Broadband Services:
Economic and Environmental Benefits

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Executive Summary

People around the world are becoming more and more aware of and concerned about changes in the atmosphere due to extreme weather events, melting glaciers, and changing ecosystems. As the *Washington Post* noted in a special report about global warming and climate change, "broad scientific evidence suggests that carbon dioxide and other greenhouse gas emissions have already triggered changes in the Earth's climate and that more disruptive changes lie ahead."[2] The story discussed a range of costly and daunting measures to address the problem by reducing emissions. These include changes in waste and forestry management, building construction and transportation.

This study adds to the discussion of how to reduce greenhouse gas emissions by documenting the reductions that can be realized by the widespread delivery of broadband services in the U.S. Current carbon dioxide emissions in the U.S. hover around 7.9 billion tons and are growing.[3] This study finds that wide adoption and use of broadband applications can achieve a net reduction of 1 billion tons of greenhouse gas over 10 years, which, if converted into energy saved, would constitute 11% of annual U.S. oil imports.

The opportunity for broadband and information technology to reduce or avoid energy use, and thus help the environment, is evident in where we work, how we shop and what we consume. For instance, electronic communications are reducing the demand for first-class letters and newspaper subscriptions, which, in turn, reduces the need for paper, saves trees, conserves energy, pollutes less water and emits less greenhouse gases into the atmosphere. As workers

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[1] This research was conducted by TeleNomic Research and released by American Consumer Institute Center for Citizen Research, an independent nonprofit educational and research institute. For more information, see www.aci-citizenresearch.org. Both authors are policy experts for the Institute and, in addition, Dr. Joseph Fuhr is a Professor of Economics at Widener University.

[2] "In the Greenhouse: Confronting a Changing Climate," *Washington Post*, July 15, 2007.

[3] This figure includes all greenhouse gas emissions, was converted from metric tons to U.S. (short) tons and is from Energy Information Administration, Department of Energy. The raw data and its detail are available for download at http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/ghgeuse_table.pdf.

telecommute, billions of gallons of gasoline are saved. E-commerce means that less square footage of commercial, retail and wholesale facilities are needed, which saves the energy required to build and operate these facilities. As workers teleconference, business travel is reduced, sparing carbon and other emissions as well. In short, high-speed Internet services and other technologies are affecting how people shop, travel, work and use products, and, as this study shows, the benefits to the environment can be significant.

This study reviews scientific literature, estimates the current emission savings that result from the cumulative "network" effects of wide adoption and use of broadband-based applications and forecasts the additional environmental benefits if trends continue over the next ten years. In terms of greenhouse gas emissions, these activities are likely to produce the following cumulative incremental benefits:

- Business-to-Business and Business-to-Consumer e-commerce is predicted to reduce greenhouse gases by 206.3 million (U.S.) tons.
- Telecommuting will reduce greenhouse gas emissions by 247.7 million tons due to less driving, 28.1 million tons due to reduced office construction, and 312.4 million tons because of energy saved by businesses.
- Teleconferencing could reduce greenhouse emissions by 199.8 million tons, if 10% of airline travel could be replaced by teleconferencing over the next 10 years.
- Reduction in first-class mail, plastics saved from downloading music/video and office paper from emails and electronic documents could reduce emissions by 67.2 million tons. For example, over the next 10 years, shifting newspaper subscriptions from physical to online media alone will save 57.4 million tons of carbon dioxide and other greenhouse gas emissions.
- In summary, a review of existing literature shows that the potential impact of changes stemming from the delivery of broadband is estimated to be an incremental reduction of more than 1 billion tons of greenhouse gas emissions over 10 years.

It is important to note that the promise of these advancements and their contribution to improving the environment can only be fully realized with the widespread use of broadband services by consumers and businesses. Just as the use of fax machines only shifted from a

curiosity to become a standard tool in the conduct of business once *every firm* had one, so it is with information technology and broadband applications. In fact, it is likely that more widespread use of broadband services will lead to further innovation of services and applications that will produce even greater benefits for the environment, beyond those anticipated in this study. These innovations may include even faster Internet speeds, advances in wireless broadband networks, increased reliability and features that make online activities and transactions safer and more secure. To the extent this is true, this study underestimates the potential for greenhouse gas reductions and other environmental benefits that can result from the transformation of U.S.'s communications infrastructure from narrowband to broadband.

As noted in this study, only one in two of every American household subscribes to broadband Internet services, despite the fact broadband access is available to nearly 95 out of every 100 homes.[4] Broadband subscriptions cannot be mandated in a market economy like the U.S., but the potential environmental benefits documented in this study – most notably the reduction in greenhouse gases – can be fully realized only if broadband investment, delivery and consumption continue to expand at a rapid pace. The American public is actively seeking ways to help be a part of a solution to the environmental threats of climate change. Awareness of these environmental benefits will help people to answer the question "What can I do?" by inspiring the adoption of broadband and creativity in its uses.[5]

In summary, this study shows that reduced energy use and lower greenhouse gas emissions associated with information technology and broadband use are significant and deserve to be an important consideration in developing a comprehensive energy policy. Focusing on ways to use these technologies as a tool to change behavior and energy use may achieve even greater savings. More research and ideas are needed to incorporate information technology solutions into the nation's energy policies. And even on a personal level, as people and businesses consider their own carbon footprints, they should be aware of the solutions that broadband and information technology can bring.

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[4] Kagan Research: Broadband Cable Financial Databook 2006. Kagan reports cable high speed data service is available to at least 94% of all U.S. households. The National Cable & Telecommunications Association reports 119.1 million housing units in 2006, citing Kagan Research at www.ncta.com.

[5] A policy discussion of how to best encourage the adoption of broadband services is beyond the scope of this study.

Broadband Services:
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I. Introduction

A. Need for a New Direction in U.S. Energy Policy

U.S. legislators are trying to balance tough economic and environmental issues. On the one hand, energy is necessary for a vigorous and growing economy, but it has significant environmental effects including carbon and other emissions that have been linked to global warming. In addition, the U.S. economy is very dependent on foreign oil that has been subject to sharply increasing prices. That leaves the U.S. with three challenges – high energy prices, high energy use and high environmental impacts.

Environmental concerns are growing due in large part to energy consumption that results in the emission of greenhouse gases. Greenhouse gases trap sunlight in the earth's atmosphere and increase the temperature within the Earth's atmosphere. These greenhouse gases, which most notably include carbon dioxide, as well as nitrous oxide, methane, and primarily man-made gases such as hydrofluorocarbons, are directly linked to energy consumption and, more generally, economic activity. Besides being pollutants that make their way into the atmosphere, greenhouse gases are believed to affect climate change, altering weather patterns and raising sea levels. As a result, increased greenhouse gas emissions could have severe worldwide consequences in terms of where people live and where they cultivate food.

Carbon dioxide from combustible fossil fuels represents 82% of greenhouse gas emissions,[6] and from 1990 to 2000 greenhouse gas emissions have increased 16%.[7] Actions to stem this threat have to date been modest at best and some proposed actions will most certainly

[6] According to the Department of Energy's National Information Administration, available online at http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html.

[7] This is a 2001 estimate from the Department of Energy. For more information, visit the Energy Information Administration's environmental website at www.eia.doe.gov/environment.html.

affect economic growth and the basic standard of living of American consumers.[8] However, to do nothing simply would contribute to another set of problems – namely, pollution and global warming, which will affect our health and welfare.

As the adage goes -- *there is no silver bullet*. Most energy specialists concede that fixing the energy problem will be very difficult and that any success will require actions on a number of fronts – creating many alternative energy sources, imposing taxes to curb consumption,[9] encouraging energy efficiency, expanding recycling and encouraging domestic production. Public policies need to adopt uniform standards that reduce pollutants, protect green areas and invest in clean energy research. These commonsense measures may not by themselves be enough. Some hard choices need to be made that address a comprehensive energy policy that deals with our consumption and production of energy on many fronts. Unfortunately, these choices will likely come at a cost to consumers.

B. Purpose of this Study

The purpose of this paper is to investigate the use of advanced technologies, including broadband services and telecommunications technologies, and their specific effects on energy use and the environment.

Telecommunications services are changing our lives for the better. Broadband services and applications provide new ways to communicate and transfer information, including voice, data and video services. These services can facilitate telecommuting, teleconferencing, e-commerce, telemedicine and other applications that will save consumers and businesses travel expense, traffic congestion and time, as well as reducing greenhouse gas emissions. These technology solutions can increase business and personal productivity, while discouraging some of the migration to offshore jobs and encouraging what is called *homeshoring*, at little or no additional costs to consumers or economic welfare.

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[8] "A Bargain," *The Economist*, May 4, 2007. A 0.1% reduction in worldwide GDP in each of the next 43 years is estimated to be the cost to "stabilise greenhouse-gas concentrations at 550 parts per million," according to www.economist.com/world/international/PrinterFriendly.cfm?story_id=9135283.

[9] Robert J. Shapiro, "Addressing the Risks of Climate Change: The Environmental Effectiveness and Economic Efficiency of Emissions Caps and Tradable Permits, Compared to Carbon Taxes," The American Consumer Institute, Feb. 2007, downloadable at www.aci-citizenresearch.org.

For example, the transmission of bits of information means that consumers can download the content of books, CDs and videos, sparing the transport costs between manufacturer, warehouse and retail store, as well as reducing the production of paper and plastics. Broadband services in homes reduce the need for workers to commute to the office. Nurses can use remote health monitoring equipment to check the vital signs of some homebound patients. Students can attend class without ever leaving home.

In this study, we examine the general benefits of these technologies and their effects on workers and consumers. We analyze the *environmental benefits* of these technologies in addressing the nation's energy problem and reducing greenhouse gas emissions. In summary, this paper explores these broadband services and their effects on the environment, specifically as a means to achieve better and cleaner energy use, without stifling economic output, worker productivity and the standard of living of American consumers.

C. Study Direction and Approach

There can be both financial and environmental payoffs from changing behaviors. With more than 65 million broadband subscribers in the US, [10] a considerable amount of travel is displaced through telecommuting, videoconferencing and e-commerce. These changing behaviors also produce clear environmental benefits.

In 1991, Boghani, Kimble and Spencer claimed that telecommunications could solve the transportation problem.[11] They estimated that annually telecommunication services could replace from 10% to 20% of transportation, including: 6 million fewer commuters, due to telecommuting; 3 billion fewer shopping trips, substituted by e-commerce; thirteen million fewer business trips, replaced by teleconferencing; and 6 million fewer truck and airplane delivery miles, because of a reduced need to transport paper documents. They estimated that an increase in telecommunications services would result in $23 billion in annual benefits in 1998 dollars. In

[10] High-Speed Services for Internet Access: Status as of June 30, 2006," Industry Analysis and Technology Division, Wireline Competition Bureau, FCC, Washington, DC, January 2007, Table 1.
[11] Ashok B. Boghani, Eric W. Kimble and Ethan E. Spencer, "Can Telecommunications Help Solve America's Transportation Problem," Arthur D. Little, Inc. Cambridge, MA, February, 1991.

addition, this substitution would eliminate 1.8 million tons of pollutants by vehicles, save 3.5 billion gallons of gasoline, add 3.1 billion hours of personal time and as a result of less driving and reduced maintenance cost decrease transportation cost by around $500 million.[12] In the 16 years since Boghani, Kimble and Spencer published their study; there have been tremendous improvements in telecommunications technology and infrastructure, including the commercialization and exponential growth of the Internet, as well as the adoption of mass market broadband services. It would appear that the potential for substitution, and any resulting benefits, would be even greater.

This paper does not attempt to quantify all of the benefits from new telecommunications technology such as broadband. Instead, this paper estimates the principal benefits to the environment – both actual and potential benefits – attributable to use of advanced information technologies. The benefits are likely to be widespread, accruing to broad groups such as consumers, employees and employers, as well as specific niche groups, such as the elderly and disabled. Estimates of some of these benefits are calculated by us or reported by others in the literature.

In the sections that follow, this study examines a number of activities that advanced telecommunications and other technology-based services can help the environment without sacrificing economic output, including e-commerce, telecommuting, e-materialization, telemedicine, teleconferencing and distance learning. Where possible, this study will measure and quantify the environmental effects that result from these activities.

[12] Boghani, Kimble and Spencer, pp. 1-2.

II. E-Commerce

A. Consumer and General Business Market

E-commerce has become a common means for consumers and businesses to conduct business transactions and is composed of three principle components – namely, business-to-consumer (B2C), business-to-business (B2B) and consumer-to-consumer (C2C). Each component has grown rapidly since the Internet was commercialized a little more than 10 years ago.

In 2005, B2B e-commerce accounted for $2.2 trillion of commerce and B2C accounted for $189 billion of which $93 billion was retail sales and $96 billion was services.[13] In 2006, B2C comprised 6% of total retail sales and is projected to grow to 10% by 2011.[14] The key driver of consumer online shopping growth is the continued spread of broadband Internet access.[15] In the past 12 months, 77% of online consumers have purchased something over the Internet, 43% of online adults do online banking and 9% trade securities.[16]

As far as C2C activity, 44% of online adults purchased from other consumers online, and 18% of consumers bought and sold items online directly from marketing or multi-level marketing sites.[17] However, 34 % of consumer will not do financial business and 48% do not consider it safe to give credit card information over the Internet. As online services become faster, safer and more reliable, there is great potential for increased e-commerce activity.[18]

E-commerce is environmentally friendly. For example, the energy involved in selling $100 worth of books is 14 times more for a traditional superstore than an online bookseller. A 20 mile round trip to the mall to purchase 2 five-pound products consumes about 1 gallon of gasoline while shipping the packages 100 miles by truck consumes 0.1 gallon of gasoline

[13] "E-Stats," U.S Census Bureau, May 25, 2007, p. 2.
[14] Sucharita Mulpuru, "Topic Overview: US Online Retail" Forrester, March 13, 2007, p. 2.
[15] Jeffrey Grau, "Retail E-Commerce: Future Trends," *eMarketer*, February, 2006, p .6
[16] Rockbridge Associates Inc., "2005/2006 National Technology Readiness Survey," Summary Report, Great Falls, VA, July 12, 2006, p. 13.
[17] Ibid.
[18] Ibid, p. 14.

because other transactions share the same trip.[19] "Compared to conventional shopping e-commerce has been found to require 16% less energy and to generate 36% less conventional air pollutants, 23% less hazardous waste and 9% less greenhouse gases."[20] Also, compared to conventional grocery shopping, shopping electronically, with home e-delivery services, decreases greenhouse gas emissions by 18% to 87%.[21] E-commerce also reduces retail and warehouse space requirements, which in turn reduces energy requirements to build, heat and cool retail and wholesale showroom and office space. One report estimates that, by 2007, B2C and B2B commerce (combined) could avoid the need for 1.5 billion square feet of retail space and up to 1 billion square feet of warehouses. It is estimated that for every billion square feet saved 8.49 million tons of greenhouse gases will be not emitted and Energy Information Association estimates that 6.4 kWh are consumed for every square foot of warehouse space.[22] Furthermore, the decrease in energy use leads to delays in expanding power plant capacity. Also the rise of the Internet as a source of product information is replacing traditional media such as newspapers and magazines.[23] This is a topic that will be discussed later in this paper in what is termed *e-materialization*.

This section has reviewed the potential environmental benefits of e-commerce. However, a large part of the B2C activity goes unmeasured and has not been addressed in this study. This involves the incidence of Internet-based research on products, services, pricing and location by potential buyers. These searches and research may produce no financial transaction online, but consumers can save a huge amount of time and travel by avoiding physical shopping – driving from store to store in search of the right "deal." This study has not accounted for the reduced travel and time associated with online shopping research for products and services that are eventually purchased at bricks-and-mortar establishments. More research is needed to understand this potentially sizable savings.

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[19] Robert D. Atkinson and Andrew S. McKay, "Digital Propensity: Understanding the Economic Benefits of the Information Technology Revolution," The Information & Technology Foundation, Washington D.C. March 2007, p. 27.

[20] Michael W. Toffel and Arpad Horvath, "Environmental Implications of Wireless Technologies: News Delivery and Business Meetings," *Environmental Science and Technology*, 2004, citing Matthews, p. A.

[21] Toffel and Horvath, p. A.

[22] Joseph Romm, "The Internet and the New Energy Economy," Center for Energy and Climate Solutions, Global Environment and Technology Foundation, 2002, p. 11.

B. Business Supply-Chain

Information technologies can have an important role in supply-chain management – efficiently administrating the flow of products and product information between vendors, manufacturing, suppliers, partners, wholesalers and retailers. Romm states "as traditional manufacturing and commercial companies put the supply chain on the Internet, and reduce inventories, overproduction, unnecessary capital expenditures, paper transactions, mistaken orders, and the like, they achieve greater output with less energy consumption."[24] For example between 1990 and 1998, Dell moved many of its operations to the Internet. Its sales increased 36 fold while its physical assets only quadrupled.[25]

There are many ways that high-speed services can benefit businesses. For example, many manufacturers require suppliers to be capable of Electronic Data Interchange (EDI). As a result, many suppliers are connected and conducting business over the Internet. In 2004, 93.3% of the value of shipments and sales from manufacturing and merchant wholesalers was conducted using B2B e-commerce.[26] Being connected can produce savings for businesses. According to one study, high-speed services can aid businesses in saving $233 billion over six years.[27]

Supply chain management increasingly uses broadband technologies to produce and distribute goods and services more efficiently, as well as to reduce inventories and their associated holding costs. The latter has decreased the amount and size of storage facilities as well as transportation costs as more products are shipped directly to the store using just-in-time strategies. Mars Incorporated used a transportation management execution system to reduce truck miles by 5% which saved 1.2 million gallons of fuel. It also resulted in decreased truck deliveries from factories to customers by 20%.[28] Home Depot uses Web and IT (information technology) solutions in its supply chain to largely bypass warehousing, which permitted 85% of

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[23] Jeffrey Grau, "US Retail E-Commerce" *eMarketer*, June 2006, p.7.
[24] Romm, p. 6.
[25] Ibid.
[26] "E-Stats," U.S Census Bureau, May 25, 2006, p. 1.
[27] "The Collaborative Commerce Value Statement: A $223 Billion Cost Savings Opportunity Over Six Years, *Module B-to-B Commerce & Applications*, Vol. 6:6, Yankee Group, June 14, 2001.
[28] "Fueling New Supply Chain Practices," MIT Center for Transportation & Logistics, Massachusetts Institute of Technology, downloadable at http://ctl.mit.edu/index.pl?id=7165.

its merchandise to move directly to its stores. Ernest & Young has estimated that bypassing warehouses could reduce inventory nationwide by $250 to $350 billion annually.[29] This reduction in inventories will decrease overstock and lead to less goods being held in intermediate or "staging" points, which will reduce pollution. Faster Internet speeds can save time and money for businesses. Also, being connected permits businesses to build web pages that advertise and market their services, providing information to the public, including attracting potential employees and customers.

Since approximately 20% of trucks at any one time are shipping empty, increased efficiency in shipping can be another significant gain. With Global Positioning Systems (GPS), wireless connected computers can track drivers and match their truck loads for return deliveries. Getloaded.com is a matching service that identifies and connects trailers that would otherwise be traveling empty with loads that need to go to the same destination.[30] Also, a number of trucking companies are auctioning empty space online such as via the National Transportation Exchange.[31] This can significantly conserve the number of miles driven by trucks nationwide which will in turn decrease pollution as well as congestion. Wireless communications devices, most notably Geographic Information Systems (GIS) and GPS, can provide autos and trucks real time traffic information that can help drivers avoid congestion, reduce travel time and distance, and improve delivery efficiency, as well as reduce air pollution associated with travel and congestion.[32]

C. Summary and Estimation of Environmental Effects: E-Commerce

It is estimated that by 2007 B2C and B2B commerce (combined) will have avoided the need for 1.5 billion square feet of retail space and up to 1 billion square feet of warehouses.[33] Based on this estimate, the reduction in greenhouse emission will equal 17.3 million tons, including 12.7 million tons saved for retail and 4.6 million tons saved for warehouses. Furthermore, the decrease in energy use will lead to fewer power plants being constructed, which

[29] Romm, p. 7.
[30] Atkinson and McKay, p. 26.
[31] Romm, p. 14.
[32] Alice Jackson, Chris Lee, Qisheng Pan and Joe Weber, "ICT, Innovation and the Transport System, Star/Stella, March 31, 2003, p. 4.
[33] Romm, p. 11.

we estimate to be an additional 20.2 million tons of greenhouse gas not being emitted into the atmosphere. Therefore, e-commerce can reduce greenhouse gas emissions by 37.5 million tons per year.

Department of Commerce figures show that B2C revenues grew at an annual average rate of 36% from the fourth quarter of 1999 to the fourth quarter of 2006.[34] However, the growth rate has slowed in the last two years to 15% per year. Most recent data from the Department of Commerce show that B2B revenues have increased by 14% in the last year. In terms of forecasts, Jupiter estimates that B2C sales will increase by 71% over a five-year period ending 2011, approximately an annual rate of 11%.[35] Therefore, it is reasonable to assume that the growth rate of total online commerce will slow somewhat – only doubling over the next ten years – and produce an average savings in greenhouse gas emissions equal to 3.8 million tons per year in total e-commerce. Based on this scenario, the ten-year incremental cumulative effect of e-commerce growth on avoiding greenhouse gas production is estimated to be 206.3 million tons.[36] This study makes no estimate of environmental effects of C2C.

By our preliminary estimate, the environmental benefits that result from the expansion of e-commerce appear to be quite immense. More work is needed to improve these estimates and consider other activities that could produce environmental benefits. While not estimated in this study, there are other activities with potentially significant savings. For instance, it is likely that online research for items, reviews, prices and locations by consumers are more prevalent than actual online purchases. This aids in consumers' buying process, reduces uncertainty, and saves considerable travel costs and time, even though the good or service may ultimately be purchased at a bricks and mortar outlet. Those travel costs and emissions have not been estimated in this paper. In addition, auction sites such as eBay and Amazon host many sell/buy transactions of the C2C variety. Their members normally use PayPal, an electronic payment vehicle regarded as

[34] All of these figures are from "E-Stats," U.S Census Bureau, May 25, 2006, and are available online at http://www.census.gov/eos/www/ebusiness614.htm.
[35] "U.S. Retail Forecast, 2006-2011," JupiterResearch, 2007.
[36] Throughout this study, we provide forecasts of several activities in terms of their reduction in total greenhouse gases. These forecasts do not include any existing benefits, only those benefits predicted to accrue over the next ten years. As a result, the forecast values presented in this paper reflects the new cumulative benefits covering the forecast period. For consistency, the sections to follow will use the same approach in presenting 10-year forecasts.

safe and secure. That practice avoids sending payment checks in the mail, saving paper and transport. In total, the hundred million registered “members” of these sites conduct efficient commerce and usually have the package shipped by carriers such as UPS, US Postal Service or FedEx. Again, the cost and emissions savings over physically shopping at stores or flea markets has not been estimated in this study.

III. Telecommuting

A. Background and Supporting Evidence

In 2005, there were 247 million motor vehicles registered in the U.S., with automobiles and trucks accounting for 55% and 42% of these vehicles, respectively.[37] By one source, the use of personal vehicles accounts for 30% to 50% of greenhouse gas emissions, as well as similar effects on toxic water and air pollutants.[38] The typical personal vehicle produces 5.0 tons of carbon dioxide annually,[39] as well as methane, nitrous oxide and various man-made gases. The roads needed to move vehicles are also a threat to the environment, as they replace forests and affect animal habitats. These roads are usually constructed with petroleum components, their maintenance expends energy and resources, and they produce hazardous runoff into nearby streams.

A number of legislative proposals have called for requiring more energy efficient automobiles and encouraging the production of alternative fuels. While providing benefits, however, these proposals are likely to produce more expensive automobiles and significantly higher fuel costs. The most popular alternative fuel, ethanol, is typically produced from corn and is more expensive than gasoline. Since corn prices have increased faster than other goods and services, the outlook for ethanol as an alternative source of energy will mean that corn prices are likely to continue to increase faster than the price of other goods and services. Since corn is used as feedstock, as well as for cereals and other foods, higher prices will mean higher food prices for consumers, in addition to higher energy prices. Moreover, the use of many of these alternative fuels, like ethanol and other bio-based energies, still result in carbon emissions. One advantage is that domestically-produced ethanol relieves some pressure on oil-imports. Alternate fuels still leave policymakers with difficult choices that pose high costs for consumers, at least in the short run, but the cost of oil is likely to rise as reserves are depleted.

Broadband services help provide seamless data, video and voice communications, permitting workers to use their home in the same manner as a businesses' office in what is described as *telecommuting* and *telework*. *Telecommuting* is the use of telecommunications

[37] Highway Statistics: 2005, U.S. Federal Highway Administration, October 2006.
[38] See http://www.globalgreen.org.

technology to allow employees to work from their homes and avoid the use of transportation to commute to and from work. *Telework* is the use of telecommunications to work anywhere other than the home office, such as telework sites satellite offices, and remote locations. Another group not covered by either term is *home-based workers*, who consist of self-employed workers who work at home instead of renting office space. Of the 25.4 million firms in the U.S., nearly 20 million (77%) are non-employer firms.[40] Of these, nearly 85% are in service industries, many of which are very conducive to home-based working arrangements.[41] However, the amount of telecommuting in the U.S. is constrained by the fact that only about one-half of U.S. households have a high-speed connection to the Internet.[42] These statistics suggest that there is potential for growth in telecommuting.

Based on data through early 2006, only 2% of workers telecommute full time and 8% operate businesses from home, suggesting that 10% regularly work at home. [43] However, 25% had the potential to regularly work from home.[44] Similarly, a survey by Dieringer Research found 14.7 million individuals working almost every day from home during 2006.[45] Given that there are 146 million persons employed in the U.S,[46] the percent of full time home workers is (again) about 10%.[47] However, 28.7% of workers work at least one day per month from home, and 44.8% report having done some work from home.[48] Therefore, the potential for expanding telework could be significant, providing that workers and employers see the benefits of working remotely from the office.

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[39] See http://www.epa.gov/otaq/climate/420f05004.htm.
[40] This statistic comes from the U.S. Small Business Administration, Office of Advocacy, from data provided by the U.S. Census Bureau, Nonemployer Statistics. See www.sba.gov for more information.
[41] Ibid.
[42] For instance, Park Associates estimates that 52% of U.S. households have broadband services, as of first quarter 2007. See National Technology Scan, Park Associates, 2007, press release available for download at http://www.parksassociates.com/press/press_releases/2007/nat_scan1.html.
[43] "U.S. Workers Waste $3.9 Billion Annually by Not Telecommuting," Rockbridge, new release, downloadable at www.rockresearch.com/news_071206.php. In addition, 9% work at home on occasion.
[44] Ibid.
[45] 2007 Survey Brief, Dieringer Research Group, Telework Trendlines for 2006, commissioned by WorldatWork, February 2007, Figure 3. These and other data, as well as related analyses Joanne H. Pratt Associates can be found www.Joannepratt.com.
[46] See http://www.bls.gov/news.release/pdf/empsit.pdf. Dieringer Research Group survey is sponsored by WorldatWork.
[47] Ibid.
[48] Ibid, Figures 1 and 2.

In addition, the potential for increased telework for government workers is high. According to the Office of Personal Management 41% of federal workers are eligible for telecommuting but only 19% do,[49] which constitutes 7.7% of total federal workforce.[50] Senators Landrieu (D-La.) and Stevens (R-Ak.) have introduced a bill that will make more federal government employees eligible for telecommuting.[51]

Balaker adeptly describes telecommuting as "the most cost-effective way to reduce rush-hour traffic and it can improve how a weary nation copes with disasters, from hurricanes to terrorist attacks."[52] He states:

> *"It helps improve air quality, highway safety, and even health care as new technologies allow top-notch physicians to be (virtually) anywhere. Telecommuting expands opportunities for the handicapped, conserves energy, and – when used as a substitute for offshore outsourcing – it can help allay globalization fears and save American jobs. It can even make companies more profitable, which is good news for our nation's managers, many of whom have long been suspicious of telecommuting."*[53]

The major gain to the environment from telecommuting is the decrease in the number of automobile trips. A recent survey found that 91% of workers commute by car, 4% by ride sharing, 3% by public transit and 3% by other means.[54] Telecommuting is zero emission transportation. Studies show that telecommuters reduce daily trips on days that they telecommute by up to 51% and automobile travel by up to 77%.[55]

Since people are staying home instead of driving to work, telecommuting reduces fuel consumption and improves air quality. There is less traffic congestion, oil consumption, and

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[49] Stephen Barr, "Senators Push for More Telecommuting," *Washington Post*, March 30, 2007, p. D4. For federal government telework and telecommuting programs, see the General Services Administration, Office of Personnel Management at www.telework.gov.
[50] Ibid.
[51] Ibid.
[52] Ted Balaker, "The Quiet Success: Telecommuting's Impact on Transportation and Beyond," Reason Foundation, Los Angeles, November, 2005, executive summary.
[53] Ibid, p. 1.
[54] Rockbridge Associates Inc., p 8.
[55] Balaker, p. 16.

noise and air pollution as a result of telecommuting. Since fewer cars are needed, telecommuting will also save emissions and pollution associated with automobile production. With fewer cars needed for commuting, car production can be reduced. Another benefit is that less infrastructure will be needed, avoiding construction and road maintenance costs, as well as reducing hazardous runoff into nearby streams.

On the other hand, those who telecommute may not save the entire trip-miles to and from work. They may still use their car to drop off a child at daycare or pick up groceries, as they formerly did on route to and from an office. They may move further from an urban area to take advantage of a rural setting, increasing the commute distance when they actually go to an office. These offsets have been referred to as the "rebound effect" and more study is needed to determine how they impact the overall savings which telecommuting can potentially deliver.

Who benefits from telecommuting? In general, telecommuting can benefit various groups such as consumers, employees, employers and society especially the elderly and disabled.

B. Benefits to Employees

Employees can benefit in various ways from telecommuting. Teleworking can provide job flexibility, which can improve the balance between work and personal time. Teleworkers have increased job satisfaction, a distraction free environment, better time management, are less involved in office politics and generally have less stress. Pitney Bowes offers telecommuting "to enhance employee effectiveness and positively impact the quality of life of workers by minimizing the stress, fatigue, time and cost associated with commuting to and from work."[56]

Also, by eliminating the commute to work people have more time for work or leisure. According to US Department of Census data, the average commute is 26.4 minutes each way or 53 minutes daily.[57] Telecommuting allows workers to find more time savings by reorganizing their lives to take advantage of many different kinds of low congestion periods. Those who shop

[56] Pitney Bowes, "Commute Options Programs," see http://www.bwc.gov/pdf/awlp/commute_opts.pdf.
[57] For more information, see "From Home to Work, the Average Commute is 26.4 Minutes," Bureau of Transportation Statistics, U.S. Department of Transportation, Vol. 3:4, October 2004, available online at http://www.bts.gov/publications/omnistats/volume_03_issue_04/html/entire.html.

during off-peak find parking easier and they also spend less time at the checkout line.[58] Quality of life increases as they workout in a less crowded health club which saves time. During breaks from work, they can do household chores. They can take their children to and from school, and be home when the children leave or arrive.

There is also gas savings as well as lower maintenance costs as usage of the vehicle decreases. By one estimate, the typical worker pays $688 annually for work-related gasoline, and represents a direct savings for telecommuters.[59] This decrease in usage from telecommuting means that fewer cars are needed. Telecommuters save money by eating out less, decreasing daycare needs, and spending less on work-wardrobes and dry cleaning. There is also the potential for a tax deduction for a home office.

C. Benefits to Employers

Employers have also gained from telecommuting. There are various estimates of the gain in productivity as a result of telecommuting. Allenby reports that Siemens, Compaq, Cisco, Merrill Lynch, Nortel and American Express have reported increases in productivity as a result of telework programs of between 10% and 50%, and a five-year Smart Valley study found an average of 25% increase in productivity for participating companies.[60]

Another advantage is that performance is measured by results rather than hours in the office. While absenteeism increases when employees are sick or have a sick child, telecommuting may allow the worker to be somewhat productive. Also if an employee has a contagious illness, telecommuting will reduce the spread of illnesses to other workers, thereby increasing productivity. Thus both absenteeism and presenteeism decreases. It is estimated that presenteeism costs US companies about $150 billion a year[61] and that the increased flexibility in

[58] Balaker, p. 18.
[59] Rockbridge Associates Inc., p. 9. This assumes a round trip commute of 20 miles and 40 minutes with an average of 21 miles per gallon and a price of $2.89 a gallon. This assumption is very conservative, considering that government statistics report the average one-way commute to be 15 miles and 26.4 minutes. See "From Home to Work, the Average Commute is 26.4 Minutes," Bureau of Transportation Statistics, U.S. Department of Transportation, Vol. 3:4, October 2004, available online at http://www.bts.gov/publications/omnistats/volume_03_issue_04/html/entire.html.
[60] Brad Allenby and Joseph Roitz, "Implementing the Knowledge Economy: The Theory and Practice of Telework" Batten Institute Working Paper, 2003, p. 35.
[61] Balaker, p. 24.

scheduling as a result of telework saves companies around $2,000 per teleworker annually in reduced absenteeism.[62]

Bad weather and emergencies, like terrorism, fires or natural disasters, are less likely to affect employees' ability to get to work. For example, JetBlue uses at-home agents for its reservation center which greatly increases the flexibility of the firm, as well as reducing the cost of booking a flight by 20%.[63] A company spokesperson stated:

> *"When things get busy, like during a weather event, we can send an e-mail to all agents asking them to log in to help. The response is immediate – we don't have to wait for them to come in."*[64]

Studies have shown that telecommuting decreases the turnover rate which can significantly decrease the cost of training and recruiting. Best Buy has instituted a program for telecommuters called *ROWE*. This program has a 3.2% lower voluntary turnover rate than non-ROWE teams. Best Buy has estimated the per-employee cost of turnover is $102,000 and productivity is 35% higher for ROWE team members.[65] Also employees are more loyal, focused and energized. Telecommuting allows employees who otherwise would not be able to commute such as mothers, the elderly and the disabled the opportunity to be gainfully employed. Since telecommuting increases the pool of applicants and thus the quality of employees it can give a firm a competitive advantage by being the employer of choice. A senior Director at Sun Microsystems states "We found that our remote employees were among our most excellent performers."[66]

As a result of telecommuting, firms will need less equipment, office space, parking spaces, office equipment, supplies and other amenities. IBM claims it saves almost $1 billion a year in avoided real estate costs, thanks to telecommuting.[67] Sun Microsystems estimated that it

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[62] Allenby and Roitz, p. 12.
[63] Allenby and Roitz, p. 34.
[64] Martha Frase-Blunt, "Call Centers Come Home," *HR Magazine*, January 2007, p. 86.
[65] Patrick J. Kriger, "Flexibility to the Fullest," *Workforce Management*, September 25, 2006.
[66] Jennifer Taylor Arnold, "Making the Leap," HR Magazine, May 2006.
[67] Allenby and Roitz, p. 34.

saved $69 million in real estate cost in 2005, as a result of its telecommuting program,[68] and it was able to decrease office space use by 30% after implementing its "iWork" program.[69] Nortel and AT&T estimate telecommuting saves $20 million and $25 million in real-estate costs, respectively, while Unisys cut office space 90%.[70] In one study, AT&T found that employee productivity improved by $65 million, increased labor retention saved $15 million,[71] and teleworkers avoided commuting 100 million miles, which reduced carbon dioxide emissions by 45,000 tons less of CO_2 emissions, or around 1.8 tons per teleworker.[72] In that study, broadband access to the Internet was found to be a critical success factor.[73]

Studies also found energy savings because construction was avoided and because the energy required in a home office was substantially less than in a commercial office. For instance, one study found a reduction in energy use and a savings in real estate costs of $25 million.[74] Another estimate found that home offices use less energy than a commercial office – a difference between 3000 to 4400 kWh per year.[75] Romm estimated that 3.5 billion square feet of saved commercial space would result in the avoidance of 35 million metric tons of greenhouse gases.[76] Also, the avoidance of construction of these buildings would save another 36.4 million metric tons of greenhouse pollution.[77]

D. Other Benefits to Society

Besides the environmental benefits of telecommuting, there are various other benefits to society. With less commuting, the number of automobile accidents and deaths will decrease as well as maintenance and infrastructure cost for roads, there will be less of a strain on public transit, and there will be more opportunities for the disabled and elderly to be gainfully employed. There are also benefits to rural economies, since people can live where they work. Workers can also supplement their earnings by using technology to earn money by working at

[68] Arnold.
[69] Atkinson and McKay, p. 28.
[70] Balaker, p. 24.
[71] Allenby and Roitz, p. 34.
[72] Ibid, p. 15.
[73] Ibid, p. 31.
[74] Ibid, pp. 34-5.
[75] Romm, p. 35.
[76] Ibid.
[77] Ibid.

home as a second job. Decreasing the amount of pollution will also decrease health-related problems especially respiratory ailments which are exacerbated by particulate pollution.

1. Benefits to Elderly and Disabled

Broadband can greatly increase the quality of life and potential job opportunities for the elderly and disabled. Litan found that broadband deployment and use lowered medical costs and institutionalized living, while increasing labor force participation for seniors and individuals with disabilities.[78] All told, Litan estimated the cumulative benefit to be at least $927 billion over a 25-year period (with future benefits discounted in 2005 dollars).[79]

Litan states that "the broader use of the Internet, and specifically 'broadband' technologies, to deliver health care services and information to senior citizens and individuals with disabilities, and to make it easier for members of both populations to work, if they are willing to do so."[80] Given that many elderly and disabled are unable to travel to work, telecommuting offers expanded work opportunities. The potential for increased employment is especially important to disabled Americans whose unemployment rate is 75%.[81]

2. Homeshoring

Reports suggest that millions of jobs have been outsourced to overseas companies, a phenomena referred to as *offshoring*. One report cites that half of the Fortune 500 companies have offshored jobs,[82] and Forester Research predicts 3 million jobs will be moved overseas by 2015.[83] Concerns over these lost domestic jobs have led to lawmakers crafting over 200 bills designed to impede offshoring.[84] The alternative, *homeshoring*, can be the domestic answer to this exodus, and broadband technology can play an important role in this reversal. Homeshoring

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[78] Robert E. Litan, "Great Expectations: Potential Economic Benefits to the Nation from Accelerated Broadband Deployment to Older Americans and Americans with Disabilities," New Millennium Research Council, December 2005.
[79] Ibid, p. 2.
[80] Ibid, p. 5.
[81] Balaker, p. 5.
[82] Bill Moyers, "The Outsourcing Debate,"various reports, Public Broadcasting Service, visit www.pbs.org/now/politics/outsourcedebate.html and www.pbs.org/now/politics/outsource.html.
[83] Clare Ansberry, "Outsourcing Abroad Draws Debate at Home," *Wall Street Journal*, July 14, 2003, p. A2. Also see John C. McCarthy, "3.3 Million US Services Jobs to Go Offshore," *Forester Research Brief*, November 11, 2002, at *www.forrester.com/ER/Research/Brief/Excerpt/0,1317,15900,00.html*.
[84] Balaker, p. 26.

is the use of home-based agents to field various types of customer care inquirers. "Virtual" call centers employ home based agents which takes away the need for the brick-and-mortar. Early adopters of homeshoring include JetBlue Airways, Alpine Access, PHH Arval and LiveOps.[85] Homeshoring encourages a diverse workforce that could include mothers, retirees, students, and people with disabilities and people who want maximum flexibility.[86] Technology has the potential to change the landscape of customer care services.

Growth in broadband services to the home, including voice-over-Internet telecommunications and softswitch technologies, has decreased labor and facility costs. One study estimated that in a traditional call center in the United States costs are around $31 per employee hour, including overhead and training, whereas home based agents can decrease cost by up to $10 an hour. Home-based retention rates are around 85%, whereas conventional call centers have a retention rate of between 10% and 20%.[87] The higher productivity and lower cost have made homeshoring a competitive alternative to offshore outsourcing, which has had a negative impact on domestic employment opportunities. The presence of broadband infrastructure in rural communities can serve to develop a pool of online workers, which may attract information-based businesses, such as IT development, software and IT service businesses, as well as back-office telecommunications centers. By increasing broadband development and use, as well as encouraging telework participation, a pool of flexible workers can be drawn upon that can stem, and possibly reverse, the loss of domestic jobs.

3. General Consumer Benefits

As worker productivity and morale increases, a firm's per unit costs decrease. Given competitive markets, decreases in per unit costs result in lower prices and increased quality for consumers. In addition, the quality of the customer service experience will improve, since domestic-based telecommuters can more easily and quickly be called upon to deal with peak periods of demand, thereby reducing long hold times in customer service call centers and help hotlines.

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[85] Martha Frase-Blunt, "Call Centers Come Home," *HR Magazine*, January 2007, pp. 84-89.
[86] Ibid.
[87] Stephen Loynd, "VIPdesk Helps Chart the Future: Homeshoring Brand Ambassadors and the Shifting of the Customer Management Landscape," IDC, 2006, p. 5.

E. Summary and Estimation of Environmental Effects: Telecommuting

On an average work day, millions of Americans commute between home and work by way of their personal vehicle. According the Bureau of Labor Statistics, there are 146 million persons employed in the U.S,[88] and transportation statistics show that 91% of workers (or 132.9 million workers) use personal cars to commute to work.[89] Assuming that that the average number of people in a carpool is 3, approximately 127.5 million personal vehicles are regularly used to commute 132.9 million workers. This activity expends time, creates congestion, costs lives in car accidents, and it wastes motor vehicles, maintenance, fuel and public resources.

The average U.S. worker commutes 15 miles and 26.4 minutes one-way to their job, [90] which means that 918 billion miles are traveled and 1.7 billion minutes are lost in the course of commuting each year.[91] To put this into context, the travel time wasted is equivalent to the annual paid hours of 17.2 million production workers.[92] In terms of dollars, the lost wages and cost of the vehicle (including gas, depreciation, insurance and maintenance) would be nearly $1 trillion or, incredibly, 7.2% of the total gross domestic product of the U.S.[93] In other words, for every $14 produced in the economy; $1 is wasted just getting employees to work using their personal vehicle.

The effect on the environment is equally stunning. Assuming fuel efficiency of 21 miles per gallon, commuting to work using personal vehicles consumes 44 billion gallons of gasoline per year. In terms of greenhouse gasses, private vehicles used during commuting release 424

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[88] See http://www.bls.gov/news.release/pdf/empsit.pdf.
[89] "National Household Travel Survey: Daily Travel Quick Facts" Bureau of Transportation Statistics, Department of Transportations, available at www.bts.gov/programs/national_household_travel_survey/daily_travel.html.
[90] "From Home to Work, the Average Commute is 26.4 Minutes," Bureau of Transportation Statistics, U.S. Department of Transportation, Vol. 3:4, October 2004. This report, statistics and methodology are available online at http://www.bts.gov/publications/omnistats/volume_03_issue_04/html/entire.html.
[91] Assuming there are 240 commuting days per year, an average weekly hour of a production worker as of March 2007 (see www.bls.gov), and workers commuting 5 times per week. In calculated lost time, this estimate is based on the 133 million workers that commute in a private car.
[92] This assumes an average hours per week of 34 hours, as measured by the Bureau of Labor Statistics. See www.bls.gov for these statistics.
[93] This assumes an average hourly wage of $19.83, which is based on an average from the 2005 BLS National Compensation Survey, and reflects an annual increase of 3.2% for 2006 and 2007, representing the approximate increase in the Employment Cost Index. All wage and employment cost statistics are from the Bureau of Labor Statistics at www.bls.gov. Vehicle costs are based on the 2006 IRS estimate of 45 cents per mile traveled.

million tons of carbon dioxide into the atmosphere each year.[94] In addition, other emissions include 23 million tons of carbon monoxide, 1.8 million tons of volatile organic carbons and 1.5 million tons of oxides of nitrogen each year.[95] All of these statistics ignore the fuel expended for public transportation, government vehicles and other vehicles, most notably those used for construction, material transportation, shipping and commercial sales fleets.

As the literature presented in this study shows, telecommuting can reduce pollutants without sacrificing, and likely augmenting, economic productivity. As previously noted, around 10% of workers telecommute full time, approximately one-tenth of these economic and environmental costs are already being saved, which approximates an annual reduction of 45 million tons of greenhouse gases.

According to a survey conducted by Rockbridge the potential for telecommuting could reach 25% participation. One holdback on telecommuting is the fact that only half of U.S. households have broadband services, which suggests (again) that telecommuting could well double in the U.S.[96] Using the economic and environmental costs discussed earlier in this paper, a doubling of the current level of telecommuting, to say 20%, would mean that one-fifth of the environmental cost of commuting could be eliminated.

To highlight the future (potential) benefit of telecommuting, this study estimates the effect of an increase in telecommuting equal to an additional 10% of the workforce over the next ten years. Based on this incremental increase and using the same calculations as before, the total economic savings direct time and expense would be $96.5 billion, including the cost of 4.4 billion gallons of gasoline each year. In terms of the environmental benefits, if 10% more of the workforce could telecommute fulltime, emissions of greenhouse gases into the atmosphere would be reduced by an additional 42.4 million tons of carbon dioxide, as well as 2.6 million tons of other pollutants, which results in 45.0 million fewer tons of greenhouse gases each year.

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[94] Environmental Protection Agency estimate for the conversion of gallons to tons of carbon dioxide can be found at http://www.epa.gov/otaq/climate/420f05001.htm.

[95] These other factors are based on an Environmental Protection Agency emission model, Mobile 6, as displayed in the Telework Coalition's Teletrips Emissions Calculator found at http://www.telcoa.org/id134.htm.

Over the next ten years, the cumulative incremental savings would be equal to 247.7 million tons of greenhouse gases.[97] Keep in mind that these benefits include only those associated with the use of a personal car, and not with public transportation.

While these are potential direct benefits, there are many indirect benefits, some of which can be approximated, such as the benefits from reduced traffic. While there are benefits to drivers who telecommute, the reduction in traffic bestows a benefit on all other drivers. In other words, as road congestion is reduced, there are benefits for those who continue to use the roads, and these benefits could be significant. In 2003, according to the Texas Transportation Institute, $63.1 billion worth of time and fuel was wasted due to traffic congestion during rush hour in 85 metropolitan areas. This resulted in 3.7 billion hours per year, which is an average of 47 hours per commuter and 2.3 billion gallons of gas.[98] As previously estimated there are 127.5 million work commuter vehicles. According to 2000 U.S. Census of those commuters, 66.9 million or 52.5 percent leave for work between 6:30 and 8:29 in the morning which will be considered peak time. John Edwards, chairman and founder of the Telework Coalition notes that "for every 1% reduction in the number of cars on the road there is a 3% reduction in traffic congestion."[99] If the average number of vehicles on the road during rush is 100 million, a 10% increase in telecommuting would result in 6.7 (6.7%) million less private vehicles commuting to work during rush hour, or 20.1% decrease in congestion. In this scenario, the savings in wasted time and fuel would be $12.7 billon and 744 million hours would be saved as well as 462 million gallons of gasoline, which is equivalent to 4.8 million tons of greenhouse gas not being emitted into the atmosphere. This study makes no attempt to forecast future benefits of decreased congestion.

Since telecommuting reduces the need for office space, there is reduced energy use for a home office versus a commercial office, as well as energy savings that results from avoiding

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[96] For instance, Park Associates estimates that 52% of U.S. households have broadband services, as of first quarter 2007. See National Technology Scan, Park Associates, 2007, press release available for download at http://www.parksassociates.com/press/press_releases/2007/nat_scan1.html.

[97] As stated before, this figure in addition to any current savings and represent the cumulative benefits over a ten-year period. All forecasts will be represented in the same manner.

[98] Tim Lomax and Davic Schrank, "2005 Annual Urban Mobility Report," Texas Transportation Institute, 2006.

[99] "It all adds up to cleaner air," Quarterly Newsletter, Winter 2006. http://www.italladdsup.gov/newsletter/winter06/experts.html.

office building construction. What would the savings be, if each full time telecommuter resulted in one less office? Based on this study's prediction of the number of telecommuters that could be added to the existing base and assuming that the average office worker utilizes 250 square feet of commercial office space, the total reduction in office space would equal 3.3 billion square feet.[100]

Since less corporate office space would be needed, there is an additional environmental savings because less energy will be expended constructing additional office space. We assume that for every 1 billion reduction in sq. ft of construction 8.5 million tons of greenhouse gas is not produced.[101] Thus by avoiding 3.3 billion sq. ft. of construction, 28.1 billion greenhouse gases would not be emitted. [102] These estimates do not take into account the reduction in power plant construction averted as the demand for electricity decreases which is a one-time benefit.

With less office space and because a home office uses less energy than a commercial office, there would be less electrical power used, which would produce additional environmental benefits. Assuming an average savings of 3500 kWh per home office and 13.3 million telecommuters, we estimate that the total energy savings would be 46.6 billion kWh per year.[103] According to federal government statistics from the Oak Ridge National Laboratory 2.3 pounds of CO_2 are produced from using one kWh of electricity.[104] Converting this into tons of CO_2 and including other greenhouse gases, the energy savings from reduced office space would be 56.8 million tons of greenhouse gases. This means that over the next ten years, the incremental cumulative benefit would be 312 million tons of greenhouse gases. Again, these benefits do not include any savings from reduction in commuters who use public transportation.

As previously noted, these environmental benefits come without sacrificing economic output and productivity. Thus, telecommuting can lead to increased profits for the firm, better work life balance for the employees, more employment especially for the disabled, mothers and

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[100] A typical office (with overhead space) can vary between 175 to 300 sq feet per employee, according to AllBusiness.com at http://www.allbusiness.com/.
[101] This assumption comes from "Paper and the Electronic Media," Boston Consulting Group, September 1999.
[102] "Paper and the Electronic Media," Boston Consulting Group, September 1999.
[103] This is approximately the midpoint between the differences in commercial office energy use minus home office energy use. See, Romm, p. 35.

rural residents, and less pollution and oil consumption for society, as well as lower prices and better quality for consumers. Encouraging the development of technology such as broadband services, which will facilitate the use of more telecommuting, could become one of the most important economic public policy initiatives, because it helps the environment while augmenting economic growth.

While this study provides a number of simple estimates of the environmental effects of information technologies, further research is needed to develop a more comprehensive analysis. Future studies should consider the increased jobs that could be eligible for telecommuting once high-speed "telepresence" video conferencing tools become common. These tools could open up telecommuting to those employees whose jobs require face-to-face contact with peers or clients. This may substantially increase the potential benefits beyond what has been already noted in this study. In addition, there are environmental and economic benefits from telecommuting that would result in reduced public transit use, which have not been measured in this study. In summary, while this study attempts to quantify many of the benefits of telecommuting, more work is needed.

[104] Available at http://cdiac.ornl.gov/pns/faq.html.

IV. E-materialization

A. Background and Supporting Evidence

The convergence of telecommunications and computers are replacing the need to manufacture, publish, print and ship documents, books, CDs and DVDs; or as one author writes, "the Internet has the ability to turn retail buildings into Web sites and to turn warehouses into better supply chain software, to dematerialize paper and CD's into electrons, and to turn trucks into fiber optic cables."[105] Wired Magazine states "while those who produce electronic goods must expend the same capital, labor, and knowledge as those producing tangible goods, their products can be copied in nanoseconds, and transported at the speed of light."[106] Thus, the Internet has a tremendous impact on delivering goods without the actual physical production and physical transportation of the good. This dematerialization which is sometimes referred to as *e-materialization* has and will have a significant impact on energy use and pollution.

E-materialization is becoming evident in much of what we do in our daily lives, in large part due to digital technologies and the Internet. As a result, the need for paper has diminished, as offices track products and complete reports electronically, airlines produce e-tickets, retail price tags are being replaced by barcodes and first-class U.S. mail is being replaced by e-mails, instant messages and text messages. Dentists and physicians no longer need to print x-ray films, because they can now be viewed from the computer in high resolution, and, for a second opinion, can later be transported worldwide over the Internet. The same is true of photography, where for most of us the need for film and photo processing is being replaced by digital technologies that allow them to be stored, copied, transmitted and shared worldwide, without producing a physical copy. Software, particularly updates, are less frequently being sold materially; giving way to more convenient downloaded versions. These activities provide environmental benefits by reducing energy used in production, as are material resources, including paper and plastic materials.

[105] Romm, p. 9. Updating Romm's quote, it is worth noting that, with the use of fiber technologies in local and backbone networks, electronic goods are frequently transported as photons in passive optical networks, which requires far less energy than more traditional electronic transmission systems.
[106] Brad Cox, "Superdistribution," *Wired*, September, 1994.

Today, users have moved toward more bandwidth intensive applications, such as downloading music and movies. According to IDC, the equivalent of one million times the storage of the Library of Congress would be needed to house just the digital information that was created last year.[107] Consumers are beginning to download videos and movies, which replace travel to retail and video rental stores. Adams Media Research estimates that consumers spent $111 million to download videos in 2006, and these expenditures are likely to increase to $4 billion by 2011, fueled, in part, by new services such as Apple TV.[108] By one report, YouTube streams in three months the combined data "of the world's radio, cable and broadcast television channels;"[109] and, by another report, YouTube now serves 100 million video downloads per day.[110] Sony has plans to offer video downloads to its 20 million customers with its PlayStation Portable,[111] which comes on the heels of Xbox, which is now offering TV and movie downloads, including some in bandwidth-intensive high-definition format.[112] Amazon has its Unbox video download service and Sling Media has its Slingbox, both permitting watching movies on portable devices.[113] Besides a couple dozen peer-to-peer downloading services where consumers can swap movies, subscription services are also available from CinemaNow, MovieFlix, Starz Vongo, BitTorrent, Totalvid, Starz Real Movies and Movielink – all of which permit full movie downloads from the Internet, including high-definition format. Next, consider that Wal-Mart, which accounts for 40% of the DVDs sold in the U.S., now sells downloadable movies that you can watch on your PC.[114] Of course, there are many other services that sell downloadable games and music.

However, there appears to be one area where office workers and consumers could do more – namely, save paper. While in subsequent years the current value of shipments for manufactured paper and paper output have not surpassed the level of 1995, the promise of a

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[107] Brian Bergstein, "Tech Researchers Calculate Digital Info," *The Associated Press*, March 6, 2007.
[108] "Spending on Video Downloads to Survey: Study," *Reuters*, February 21, 2007.
[109] Bret Swanson, "The Coming Exaflood," *Wall Street Journal*, Commentary, January 2007, p. A11.
[110] Marshall Kirkpatrick, "YouTube Serves 100m Videos Each Day," *Tech Crunch*, July 17, 2006, downloaded from www.techcrunch.com.
[111] Matthew Garrahan, "Sony to Enter Video Download Market, *Financial Times*, December 17, 2006.
[112] Daniel Terdiman, "Xbox Cues up TV, Movie Downloads," *CNET News*, November 6, 2006.
[113] Rob Pegoraro, "Slingbox Video Streaming Not Perfect, but Remarkable," *Washington Post*, March 23, 2006, p. D5.
[114] David Lieberman, "Curtain's Finally Rising on Movie Downloading: Wal-Mart's Entry into the Biz Signals It's Hitting Big Time, *USA Today*, March 8, 2007, p. 1B.

paperless environment has failed to emerge. It could be that the computer has made it too easy for users to print what can be electronically shared. It may also be that having paper copies remains an artifact of old habits. However, the prevalence of inexpensive and dependable electronic storage media would suggest that the potential to reduce paper could be quite significant. More work is needed to identify this potential and the barriers that prevent the substitution of electronic media for common paper documents.

B. Summary and Estimation of Environmental Effects: E-Materialization Examples

1. Saving Plastic by Downloading Music

CDs and DVDs products, such as music, videos and games are being replaced by downloading, as computers, broadband services and online applications become more widely available. This downloading activity is evident in its impact on music sales. Unit sales of music CDs have decreased by 25% (267 million units) from 2000 to 2006 according to the Recording Industry Association of American,[115] and sales during the first quarter of 2007 appear to have declined by another 20%.[116] Digital downloading was virtually nonexistent just a few years ago, but that is clearly no longer the case. While 615 million plastic music CDs were shipped in 2006, 586 million digital singles, 28 million albums and 9.9 million music videos were downloaded last year.[117] The decline in CDs represents a reduced demand for plastic that is made mostly from petroleum.

What could be saved if CDs (and their cases) could be completely replaced by electronic and optical transmissions, such as downloading to personal computers, saving onto digital video recorders, ordering via video-on-demand services or by some other means? Given that 10 CDs (with cases) weigh roughly 2 pounds, and given the current level of 615 million CDs sold in 2006, the greenhouse savings from eliminating CDs can be roughly estimated by calculating the oil saved by not producing these CDs. By one estimate, recycling a ton of plastic saves 685 gallons of oil,[118] approximating the amount of oil contained (stationary) in plastic material. Because the amount of energy contained in plastic is roughly equal to the energy required during

[115] For industry data see Recording Industry Association of American at http://www.riaa.com/keystatistics.php.
[116] Ethan Smith, Sales of Music, Long in Decline, Plunge Sharply," *Wall Street Journal*, March 21, 2007, p. A1.
[117] Again, industry data is available at http://www.riaa.com/keystatistics.php.
[118] See http://www.grist.org/advice/ask/2007/03/14/plastics/ for the amount saved by reusing plastic.

the manufacturing process, we use this figure as a rough estimate of the energy used in the manufacturing process.[119] The energy used in the production process is assumed to be the only portion directly associated with greenhouse gases emissions. We recognize that disposal of plastics through incineration will add additional pollutants, though we have not included these emissions in our estimates.[120] Based on this conservative approach, the elimination of CDs will save the equivalent of 42 million gallons of oil. Because there is 22 pounds of carbon per gallon of oil,[121] there are 0.5 million tons of emissions that could be saved. If this savings could be realized in the next ten years, the cumulative savings from eliminating plastic CD cases would be 2.5 million tons of greenhouse gas emissions. The reduction in plastics will also occur in DVDs, games cartridges and other forms of plastic media, none of which were included in this study's estimate. In summary, there is no doubt that the substitution from physical units to digital downloads will continue as broadband services reach the vast majority of American homes.

2. Estimated Savings from U.S. Mail

The greatest effect of dematerialization is the use of paper. Consumers and businesses are increasingly automating their payments, using electronic means to conduct transactions and communicating by emails instead of first class mail. As a result of this transition from a paper to an electronic world, between 2002 and 2006, first class mail declined from 103.5 billion pieces to 97.6 billion pieces, a total decline of 5.9 billions pieces. At 41 cents per first class letter, consumers are saving $2.4 billion dollars in postage.

In addition, the environmental savings from reduced first-class mail is significant. Assuming each first class letter is just 1 ounce, the decline in first class mail is equivalent to a reduction in 184 thousand tons of paper. This means that about 4.4 million trees are saved and 608,000 cubic feet of landfill were spared in 2006, compared to 2000 levels.[122] The trees saved

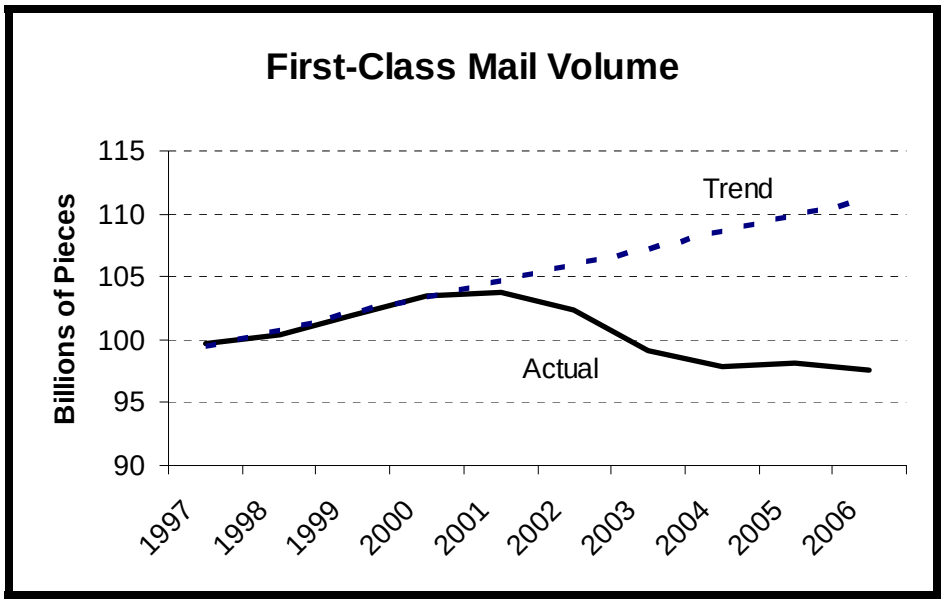
[119] Approximately 50% of energy is used as feedstock to make plastic resin, while a roughly equal portion is used in the manufacturing process, according to http://www.drf.umd.edu/Recycling/documents/3-Stillnotconvinced.pdf, citing recyclenow.com. We will leave it to further research to refine this rough estimate.
[120] To repeat, our estimates only include the energy used in the manufacturing process, not the energy contained in plastic material.
[121] Several sources report this. For example, see Mike Tidwell, "Food and the Climate Crisis: What you Eat Affects the Sky," *Sierra Club Redwood Chapter Newsletter*, Sierra Club, December/January 2005, fn. 2, citing U.S. EPA.
[122] Estimates vary and have been available at www.epa.gov, as well as various other organizations, such as http://www.unlv.edu/facilities/recycling/reports.html http://www.recycledpapercraft.com/prespap.htm and http://www.conservatree.com/learn/Essential%20Issues/EIGoingOn.shtml.

produce 575,000 tons of oxygen and filter out 133,000 tons of pollutants. While these figures reflect one year of savings, the benefits cumulate over many years.

The environmental impact is also considerable in terms of reduced chemicals that are used during the bleaching, as well as the energy and water necessary to cut, produce and bring paper to the market.[123] For instance, the annual savings from the reduction in demand from 2000 to 2006 reduces the amount of polluted water by 3.8 million gallons, solid wastes by 240,000 tons and electricity by 7.4 million BTUs. The greenhouse gas saved from the atmosphere (in terms of CO_2 equivalence) is 610, 000 tons. In summary, the current effect of electronic communications has significantly reduced the demand for paper communications, without increasing consumer expenses.

However, these figures underestimate the complete effects from reduced first-class mail. As the figure below shows, based on a simple trend from 1997 to 2000, first-class mail volumes have been growing. If that growth continues, 111 billion pieces of first-class mail would have been delivered instead of 97.6 billion. This suggests that the effective decline in first-class volumes is much greater than estimated using a simple absolute decline. Based on this, if comparing the 2006 level to the 2000 level, the net greenhouse gases that are now being saved due to the decline in postal volume is equal to 1.4 million tons of greenhouse gas. There is no reason to believe that decline in volume will not continue, as broadband services reach the remaining 50% of U.S. households and mass market applications make it easier for consumers to conduct retail transactions, bank, receive newsletters, communicate and ship electronic documents to others, and pay their taxes. At the current rate of decline in first-class mail, the cumulative incremental 10-year savings from reduced paper consumption use will equal 7.3 million tons of greenhouse gases. Keep in mind that much of the mail that households receive are not considered first class mail, including postcards, newsletters and advertisements, which can and are being replaced by electronic communications as well. More research is needed to quantify these environmental benefits.

[123] In converting the resulting savings in solid wastes, energy emissions, atmospheric emissions and waterborne waters from an initial savings of newsprint and office paper, this study relies on "Lifecycle Environmental Comparison: Virgin Paper and Recycled Paper-based Systems," Environmental Defense, Paper Task Force, White Paper #3, updated February 2002, available at http://www.environmentaldefense.org/documents/1618_WP3.pdf.



3. Estimated Savings from Lower Newspaper Circulation

Newspapers are increasingly being read online.[124] Compared to reading a newspaper, receiving the news on PDA wirelessly results in the release of 32 to 140 times less CO_2 and several orders of magnitude less of nitrogen oxide and sulfur oxide and the use of 26-185 times less water.[125] Catalogues, magazines, directories and other "printed" material are all affected by the Internet. The resulting decline in newspaper circulation can be directly linked to increased electronic information available on the Internet.[126] So, while a paperless society has not arrived, the demand for printed material is declining in large part due to the expansion of the Internet and online use.

Boston Consulting Group projected that by 2003 e-materialization will reduce the demand for paper by 2.7 million tons which would result in 9.1 million tons less of greenhouse gases being emitted into the environment.[127] By 2008 it estimated that the greenhouse gas savings would double to 18.2 million tons. This is a conservative estimate since the authors

[124] David Lieberman, "Newspaper Sales Dip, but Websites Gain," *USA Today*, Inside Money, May 9, 2006.
[125] Toffel and Horvath, p. D. For this estimate, the unit of analysis is one person reading the daily news for 1 year.
[126] Lieberman, May 9, 2006.
[127] Romm, p. 39.

assumed that in 2003 only 44% of the US population would be Internet users.[128] It also does not take into account the decrease in square footage of buildings for retail, warehousing and production facilities as a result of e-materialization.

By one estimate, there are 14 million tons of newspapers printed each year.[129] Using the historical decline from 1999 to 2006 for daily and Sunday readership, newspaper print has declined by 1.7 million tons. This decline translates into 21 million trees that were saved each year, sparing 5.8 cubic yards of landfill, producing 2.7 million tons of oxygen and filtering out 628,000 tons of pollutants.

Since the paper industry uses the most energy, outside of the petroleum and chemical industries, the reduction has spared 2.5 million tons of solid wastes, saved 67 million BTUs of energy and 24.6 million gallons of polluted water. In terms of carbon emissions, the reduction in circulation has lead to 7.9 million tons less of greenhouse gases. The declining trend in newspaper circulation, which appears to be approximately 1.7% per year, is likely to continue.[130] Based on this trend, the 10-year cumulative incremental savings in greenhouse gases would be approximately 57.4 million tons.

4. Estimated Savings from Reduction in Office Paper

As broadband services become more widespread, workers telecommute and providers sell online content, paper of all kinds are reduced. Workers send invoices, bids and specs without printing a page, and doctors share x-rays in PDF format. Office memos are not copied; they are e-mailed. Just small changes in workers habits can make big changes to the environment.

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[128] Ibid.

[129] In 2005, the U.S. supply was 14 million tons, according to "The Source: Newspapers by the Numbers," Newspaper Association of America, Arlington, VA, 2006, p. 40.

[130] This declining trend was calculated using the last six years of the average daily and Sunday readership. This percent was applied to current level of newspaper production (14 million tons) to produce the expected savings due to electronic media. Readership volumes came from Journalism.org's *The State of the News Media*, downloadable at http://www.stateofthenewsmedia.org/2005/narrative_newspapers_newsinvestment.asp?cat=6&media=2.

One source estimates that the average office worker generates 10,000 pages of paper in one year.[131] The use of the computer, the Internet and broadband services can facilitate a considerable reduction in the use of office paper. For example, if the average worker generates just 5 fewer pages per year, 21 million trees would be saved,[132] 18 million fewer gallons of water would be polluted, 35 million BTUs of energy would be conserved and 2.9 million tons of greenhouse gases would not be released into the atmosphere. This number is quite conservative, providing a substantial opportunity for additional environmental benefits.

Similarly, as consumer broadband use continues to grow, the ability to save paper would provide considerable benefits to the environment. For example, if a household could save just one page of paper per day, that would spare 5 million trees per year, 4 million less gallons of water would be polluted, conserve 8.4 million BTUs of energy and reduce greenhouse gas emissions by 700,000 tons.

While we cannot know all that e-materialization has and will save in terms of paper, plastics and other resources, it is certain that these technologies can provide major benefits to the environment. Therefore, policies that encourage the development of these technologies can have an increased positive environmental effect, without necessarily sacrificing economic output and productivity.

[131] See http://eetd.lbl.gov/paper/ideas/html/copyfactsA.htm.
[132] One tree produces 25,000 pages, according to this National Geographic's *The Green Guide*. For more information, visit http://www.thegreenguide.com/doc/gginnews/nytimes100506.

V. Telemedicine

A. Background and Supporting Evidence

Telemedicine applications are another commonly cited example of broadband benefits to residents and businesses. The type of broadband favored for telemedicine tends to be synchronous in download/upload speed, HIPPA compliant, with low jitter and consistent high bit-rate. Telemedicine applications allow doctors and hospitals to share and send video telecommunications, as well as X-ray and digital images, to other doctors and hospitals located in other parts of the country, thereby giving patients, especially those living in remote communities, better quality of care and increased convenience. Broadband services work to facilitate medical access to and advice from multiple medical specialists.[133] Today, telemedicine applications are being used to diagnose diseases such as diabetic retinopathy,[134] osteoporosis,[135] arthritis[136] and real time cancer detection.[137] They are also being used to monitor homebound patients with congestive heart failure and other serious illnesses. Broadband services are the means by which services and applications are made possible – by exchanging bandwidth-rich content, connecting patients to their doctors and giving doctors access to a pool of experts from across the country – in either "store and forward," or real-time consults.

Information technology has greatly advanced the potential of telemedicine. Rural patients have the same access to care as patients living in a major metropolitan area without the need to travel. Patients are using the Internet; 10% have consulted with medical professionals online and 12% have purchased prescription drugs online.[138] Thus the number of visits to the doctor's office is decreased as well as the number of trips to the pharmacy.

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[133] For one example of telemedicine applications, see the Center for Telehealth at the University of Georgia, Augusta, GA at http://www.mcg.edu/telehealth.

[134] "Telemedicine Application Fights Diabetic Blindness Epidemic," *Science Daily*, April 18, 2000, available for download at http://www.sciencedaily.com/releases/2000/04/000417100749.htm.

[135] There are a number of telemedicine programs for osteoporosis: post-fracture care for osteoporosis at the Institute for Clinical Evaluative Sciences and Osteoporosis-Telehealth at North Network, both in Ontario, Canada; see, http://www.ices.on.ca/webpage.cfm?site_id=1&org_id=2&morg_id=0&gsec_id=2079&item_id=2079&category_id=46 and http://www.northnetwork.com/about/specialprojects.shtml, respectively.

[136] In North Dakota, St. Alexius Medical Center offers telemedicine Rheumatology/Arthritis services. For more information, see http://www.st.alexius.org/news/details.asp?NewsID=160.

[137] For a general discussion of this and other telemedicine projects see, R. S. Weinstein, A. M. Lopez, et. al., "The Innovatative Bundling of Telereadiology, Telepathology, and Teleoncology services, *IBM Systems Journa*l, Vol. 46, No. 1, 2007, available for download at http://researchweb.watson.ibm.com/journal/sj/461/weinstein.html.

Danzon estimated that web-based claims processing alone would cut costs in 1999 by $1.8 billion.[139] One estimate finds that a national electronic patient record system could save $140 billion dollars per year by increasing care and eliminating duplicative testing.[140] Broadband can reduce medical errors through the use of electronic prescriptions.[141] The implementation of these three functions could greatly decrease the use of paper, including paper documents from doctors, patients, pharmacists, stores and payers, and thus be environmentally friendly. Also x-rays are now available over the Internet which greatly reduces the need to make hard copies of the film. This technology is environmentally friendly in that the use of chemicals for the development of films is decreased as well as the need to transport the developed films.

Telemedicine could improve patient recovery, decrease readmission, and reduce costs by 80% simply by allowing basic medical checks, such as for weight, blood pressure, blood sugar etc., that can be performed regularly at home and then transmitted to the central database.[142] Two physicians developed a remote monitoring system complete with high-resolution video feeds and real time real data on patient vital signs, allowing one doctor to tend to patients in multiple ICUs at once. At Johns Hopkins this type of telemedicine cut ICU deaths by 50% and saved 90 lives annually.[143]

The VA's integrated chronic disease monitoring program has resulted in cost savings, decreasing hospital admissions by up to 60% and it saves lives.[144] If this program was used on 4 million Medicare patients posing the highest risk, net savings would be $30 billion with 1.7 million fewer admissions.[145]

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[138] Rockbridge Associates Inc., p. 5.
[139] Litan, p. 15.
[140] "Secretary Thompson Seeking Fastest Possible Results, Names First Health Information Technology Coordinator," *E-Gov*, White House press release, May 6, 2004, available for download at http://www.whitehouse.gov/omb/egov/press_releases/gtob/040506_chi.html.
[141] Litan.
[142] Balaker, p. 28.
[143] Ibid.
[144] Litan, p. 17.
[145] Ibid.

Thus, information technology as applied to telemedicine is not only environmentally friendly but also saves lives, increases the quality of life of patients and decreases the cost of medical care.

B. Summary and Estimation of Environmental Effects: Telemedicine Example

Telemedicine applications vary, as do their benefits. In general, telemedicine is reputed to increase access to care, cut costs and deliver better clinical outcomes. For instance, telemedicine can provide collaboration between physicians, permit specialists to provide second opinions or make diagnoses, monitor homebound patients, thereby reducing nurse visits and help patients and doctors have access to medical resources – all remotely and in real time. While the benefits from telemedicine are clear, the precise benefits are harder to measure.

One clear example of the benefits of telemedicine is in-home health care, where studies have shown a decrease in emergency room visits and readmissions due to healthcare monitoring for patients, particularly those with congestive heart failure.[146] Besides these direct medical benefits, the reduction in-home health visits and patient visits to the hospital could produce sizable benefits to the environment.

By one estimate, there are a half a billion in-home health visits each year.[147] If we assume that the average visit requires the nurse to drive 10 miles one-way and if 33% of these visits can be completed through remote monitoring of vital signs and conversation with the patient, 3.3 billion miles will be saved, not to mention the travel time of the nurse – approximately, $1.5 billion in travel time, gas and vehicle expense. The actual time for evaluation of the patients' vital signs may be decreased. This means that patients can be monitored more often at lower costs. In other words, medical resources can be stretched without sacrificing quality of services to patients.

[146] Referring to the use of so-called *electronic nurses* for patients with congestive heart failure (CHF), Terry Goodwin, vice president of Montefiore's Home Health Agency said, "In one study, visits by CHF patients to emergency rooms decreased by 61.7 percent and readmissions to hospitals decreased by 65.9 percent." For information on this study see http://www.montefiore.org/whoweare/stories/electronic_nurses.
[147] According to http://informatics.cpmc.columbia.edu/edu/topics/New%20Folder/homehealthcare.htm.

In this scenario, the environmental benefits of tele-home visits appear quite enormous. By not using 159 million gallons of gasoline, 1.5 million tons of carbon dioxide and 100,000 tons of other greenhouse gases would not be released into the atmosphere. Tele-home health care is just part of the potential benefits that telemedicine can bring. Again, more work is needed to identify and measure these environmental benefits. There are areas of telehealth that seem to offer substantial environmental benefits that are not estimated here, including:

- In-service training for clinicians, conducted using distance learning techniques such as live, two-way voice and video. This especially helps areas where there is a shortage of medical specialists. Remote training of clinicians can save time, road-trip miles and are an effective means to stay current on treatment practices.
- In areas where telemedicine is not practiced, a rural patient with an acute problem is too often transported by ambulance, car or air-taxi to a suitable emergency room. Telemedicine could assist the doctor and patient to take the appropriate steps in treatment, thereby potentially reducing fuel consumption.
- When a clinician and patient in a clinic need the opinion of a specialist, telemedicine allows them to send full records and set up a visual and audio link with a specialist of their choice to challenge or confirm the diagnosis and treatment plan. That saves pursuing inappropriate treatment, cost, delay, and of course fuel needed to complete that "visit" had the patient driven to get that second opinion.

VI. Teleconferencing

A. Background and Supporting Evidence

Teleconferencing technologies (video-based) have advanced sufficiently to enable firms to significantly decrease business travel. The current version, *telepresence*, allows for eye to eye contact between multiple participants, life size images, shared documents and no jerky video images.[148] This not only decreases the number of local trips but also plane and train travel. The cost of transportation associated with these business trips can be eliminated thus increasing both the profits and reaction time of the firm. Also, with this reduced travel employees will spend less time away from home which will enhance their work life balance. Video conferencing expends 500 times less energy than a 1000 km business flight.[149]

B. Summary and Estimation of Environmental Effects: Teleconferencing

Where teleconferencing displaces airline travel, the effect on the economy would be substantial. Today, there are 738.4 million passengers in one year, with the average mean travel distance of 1,055 miles.[150] If 10% of air travel could be replaced by teleconferencing, 77.9 billion miles could be saved, which would reduce greenhouse emissions by 36.3 million tons.[151] Based on this annual average, the 10-year incremental cumulative reduction in CO_2 and other greenhouse gases would equal 199.8 million tons.

While the environmental benefits of teleconferencing are clear, more work is needed to identify the extent to which it can replace various modes of travel.

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[148] "The Telepresence Promise", MSNBC.com, April 16, 2007, "videoconferencing reaches a new threshold of reality when the people you're seeing are nearly life-sized, moving naturally (without that Max Headroom lag-time) and speaking with sound as clear as a CD," see: www.msnbc.msn.com/id/18055679.

[149] Toffel and Horvath, p. B.

[150] Air passengers and mean miles are from http://www.census.gov/compendia/statab/tables/07s1048.xls Source: Air Transport Association of America, Washington, DC, Air Transport Annual Report.

[151] Carbon Counter estimates that 1 million miles of air travel produces 439 tons of CO_2 per individual passenger, according to http://www.carboncounter.org/.

VII. Distance Learning

Some broadband-based applications and services appear to have clear benefits for rural communities, compared to urban communities. Broadband services facilitate distance learning, enabling students to receive an education from the comfort of their home.

This opens up the opportunity for students who for whatever reason can not obtain an education in a traditional classroom. For rural students, distance learning provides access to a wide choice of educational curriculums and programs.[152] Students who do not have the time to commute or cannot be in class at the same time each week or the disabled who may find it difficult to travel to school all can receive a better education from improved technology. Also, traditional students can and have taken advantage of the distance learning opportunity.

The Internet can be used for distance learning courses as well as learning in general. For example in Iowa which has many small rural schools and cannot afford the cost of an environmental program for each school, the Internet has allowed as many as 90 schools simultaneously to participate in various environmental education programs.[153] Also, the Internet can decrease trips to the library to do research. The Internet is also a valuable tool for people to learn about environmental issues. Thus, the Internet has the potential to decrease the use of transportation and the pollution that goes with it as people take advantage of these new found educational opportunities. This study makes no attempt to measure these benefits, which highlights the need for more research in this area.

[152] For example, Old Dominion University in Norfolk, VA has graduated more than 3,500 students from its distance learning program, which services students from across the state, as well as areas as far away as Arizona and Washington state (see http://www.odu.edu/oduhome/distance.shtml).

[153] "The Internet and Conservation Report" Taubman Center for State and Local Government, Kennedy School of Government, Harvard University, Spring 2001.

VIII. Computers and Telecommunications Technologies: Costs vs. Benefits

A. Can Information Technologies Save More Energy Than They Use?

This study has provided extensive examples of how telecommunications services, as well as other technological advances, have and can reduce energy costs, carbon emissions and save trees. However, some have contended like Huber and Mills that information technology consumes 13% of U.S. electricity and will grow to 50% in 10 years.[154]

These contentions have been thoroughly disputed and corrected in subsequent research. For example, Koomey contends "that the Huber and Mills estimates of power used by the Internet are at least eight times too high and their estimates of total power use by office equipment is overstated by at least a power of four."[155] Specifically, Koomey reports that the Internet consumes only 1% of US electricity not 8% and office equipment only 3% not 13%.[156] A study by Lawrence Berkeley National Lab supports these findings. It estimates that computers and all office equipment consume, at most, 3% of electricity and this will decrease as computers become more energy efficient.[157] Like offices, households expend only a few percent of their electricity on office computers and printers,[158] and computer servers use 1.2% of total electricity, including cooling and associated infrastructure.[159]

However, some information technology equipment and services can be used to reduce energy in ways that more than offset its electricity use. For instance, the Internet can directly save energy through remote energy management of commercial and residential buildings. Early trials of remote controlled home energy management systems suggest the savings in energy bills could be as high as 10%, a figure that far exceeds IT energy use.[160] Therefore, while the public needs to be mindful that high technology equipment uses energy, as this study shows, there are

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[154] Peter W. Huber and Mark Mills, "Dig more coal-the PCs are coming" *Fortune*, May 31, 1999, pp. 70-72.
[155] Jonathan G. Koomey, "Sorry, Wrong Number" *IEEE Spectrum*, June 2003, p.12.
[156] Jonathan Koomey, Karou Kawamoto, Matyanne Piette, Richard Brown and Bruce Nordam, "Initial Comments on the Internet Begins with Coal," memo to Skip Laitner (EPA), Lawrence Berkeley National Laboratory, December 1999. http://enduse.lbl.gov/Projects/infotech.html.
[157] Atkinson and McKay, p. 28.
[158] A household uses 1.5% of its electricity on a desktop computer plus 0.2% for a printer with fax capability according to http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html.
[159] This is an amount roughly equal to a color television. See Jonathan G. Koomey, "Estimating Total Power Consumption by Servers in the U.S. and the World," February 15, 2007. The study is available for download at http://enterprise.amd.com/Downloads/svrpwrusecompletefinal.pdf.

many useful applications for this equipment that can produce benefits – both environmental and economic – that exceed costs.

The Lawrence Berkeley National Lab also found that, for the period 2000 to 2010, the IT economy could decrease the growth of carbon emissions by 67% over what would otherwise occur.[161] In short, while computers and electronic equipment consume electricity, their negative effects on the environment, according to many studies, have been overstated.[162] In fact, while more work is needed to quantify the total effects, it would appear that information technologies provide benefits that far exceed costs.

B. Increased IT-Intensity Reduces Energy Use

There also appears to be a negative correlation between increased IT-intensity and energy use. Romm has found that "from 1996 through 1999, the U.S. experienced an unprecedented 3.2% annual reduction in energy intensity."[163] Energy intensity is defined as energy consumed per dollar of GDP. Romm found that there is a relationship between reduction in energy intensity and the growth in information technology, including the Internet economy. Growth in the Internet economy can decrease energy in two ways. First, the IT sector is less energy-intensive than manufacturing and the Internet increases efficiency in every sector of the economy, including manufacturing.

There appears to be a negative correlation between Internet and energy use – namely, as the Internet has grown, energy use and carbon emissions have declined. Prior and during the commercialization of the Internet (1992-1996), GDP growth averaged 3.2% a year, whereas energy demand grew 2.4% and carbon dioxide emissions grew by 2%. In contrast, in the years when Internet use grew exponentially and became mainstream (1996-2000), GDP growth averaged 4% per year, while energy demand grew only 1% a year and carbon dioxide emissions grew only slightly above 1%.[164] The negative correlation between the Internet and energy use

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[160] Romm, p. 18.
[161] Atkinson and McKay, p. 27.
[162] Alan Chen of Berkeley Lab comments on a number of these studies in his feature for *Science Beat*, available at http://www.lbl.gov/Science-Articles/Archive/net-energy-studies.html.
[163] Romm, p. 1.
[164] Romm, p. 3.

was noted by an administrator of the Department of Energy's Energy Information Administration, Jay Hakes, who pointed out that growth in US electricity demand has slowed since the Internet boom. In his 2000 testimony, he reported that "from 1985 to 1995, retail electricity sales grew at the rate of 2.6% per year. However, during the period 1995 to 1999, retail electricity sales have grown by 2.1% per year."[165] In examining this negative correlation, Romm concludes that Internet use has not led to an increase in demand for electricity, but instead has led to energy efficiencies that have "resulted in the biggest drop in electricity intensity and energy intensity the nation has seen in decades."[166]

C. IT-Use is Inextricably Linked to Economic Growth and Productivity

Numerous studies show an inextricable link between IT investment and the health of the U.S. economy. While total IT manufactured output accounted for a mere 2% of Gross Domestic Product (GDP) during 1990-1995,[167] IT capital investment contributed to nearly 30% of GDP growth for the same period.[168] Thus, an increase in IT investment produces a much larger increase in U.S. economic output.

According to a number of studies, IT investment, including investment in broadband networks, has provided an important catalyst for operational efficiency in the U.S. In one such study, Kevin Stiroh showed that industries with higher capital stock in telecommunications and computing equipment experienced higher productivity gains.[169] For the period 1989 to 2001, IT-intensive industries experienced a 3.0% increase in productivity, while less IT-intensive industries had productivity growth of only 0.4%. During the recent economic recession, IT-intensive industries experienced a 3.1% improvement in productivity, while less IT-intensive industries had a decline in productivity of –0.3%. Effectively, IT-intensive industries are responsible for *nearly all* of the productivity gains experienced in the economy in recent years.[170] Another study estimated that IT investment was responsible for 40% of the growth in total factor

[165] Ibid, p. 15.
[166] Ibid, p. 22.
[167] "Digital Economy 2002," Appendix, Table A-3.2, based on the gross product originating for all IT manufacturers.
[168] Dale W. Jorgenson, "Information Technology and the U.S. Economy," Presidential Address to the American Economic Association, New Orleans, January 6, 2001, p. 27.
[169] Kevin J. Stiroh, "Investing in Information Technology: Productivity Payoffs for U.S. Industries," *Current Issues in Economics and Finance*, Federal Reserve Bank of New York, 7:6, June 2001.
[170] *Digital Economy 2003*, Economics and Statistics Administration, U.S. Department of Commerce, Dec. 2003.

productivity and 68% of the accelerated growth in labor productivity.[171] Since IT manufacturing prices have fallen relative to the prices of other goods and services, the IT sector has been credited with reducing overall inflation by as much as 1% per year.[172]

Because IT investment has led to increased economic activity, it has created many new well paying jobs – jobs that pay approximately twice that of other private sector jobs.[173] In a recent issue of the *Occupational Outlook Handbook*, the Bureau of Labor Statistics projects eight of the nine fastest growing occupations to be in the IT sector.[174] In addition, the creation of IT jobs can have large spillover effects into other industries. For example, one report estimated that every Microsoft job leads to the creation of 6.7 other jobs.[175]

Consistent with the general conclusion that IT investment spurs economic growth and productivity, a handful of studies have made a direct link between broadband investment and consumer benefits. According to one study by Crandall and Jackson, the ubiquitous deployment of broadband services would create $500 billion of consumer benefits.[176] Two studies estimated that a ubiquitous deployment of broadband services would create 1.2 million new jobs, both direct to building and maintaining a broadband network as well as spillover effects into other industries.[177] In terms of investment, one of these studies reported that for every one million dollars of broadband investment, 18 new jobs are created in the economy.[178] Another one of these studies estimated that every worker employed in manufacturing and constructing a

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[171] Stephen D. Oliner and Daniel E. Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives*, 14:4, Fall 2000, pp. 3-22.
[172] Estimates have varied over the years. See *The Emerging Digital Economy II*, United States Department of Commerce, June 2000; and *Digital Economy*, United States Department of Commerce, (Various years).
[173] *Digital Economy 2002*, Chapter 5, p. 41.
[174] Occupational Outlook Handbook: 2002-2003 Edition, Bureau of Labor Statistics, Washington, DC, Chapter on Tomorrow's Jobs, Chart 8.
[175] Michael Mandel, "The New Business Cycle," BusinessWeek, March 31, 1997; and "The New Economy," The Keystone Spirit: Putting Technology to Work at sites.state.pa.us/PA_Exec/DCED/tech21/b-neweconomy.htm. These sources report the multiplier effects for the general economy to be 1.5 to 2.0.
[176] Robert W. Crandall and Charles L. Jackson, "The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access," Criterion Economics, L.L.C., July 2001.
[177] This result was reported in two independent studies using different methodologies, see Stephen Pociask, "Building a Nationwide Broadband Network: Speeding Job Growth," TeleNomic Research, Herndon, VA, February 25, 2002; and Robert W. Crandall, Charles L. Jackson and Hal J. Singer, "The Effect of Ubiquitous Broadband Adoption on Investment, Jobs and the U.S. Economy, Criterion Economics for the New Millennium Research Council, September 2003.
[178] This was the assumption used by Crandall, Jackson and Singer, 2003, p. 14.

broadband network produces 4.1 other workers elsewhere in the economy.[179] Still another recent study assumed that broadband deployment would result in very high productivity gains, create 212,000 direct and indirect jobs, and produce a massive $634 billion in economic output.[180]

This study has shown that information technologies can produce significant reductions in greenhouse gas emissions and can do so without sacrificing economic growth and productivity. In fact, a review of the literature shows that broadband investment and use have significant stimulative effects on economic growth and productivity, providing the best of both worlds – improving both environmental and economic welfare.

[179] Pociask, 2002.

[180] Thomas W. Hazlett, Coleman Bazelon, John Rutledge and Deborah Allen Hewitt, "Sending the Right Signals: Promoting Competition Through Telecommunications Reform," A Report to the U.S. Chamber of Commerce, Washington, DC, September 22, 2004. The authors are from the Manhattan Institute, Analysis Group, Rutledge Capital and the College of William and Mary, respectively.

IX. Summary and Conclusion

Advancements in technologies, most notably computers, telecommunications and high-speed Internet services, are being used to change the way consumers and businesses shop, travel, work and use products. These technological changes result in productivity benefits and measurable savings to consumers and businesses, but they also produce clear, though largely invisible and unnoticed, environmental benefits. While studies show that the productivity of a teleworker can increase, the savings to the environment can be immense. Workers and consumers routinely send and receive electronic documents that once were printed on paper, thereby saving trees, reducing air and water pollution and saving the energy needed for manufacturing, distribution and sales. Newspaper circulation is declining, in large part due to increased electronic forms of news. Home-monitoring of patients is leading to fewer emergency room visits and readmissions, while reducing the air pollution associated with some home visits by nurses. These trends are likely to continue.

This paper has reviewed the literature, estimated the current level of the environmental effects and forecasted the 10-year cumulative incremental environmental benefits that these technological changes will have in terms of reduced greenhouse gas emissions. The summary table (on the next page) shows that the potential benefits are immense, exceeding one billion tons of greenhouse gas emissions over the next ten years. The greatest potential for greenhouse reductions appears to be in e-commerce (206 million tons), telecommuting (over a half a billion tons), teleconferencing (200 million tons) and paper reduction (57 million by reductions in newspaper circulation alone). If all of the greenhouse reductions noted in this study were converted into energy saved, we forecast that IT applications could save 555 million barrels of oil by year 10, or roughly 11% of the oil imported into the U.S. today.[181] Also, there are countless other potential benefits that were noted as likely candidates, but not measured in this study, which suggests that the potential environmental benefits of these technologies could be much greater. More research is needed to analyze and quantify these other benefits.

[181] We assumed that a gallon of oil is equivalent to 40.5 kWh, 42 gallons per barrel and similar standard measures and calculated the annual savings in year 10. For comparison, there were is approximately 5 billion barrels of oil imported into the U.S. in 2006. These assumptions and U.S. crude oil and petroleum products imports come from www.eia.doe.gov and our estimates are only approximate.

Study Summary

Reductions in Greenhouse Gases for Select Activities (Millions of Tons)

Area of Technology Replacement	Current Annual Savings	Forecast Incremental (10-year)
E-Commerce Green Effects		
• B2B and B2C	37.5	206.3
• C2C	N.A.	N.A.
Telecommuting Green Effects		
• Direct Effects from Driving	45.0	247.7
• Indirect Effects from Congestion	4.8	N.A.
• Office Space Not Built	28.1	28.1
• Saved Office Space Energy	56.8	312.4
Teleconferencing		
• Business Air Travel	36.3	199.8
E-Materialization		
• First-Class Mail	1.4	7.3
• Plastic CDs	0.5	2.5
• Newspapers	7.9	57.4
• Office Paper	2.9	N.A.
• Paper used in Households	0.7	N.A.
Tele-Medicine		
• Home Nurse Visits	1.6	N.A.

N.A. – Estimate not available

In general, the evidence presented in this study shows that broadband-driven technologies can make a sizable contribution to reducing carbon emissions, as well as many other environmental benefits. This suggests that technological innovations such as these should be part of any comprehensive energy policy.

On the other hand, since public policy for energy and environmental quality is shaped by a different set of regulators than those who govern information technology and specifically broadband, it is in the public interest that they collaborate in preserving the track record and promise of information technology in curtailing greenhouse gas emissions at the same time as they foster economic growth. In a sense, the need for a "best of both worlds balance" is the main policy lesson from our study of information technology's and broadband's contribution to environmental preservation.

In terms of policy development, the promise of these advancements and their contribution to the environment cannot be fully realized without the encouragement of ubiquitous advanced technologies and widespread use of broadband services by consumers and businesses. As noted in this study, only half of American households subscribe to broadband Internet services, limiting the extent to which these environmental benefits can be fully realized. It is also likely that more widespread use of broadband services will lead to further innovation of services and applications that will produce even greater benefits for the environment, beyond those anticipated in this study. These innovations may include even faster Internet speeds, increased reliability and features that make online activities and transactions safer and more secure. To this extent, this study underestimates the potential for even greater greenhouse gas reductions and other environmental benefits.

On the other hand, public policies that impede the deployment of these technologies, such as regulations and taxes, would slow broadband investment, reduce consumption and deployment of broadband services, and threaten the potential environmental benefits – most notably the reduction in greenhouse gases. However, while acknowledging the link between broadband development and environmental benefits, further policy discussions of how to best encourage adoption of broadband is beyond the scope of this study.

In summary, this study investigates the role that telecommunications and information technologies can play in improving the environment and finds that these technologies have and can play a significant role in reducing greenhouse gas emissions. Further work is needed to explore policies that would encourage advances in telecommunications technologies, along with a sound and comprehensive energy policy that encourages energy efficiency, clean energy sources, independence, conservation and other factors – all of which can make a meaningful and sizable improvement in our environment by slowing energy use, conserving our water and natural resources and reducing greenhouse gas emissions. While this study has attempted to measure many of these benefits, much more work is needed to refine these measures and add to the collection of information on the subject.