks. The legislation would authorise the Indiana PUC to require the electric utility to record and account for its capital investment and operating expenses reasonably incurred to support both electric utility applications and other BPL services. It would also provide that a BPL system must comply with federal laws and regulations protecting licensed spectrum users from interference by BPL systems.[64] In March 2007 the Arkansas Senate passed legislation enabling electric utility companies to deploy BPL technology, and providing for ownership and operation of the broadband system by an electric utility or affiliate.[65]

European Community

In Europe, new opportunities for utility companies to exploit their existing electric network to create an alternative broadband supply route were created by the energy market liberalisation beginning in 2005. In many cases, the uncertainty of the rules governing this market had acted as a barrier to entry. To ensure clarity, the EC recommended that member states remove unjustified regulatory obstacles, in particular from utility companies, for the deployment of BPL systems, and report to the Communications Committee on future deployments and operations.[66] This recommendation also detailed how to apply the provisions of the electromagnetic compatibility directive. The Recommendation is compatible with the new electromagnetic compatibility directive which came into effect in mid-2007. The measure should overcome the principal regulatory issue for BPL in Europe – its potential interference with other users of the radio spectrum. Advances in technology since 2000 have also helped in diminishing spectrum interference as an issue.

The main aims of the EC recommendations were to:

- Provide transparent and non-discriminatory conditions for BPL deployment, and the removal of regulatory barriers relating to equipment and networks.
- Provide conditions for the development of competitive BPL networks and services.
- Provide industry conformity through various EU Directives relating to electronic communications networks, universal service and consumer rights. Some common rules relating to cross-subsidisation and the distortion of competition in internal electricity markets would be governed by other Directives (2003/54/EC, 96/92/EC6).
- Ensure that interference management systems are in place according to the requirements of the EMC Directive; and
- Monitor developments to ensure that BPL networks comply with the harmonised European standards drafted by the European Standardization Organization (ESOs) for wireline networks.

3. Technological issues

Power lines were not designed for data transmission, but were originally created to deliver power at 50 to 60 Hz. Broadband data can be transmitted at different frequencies, over the same wires, however, in order to enable high-speed and long-distance transmission of data on power lines several technological obstacles have to be overcome. These include data interference or electrical signal interference, the distance over which data can travel while still providing good quality, and the lack of international standards and specifications. The technological issues of BPL in this section deal with how BPL should be implemented to minimise interference with other services such as amateur radio frequencies and international standardisation efforts for BPL technology to increase reliability, interoperability, and security of broadband transmission over power lines.

Radio Frequency Interference (RFI)

Potentially harmful radio frequency interference (RFI) has been one of the most serious potential technological obstacles to BPL. BPL works by sending radio frequency signals along the power lines using frequencies anywhere from 1.7 to 80 MHz. Some of the BPL signals can cause interference in licensed frequency bands over 1.7-8 MHz, generally known as HF or shortwave bands. Also, various structures in or near power lines may become radiators or antennas at the high frequencies at which BPL data are transmitted. This can also result in interference with a variety of existing licensed radio services, including ham/or amateur radio operators, public safety, emergency response frequencies, military, aviation, maritime, and shortwave broadcasts. Among others, the American Radio Relay League (ARRA), one of most vocal opponents to the deployment of BPL, opposes BPL as a way to achieve broadband access to the home because it is claimed the technology has a high potential for causing interference to radio communication.[67]

The main factors that contribute to radio-communication interference are:

- Lack of solid shielding of the wires and inadequate balancing with close conductor spacing (in case of 2 phase coupling); and

- Injection of radio frequency energy at relatively high levels to overcome the high noise environment of power lines as telecommunications conductors and high attenuation of conducted signals on power lines at radio frequencies.

BPL signals may propagate down the wires by conduction, but due to the fact that the wires are not solidly shielded or adequately balanced with close conductor spacing, the BPL signal will tend to radiate, which can result in interference. Furthermore, both the high level of injection of radio frequency energy and attenuation of conducted signals on power lines will have a direct influence on interference.

To properly cope with the interference issue, the FCC in the United States had already developed standards for the technical operations of BPL in 2004. Those technical standards protect against possible radio frequency interference from BPL systems and, in particular, radio frequency interference between unlicensed devices, including BPL modems, and other electronic devices are subject to Part 15 of the FCC's Rules.[68] All electronic devices sold in the United States have to meet FCC radio frequency (RF) emission limits. When BPL modems are installed on underground electric lines, the communications signal is shielded by the conduit and the earth and as a result is unlikely to cause interference to other communications services. The FCC is more concerned about the interference potential of BPL signals transmitted on exposed, overhead medium voltage power lines. In order to alleviate the problem, the FCC set up rules requiring:[69]

- BPL devices to employ adaptive interference mitigation techniques to prevent harmful interference to existing users, such as public safety and amateur radio operators. These techniques enable BPL devices to cease operations altogether, dynamically reduce transmit power, and/or avoid operating on specific frequencies to prevent harmful interference.

- BPL operators are required to take steps to protect aeronautical and aircraft communications, and should not operate on certain frequencies near sensitive operations, such as emergency service communication stations. Before any deployment, power utilities must check with public safety agencies and United States government radio installations.

- BPL operators are required to maintain a public database that includes such information as location, operational frequencies, and modulation type of BPL devices, in order to resolve interference issues in a timely fashion; and

- BPL systems need to comply with specific RF measurement guidelines to ensure that emission measurements are made in a consistent manner. While the new rules addressed radio frequency measurement guidelines, they did not propose changes to existing applicable emission limits.

In Europe, the EC has standards aimed at minimising any harmful radiation from BPL networks, and has set up an arbitration process to address interference issues. In August 2001, the European Commission issued a ‘standardisation mandate,’ known as Mandate 313, to European standards making bodies (ETSI and CENELEC).[70] The mandate required these organisations to prepare harmonised standards that would be recognised within the European Union (EU) covering Electromagnetic Compatibility (EMC) aspects of wire-line telecommunications networks which include BPL networks.

In order to minimise BPL interference with other licensed radio services, it is important for governments and/or regulators to set up a clear regulatory framework to:

- Incorporate adaptive interference mitigation techniques to remotely reduce power and adjust operating frequencies, or avoid using frequencies, or bands of frequencies used locally by licensed radio operations.

- Improve measurement requirements for BPL emissions.

- Create a publicly available database of BPL providers to ensure information is readily available in the case of interference complaints; and

- Create a dispute resolution process such as setting up time frame to respond to complaints.

International standards and specifications

International standardisation can help in terms of facilitating economies of scale in the manufacture of equipment and in accelerating its diffusion. The delay in developing an international standard has to some extent slowed the diffusion of this technology. Recently there seems to have been progress in advancing an international standard with the expectation that there will be agreement by the Institute of Electrical and Electronic Engineers (IEEE) and the European Telecommunications Institute (ETSI) by the end of 2008. Part of the causes of the delay in the standardisation of BPL is the relative complexity of BPL technology and its relationship with the power supply industry. It is not simply a matter of agreeing to signalling protocols since there are also safety, installation, monitoring, and other issues where agreement is required in addition to the need to conform to Electromagnetic Compatibility (EMC) requirements. Furthermore, the fact that there are numerous trade associations, each with a slightly different focus on BPL also complicates the standardisation process.

In June 2005, the IEEE Standards Association created a Corporate Standards working group with the participation of 20 companies, to begin to develop the IEEE P1901 MAC/PHY group, finalising hardware interoperability standards between in-home and BPL access. In March 2007, the IEEE announced that it had developed over 400 system requirements for the baseline BPL standard, and that a global draft of the standard was expected to be completed by late 2008.[71] Additionally, a safety standard known as IEEE P1675, also being developed by the association, would include safety requirements for BPL equipment installers and the general public.

In Europe, the European standards are being developed by the European Telecommunications Standard Institute (ETSI) and European Committee for Electro-technical Standardization (CENELEC), while PowerLine Harmonized Standards are to cover emissions and immunity related to BPL. The case for BPL is also being promoted by the Consumer Electronics Powerline Communications Alliance (CEPCA), an industry organisation set up in June 2005 co-ordinate various BPL system and specifications. CEPCA includes Analog Devices, Hitachi, Matsushita, Mitsubishi, Philips, Pioneer, Sanyo, Sony, Toshiba and Yamaha.

In 2004, participants in the market organised the Open PLC European Research Alliance (OPERA) project. This focused on the overall improvement of BPL technology and on the standardisation of BPL systems, the definition of business plans, network maintenance and provisioning practices, and the development of market research. In 2006, OPERA approved the first open, global specification for BPL, which was an attempt at cleaning up the divergent specifications that exist for different variations of BPL technology, as well as reducing some of its technological uncertainties.[72]

In order to ensure both compatibility and interoperability between different BPL devices, which will help develop a mass market for BPL devices, and improve the business case for the deployment of BPL systems, global, regional, and national standard setting bodies need to ensure that:

- The standard efforts of global and/or regional standard bodies focus on activities that help the market to progress such as safety and test standards that establish safe and effective techniques for mounting and installing equipment.

- The standard efforts of global and/or regional standard bodies need not duplicate national regulatory functions like emissions requirements; and

- The standard efforts of global and/or regional standard bodies need not duplicate national standards efforts already underway.

4. Socio-economic issues

The broadband industry is categorised by a number of different types of technologies (such as cable modem, DSL, fibre network, wireless, and satellite) that provide a variety of capabilities and services to the end user, both business and residential consumers. Proponents of BPL believe that it compares favourably with these other types of services, offering similar and sometimes greater speeds and equivalent and sometimes lower prices. Consequently, it is believed that BPL could be a third facilities-based option for providing broadband service, and provide market opportunities for the ‘third wire’ to the home.

The wide availability of electrical networks which are available in rural and remote areas has raised expectations that BPL technology would help in narrowing the digital divide. In Australia, innovative broadband technologies, such as BPL, are encouraged. Where appropriate, companies are allowed to conduct commercial trials, as long as they do not negatively affect legitimate spectrum users. There are currently very few companies trialling BPL in Australia with none of the previous trials having progressed to on-going commercial services.

The issue of cross-subsidisation could be of concern in the context of BPL in particular if the electric company providing BPL is a monopoly provider of electricity in its geographic area. The concern is whether electric companies use earnings or resources from the provision of electricity to subsidise their BPL businesses. Such cross-subsidies could provide electric companies with an unfair advantage in the broadband market and, second, they divert resources away from the provision of electricity which could negatively impact on the quality of electricity service. In the United States, both federal and state regulators have examined the cross-subsidisation issue and on several occasions the FCC has attempted to require companies to establish separate subsidiaries, as have some State utility regulators. Remedies, such as accounting separation have also been used to ensure fair competition and that electricity ratepayers are not subsidising broadband. The issue of cross-subsidisation should not in principle raise problems with rules for accounting separation which already are well established in a number of network industries, including the telecommunication industry.

An important reason to ensure deployment of BPL is the use of this technology to pursue a vision of a so-called 'smart grid" whereby broadband connectivity is used to create "smart meters" providing information to households to help reduce energy costs and help energy companies to better manage their network.[73] The United States Department of Energy's 'Grid 2030' plan aims to achieve a customer gateway for smart meters enabling an effective two-way communication customer-utility interface. Similarly, the Public Utility Regulatory Policy Act (PURPA) requires each utility to offer and provide individual customers, upon request, a time-based rate schedule under which the rate charged varies during different time periods. Furthermore, the recent U.S. Smart Grid legislation in the Title XIII "Smart Grid" provisions of The Energy Independence and Security Act of 2007 creates many opportunities both in terms of funding and state/federal policy support for BPL.[74] In the EU the Advisory Council of the Technology Platform for Europe's Electricity Networks of the Future has put forward a strategic agenda for smart grids.[75]

5. Regulatory issues

Putting aside technical issues, the viability of BPL as a third wire to the home also requires that there is regulatory certainty for potential suppliers. In principle there should be no reason why electric power companies are not able to enter the telecommunication market as broadband access suppliers or in providing multiple play services. If broadband power line services are limited to smart grid technology, that is a service in support of the provision of electricity, there is no need to consider such services as competing with other broadband services offered over xDSL or cable modem. However, the development of smart grids using power line communication can be an added incentive for electric power companies to start providing BPL services and, in this context, help meet the goals of governments that wish to see widespread deployment of broadband. Co-ordination between regulators responsible for electricity and telecommunication may be useful to ensure that there are no unnecessary regulatory obstacles hindering the deployment of BPL. Encouragement of smart grid networking can also give an incentive to power companies to invest in BPL.

In that most power companies have access to extensive rights of way resulting from their obligation to provide electricity to end users, it may be necessary in a number of cases to ensure that they make available these rights of way under the same conditions as required by other incumbent utility companies. As BPL service providers may in certain areas, especially rural and remote areas, have market power because of the lack of alternative operators, they may have to be subject to some regulatory oversight. Whether this occurs will depend on the regulatory framework of the country. In most OECD countries access to electric utility poles must be granted to any entity requesting it, if that utility has used the poles for any type of communications services whether provided by the utility or another company.[76] Many utilities have avoided this regulation by not allowing communications services to be transmitted via their poles. Pole attachment also needs to be addressed in light of interference concerns. It is acknowledged that this is a potential problem considering that the close proximity of BPL equipment on utility poles may affect (and be affected by) the operation of cable television service and high-speed digital transmission services, such as DSL.

In some countries there seems to be an issue on how to classify BPL. In the United States BPL was classified as an information service, bringing it in line with other broadband and cable mode services and ensuring that BPL is not subject to open access requirements. In Europe, BPL is regulated, and treated, in the same way as telecommunications networks. To the extent that electricity cable systems are used for the purpose of transmitting signals, they are included in the scope of Telecommunications Framework Directive 2002/21/CE 02_2002. Accordingly, carriers with significant market power are required to follow the European Commission's rules and regulations, which require loop unbundling, the provision of number portability, and other conditions designed to promote competition in the telecommunication sector. Since most BPL providers will be new entrants to the telecom market, most of these rules will not apply. Member states have been ordered to remove any unjustified regulatory obstacles, and similar policies are in place throughout Asia/Pacific. In those countries where local loop unbundling is part of the regulatory framework it may not be possible to require electrical utility companies to provide open access since for technical reasons it may not be feasible to accommodate more than one BPL signal on an electric distribution system.

NOTES

1 However, this advantage has diminished considerably with recent modems providing Wi-Fi access to the home.

2 See: www.nj.gov/rpa/BPLwhitepaper.pdf.

3 See: http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci953137,00.html.

4 See: www.yourdictionary.com/bpl.

5 See: www.yourdictionary.com/plc.

6 For more information about how BPL works, see Wilt, S. (2009), "Broadband over Power Lines - Where is the Technology Now and Where are We Going" – Presentation prepared for Commissioner Bode at The NARUC Summer Meeting – Salt Lake City, Utah, July 13, 2004.

7 See: http://ntrg.cs.tcd.ie/undergrad/4ba2.05/group13/index.html.

8 Spread-spectrum techniques are methods by which energy generated in a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference and jamming, and to prevent detection. For more information about spread spectrum techniques, see: www.ausairpower.net/OSR-0597.html.

9 See: http://ntrg.cs.tcd.ie/undergrad/4ba2.05/group13/index.html.

10 See: http://glasnost.itcarlow.ie/~net4/kirwans/bband.html.

11 The dichotomous classification of BPL system into access BPL and in-house BPL is based on that of the United States FCC BPL rules.

12 See: www.ic.gc.ca/epic/site/smt-gst.nsf/vwapj/bpl-e.pdf/$FILE/bpl-e.pdf.

13 *Ibid.*, p 5.

14 The head-end in the telecommunication sector means the common point of signal origin and centralised communications control in a CATV network or a traditional dataphone Digital Service network.

15 Mark Main, "Broadband over Powerline – One Last Chance?" Ovum, 02 August 2007.

16 A step-down transformer means designating a transformer in which the output voltage is less than the input voltage.

17 *Ibid,*. p5.

18 See: www.epriweb.com/public/000000000001011264.pdf .

19 See: http://hills.ccsf.edu/~jvigil02/final_report.html.

20 See: www.actaris.com/html/products-1584.html, and for more information about how Ripple Control works, see: http://energycrisis.co.za/?p=87.

21 Ibid., p6.

22 See: www.ieee-isplc.org/2007/docs/keynotes/napolitano.pdf.

23 See "Broadband over Power Line 2004: Technology and Prospects", The Electric Power Research Institute (EPRI), October 2004.

24 See: Michael Kennedy, Broadband over Power Lines Comes of Age, Telecommunications Americas, Mid-June 2004; 38,7; ABI/INFORM Global p. 28.

25 See: Breen, James D. "Broadband Over Power Lines: Finally…After All Those Years. Nov 16, 2004.

26 See: Wilt, S, Broadband over Power Lines Where is the Technology Now and Where are We Going" – Presentation prepared for Commissioner Bode at The NARUC Summer Meeting – Salt Lake City, Utah, July 13, 2004.

27 See: http://glasnost.itcarlow.ie/~net4/kirwans/bband.html.

28 *Ibid.*, p6.

29 See: "Practical, Proven Broadband over Power Line: The Power Line LV Solution", Motorola, Inc., 01 June 2006.

30 See: www.rac.ca/regulatory/BPL/bpl-e.pdf.

31 See: *Europe – Broadband – Broadband over Powerline (BPL),* Paul Budde Communication, 30 June 2007.

32 See: *Canada – Telecoms, Wireless & Broadband Overview & Analysis 2007-2008,* Paul Budde Communication, 2008.

33 See: *Europe – Broadband – Broadband over Powerline (BPL),* op.cit.

34 There is data discrepancy between 92 000 BPL subscribers in Denmark in early 2006 from a private consulting firm of Paul Budde Communication and 92 BPL subscribers in Denmark at the end of 2005 from Danish Regulator. In this paper, 92 BPL subscribers from the public source are to be used as the official data.

35 *Ibid.*, p9.

36 See: "Finland, International Telecom Intelligence", June 2007.

37 See: *Europe – Broadband – Broadband over Powerline (BPL),* op. cit.

[38] *Ibid.,* p10.

[39] *Ibid*., p9.

[40] *Ibid*., p8.

[41] *Ibid*., p11.

[42] See*: South Korea – Broadband Market – Overview & Statistics.doc,* Paul Budde Communication, 6 September 2008.

[43] See*: Europe – Broadband – Broadband over Powerline (BPL),* Op. cit.

[44] See: www.caslon.com.au/powerlinenote.htm.

[45] See*: Europe – Broadband – Broadband over Powerline (BPL),* Op. cit.

[46] *Ibid.,* p12.

[47] *Ibid*., p12.

[48] See: *Switzerland – Broadband Market – Overview, Statistics & Forecasts.doc,* Paul Budde Communication Pty Ltd, 14 May 2008.

[49] For the more information about the OFCOM's technology research on BPL, see: www.ofcom.org.uk/research/technology/research/archive/cet/powerline/.

[50] See: *Europe – Broadband – Broadband over Powerline (BPL)*, Op. cit..

[51] For the more detailed information about the deployments in the United States, see: www.bpldatabase.org.

[52] See: *USA – Broadband Market – Broadband over Powerline (BPL),* Paul Budde Communication Pty Ltd, 12 March 2008.

[53] See: www.dslreports.com/shownews/2008-The-Year-Broadband-Over-Powerline-Died-98477.

[54] For more information about business model, see: www.epriweb.com/public/000000000001011264.pdf.

[55] See: www.nj.gov/rpa/BPLwhitepaper.pdf.

[56] See: www.epriweb.com/public/000000000001011264.pdf.

[57] A flagship BPL trial in Dallas operated by DirecTV and Current Communications was sold in May 2008 to the local utility, Oncor Electric Delivery Co, which planned to use the data capabilities of the network to monitor the electric grid. See: *USA – Broadband Market – Broadband over Powerline (BPL*),Op. cit.

[58] For more information about the BPL regulation in the United States, see: *USA – Broadband Market – Broadband over Powerline (BPL)*,Op. cit.

[59] See http://fjallfoss.fcc.gov/edocs_public/attachmatch/FCC-04-245A1.pdf.

60 BPL legislation (SB5) is codified in sub-chapter 43 of the Public Utility Regulatory Act. For more information about BPL legislation of Texas House of Representatives, see: www.statutes.legis.state.tx.us/DocViewer.aspx?K2DocKey=odbc%3a%2f%2fSOTW%2fASUPUBLIC.dbo.vwSOTW%2fUT%2fS%2fUT.43.95816.84314%40SOTW&QueryText=bpl&HighlightType=1 .

61 See: www.puc.state.tx.us/about/commissioners/parsley/present/epp/BPL_072606.pdf.

62 See: http://docs.cpuc.ca.gov/Published/News_release/55876.htm.

63 For further information about the policy statement of NYSC, see at: www3.dps.state.ny.us/pscweb/webfileroom.nsf/Web/B24E62E014BDE2808525720B005050E3/$File/06m0043_10_18_06.pdf?OpenElement.

64 See: www.in.gov/legislative/bills/2007/IN/IN1068.1.html.

65 See: www.arkleg.state.ar.us/ftproot/acts/2007/public/act739.pdf.

66 See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:093:0042:0044:EN:PDF.

67 See: www.arrl.org/tis/info/HTML/plc/.

68 See: www.cga.ct.gov/2005/rpt/2005-R-0144.htm.

69 The FCC order (dockets ET 04-37 and 03-104) is available online at: http://hraunfoss. fcc. gov/edocs_public/attachmatch/FCC-04-245A1. doc.

70 See: http://ec.europa.eu/enterprise/rtte/mandates/m313en.pdf.

71 See: http://standards.ieee.org/announcements/pr_1901_proposalcall.html .

72 See: www.ist-opera.org/opera1/news.html.htm

73 See: *USA – Utilities Broadband – Smart Grids & Broadband over Powerline*, Op. cit.

74 For information about the Smart Grid in the United States, see: www.uplc.org/system/files/HR+6+-+the+Energy+Independence+and+Security+Act+of+2007.pdf.

75 See: www.smartgrids.eu.

76 For more information about rights of way regulation including the access to poles, see : “Public Rights of Way for Fibre Deployment to the Home”, OECD, Directorate for Science, Technology and Industry, DSTI/ICCP/CISP(2007)5/FINAL: www.oecd.org/dataoecd/49/9/40390753.pdf.