# The Internet Economy and Global Warming

A Scenario of the Impact of E-commerce on Energy and the Environment

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# PREFACE

The growth of e-commerce will provide a number of opportunities and challenges for all institutions, public and private. *The Internet Economy and Global Warming* looks at the way e-commerce may fundamentally shift the traditional relationship between energy use and economic growth, and how this historic shift may benefit our economy and environment.

The paper is published by the Center for Energy and Climate Solutions (CECS), a one-stop shop for helping companies reduce greenhouse gas emissions. The Center is a division of the Global Environment & Technology Foundation (GETF), a nonprofit dedicated to building the infrastructure for sustainable development. GETF facilitates the demonstration of new technologies and ways of doing business and helps make these ideas accessible and replicable throughout a number of sectors. We look for innovative technologies and partnerships that can significantly contribute to this goal.

Since 1994, GETF has utilized the emerging tools of the Internet to promote sustainable practices. GETF's networks (at www.getf.org) make information, resources and tools more accessible, and include a complete array of online services and content including communities, e-commerce, live chats, magazines, customizable networks, and personalized news.

We invite your feedback on the findings of this paper and ways to improve on it. Since this is such an important subject and since the Internet is advancing so rapidly, we plan to update the analysis periodically. We hope that our readers will provide feedback to Version 1.0 that will allow future versions to be more accurate and more comprehensive. In particular, we seek specific, quantitative examples of how the Internet is affecting energy use and the environment, for better or for worse. Since we recognize the difficulty of performing comprehensive, the Center can provide assistance to any company or organization seeking to quantify the environmental impact of its activities.

This paper would not have been possible without the assistance of a number of individuals: Erik Brynjolfsson, Mohan Sawhney, Roger Stone, Kirsten Lange, Craig Schmidt, Brad Allenby, Bruce Nordman, David Rejeski, Joel Prakken, Patricia Mokhtarian, Tad Smith, Nevin Cohen, Jesse Ausubel, Lee Schipper, Skip Laitner, Howard Geller, Gail Boyd, Amory Lovins, Alan Meier, Jon Koomey, Michael Totten, Mark Borsuk, David Malchman, Peter Arnfalk, Steve McHale, Daniel Deutsch, Lee Eng Lock, David Guernsey, Don Chen, Raymond Boggs. Special thanks goes to David Michaels for his help in researching this paper.

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### About the Center for Energy and Climate Solutions

The Center is a one-stop shop that helps companies and organizations reduce energy costs and greenhouse gas (GHG) emissions by providing them with tools and strategies that can improve the environment, while increasing profits and productivity. Center partners and clients include Fortune 100 corporations, foundations, environmental organizations, and federal agencies.

Since its inception in 1998, the Center has developed best practices and high quality case studies on corporate GHG mitigation and energy efficiency. These were published in the 1999 book *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions*, which has been featured in the *Wall Street Journal* and the "Working Wiser" section of

abcnews.com. In 1999, CECS joined alliance with the World Wildlife Fund to create the Climate Savers program, which encourages major companies to make GHG commitments.

The Center's team of nationally recognized experts work with Center clients and partners to help them reduce their energy costs and GHG emissions and verify and record these reductions and their related benefits. Key CECS team members include:

- **Dr. Joseph Romm**, an acclaimed author, scholar and energy expert, is Executive Director of CECS. He is a former Acting Assistant Secretary of Energy for Energy Efficiency and Renewable Energy at the U.S. Department of Energy. He is the author of the first book to benchmark corporate climate mitigation efforts: *Cool Companies* (Island Press, 1999). Dr. Romm is also the author of *Lean and Clean Management* (Kodansha, 1994*)* and dozens of articles, speeches and publications on energy and management topics.

- **Dr. Art Rosenfeld** is one of the foremost experts in energy efficiency in buildings and appliances, as well as climate mitigation and analysis. He is the author of 360 scientific or technical papers and three best-selling books on energy. He is the founder and former Director of the Center for Building Science, Lawrence Berkeley National Laboratory (1975-1994).

- **Hank Habicht** is the Chief Executive Officer of the Global Environment & Technology Foundation. He served as the Deputy Administrator of the US Environmental Protection Agency (1989-1993) as well as the Senior Vice President of Safety-Kleen Corporation (1993-1998), which provides industrial and recycling services to over 400,000 customers.

- **Susan Herrmann** is an engineer and economist who serves as the CECS project manager. She has designed and implemented both private and public sector strategic management portfolios including: total cost-benefit analyses, ISO 14001 Environmental Management Systems, life-cycle assessments, design for the environment and communication systems.

CECS works with corporations, governments, and organizations to supply practical strategies and tools for reducing energy costs and GHG emissions. CECS services include:

- Helping companies design and implement strategies to cut costs and boost productivity while cutting GHGs;
- Spreading best practices for GHG reduction;
- Providing neutral and credible verification of GHG emissions baselines and reductions;
- Partnering with energy service companies to spread the opportunity for energy efficiency and GHG reductions;
- Partnering with Information Technology companies and Internet companies to promote economic growth while increasing energy efficiency and reducing environmental impact, what we call "eee-commerce";
- Communicating and educating the public on GHG emission mitigation efforts through public speaking, publications and the CECS website (www.cool-companies.org).

# EXECUTIVE SUMMARY

This paper explores the impact of the growing Internet economy on current and future trends in energy consumption.

The world is only beginning to come to grips with the complex consequences of the exploding growth of e-commerce and the Internet economy. To be sure, the impacts on the way we live, work and consume will be historic, both positively and negatively. We need to understand the potential created for environmental gains and structural reductions in energy and resource use, as well as the need for certain industries to adapt to very large strategic challenges and opportunities.

This paper reflects an analysis of currently available but incomplete data, and begins to construct some rough scenarios. Hopefully these scenarios begin the process of identifying opportunities and challenges for business leaders and policy makers and suggesting the directions of future research and initiatives. These dynamics will fundamentally shape the path to sustainability in the US and around the world.

Our key points and conclusions:

- The nation experienced remarkable economic growth in 1997 and 1998, about 4% per year, driven to a significant extent by industries that produce information technology (IT). The resulting increase in electronic business transactions also played a role. The overall productivity of the economy appears to have increased substantially, driven by the IT sector.

- During those same two years, the nation's energy consumption—the principal source of air pollution and the gases linked to global warming—hardly grew at all. In the previous 10 years, U.S. *energy intensity*, measured in energy consumed per dollar of gross domestic product declined (i.e., improved) by under 1% per year. In both 1997 and 1998, it improved by more than 3%—an unprecedented change during a time of low energy prices. In 1998, U.S. emissions of greenhouse gases rose only 0.2%, the smallest rise since 1991 (which was a recession year).

- Preliminary analysis by EPA and Argonne National Laboratory suggests that roughly one third of the recent improvements in energy intensity are “structural.” Structural gains traditionally occur when economic growth comes in sectors of the economy that are not particularly energy intensive, such as the IT-producing sector, which includes computer manufacturing and software (as opposed to more energy-intensive sectors, including chemical manufacture, the pulp and paper industry, and construction).

- The remaining two-thirds improvement comes from gains in the energy efficiency of all sectors. In traditional energy efficiency, a computer factory would use more efficient motors, a software company might using more efficient lighting in its buildings, or a chemical manufacturer might redesign a process for making a chemical to cut the energy used per pound of product.

- Traditional structural gains will likely continue, since the IT-producing industries continue to show high growth rates. The EPA has performed a preliminary analysis of the potential impact of structural changes driven by rapid growth of the IT-producing industries. The analysis suggests that mainstream forecasts may be *overestimating* U.S. energy and carbon dioxide emissions in the year 2010 by up to 5%— while significantly *underestimating* overall U.S. economic growth.

- Traditional energy efficiency will also likely accelerate for two reasons. First, more and more companies are developing and implementing strategies to reduce their greenhouse gas (GHG) emissions and these strategies include investing in energy efficiency. Second, major energy service companies are increasingly offering "energy outsourcing" deals in which they take over corporate energy management for Fortune 1000 companies and invest in energy efficiency to a much higher degree than those companies had. These deals eliminate many of the barriers that have slowed more widespread adoption of energy efficiency technologies and strategies in the past decade.

- Equally important (and a primary focus of this paper), the Internet economy itself seems to be generating both structural gains and efficiency gains. Internet structural gains will occur, for instance, if the manufacturing of software on disks and CDs (delivered by plane and/or truck) continues to shift toward purely electronic files delivered over the Internet. If companies put their stores on the Internet using software, rather than constructing new retail buildings, that would also represent an Internet structural gain. Dematerialization saves energy. The Internet makes possible what might be called *e-materialization*. By 2003, e-materialization of paper alone holds the prospect of cutting energy consumption by about 0.25% of total industrial energy use and net GHG emissions by a similar percentage. By 2008, the reductions are likely to be more than twice as great. We also believe the Internet Economy could *render unnecessary as much as 3 billion square feet of buildings*—some 5% of U.S. commercial floor space—which would likely save a considerable amount of construction-related energy. By 2010, e-materialization of paper, construction, and other activities could reduce U.S. industrial energy and GHG emissions by more than 1.5%.

- Internet energy efficiency gains potentially cover a broad spectrum of activity. In business-to-consumer e-commerce, for instance, a warehouse can contain far more products like books per square foot than a retail store. Warehouses themselves also typically use far less energy per square foot than a retail store. So books and other products sold over the Internet would likely consume less energy per book then traditional retail-based sales.

- More important is business-to-business e-commerce, which is estimated at 5 to 10 times the size of business-to-consumer e-commerce. As traditional manufacturing and commercial companies put their supply chain on the Internet, and reduce inventories, overproduction, unnecessary capital purchases, paper transactions, mistaken orders, and the like, they achieve greater output with less energy consumption. Federal Reserve Board Chairman Alan Greenspan told Congress in June "Newer technologies and foreshortened lead-times have, thus, apparently made capital investment distinctly more profitable, *enabling firms to substitute capital for labor and other inputs far more productively than they could have a decade or two ago.*"[1] Imagine the Internet energy efficiency gains if electronic commerce leads "to a reduction in overall inventories of $250-$350 billion, or about a 20% to 25% reduction in current U.S. inventory levels."[2] Few things have a larger environmental benefit than pollution prevention, especially in the energy-intensive manufacturing sector. Not making products that wouldn't have been sold or not building manufacturing plants that aren't needed is pure prevention.

- Another important effect is that the Internet appears to be promoting greater use of home offices, allowing telecommuters to spend less time at the office and also spawning many purely home-based businesses. The Internet provides home-based workers more access to more useful information and increasingly high-speed connections to coworkers and/or customers. And as e-commerce itself grows, both business-to-consumer and business-to-business, more jobs will involve spending a considerable amount of time on the Internet, jobs that can perhaps be done as

easily from home as from traditional workplaces. This shift will increase energy consumption in homes, but will likely save far greater energy in avoided office building construction and utility bills, as well as reduced commuting energy.

- There are aspects of the Internet that will probably entail *more* energy use, such as greater small-package delivery by truck. These cases may not, however, result in a net increase in energy use; efficient package delivery by truck may replace at least in part inefficient personal driving to malls, supermarkets, bookstores and the like. This will be particularly true if most of the packages are delivered by the Post Office, which already passes virtually every home in the country daily. The great unknown question at this point is whether or not a significant fraction of Americans will change their driving habits over the next few years once it is possible to make a critical mass of cyber-trips on the Internet. That is, will the Internet be the mall of the 21st Century?

- Christmas shopping over the Internet for gifts that were going to be shipped anyway can avoid a considerable amount of transportation energy consumption and air pollution. The biggest environmental benefit occurs for gifts (or other e-commerce purchases) that do not have to be shipped by air freight, since that is the most energy-intensive form of shipping. We label those e-commerce choices that maximize energy savings and environmental benefits "*eee-commerce*."

- The Internet is growing so quickly, and data on it remain so inadequate, that it is certainly not possible to draw more than tentative conclusions at this point (particularly in areas as difficult to analyze as the possible substitution of Internet use for transportation). That is why we have labeled this analysis a scenario, and not a prediction. We believe the Internet may already be reducing the energy intensity of the industrial sector, and that it holds the potential to have its most significant impact in this area. If so, this would be the Internet's biggest impact on the environment, since this sector is responsible for a third of the nation's air pollution and the vast majority of its hazardous waste and other pollutants. We believe the Internet could significantly reduce the contribution of the commercial building sector to the nation's energy intensity and that gains in this sector will likely outweigh increases in electricity use in residential buildings. We suspect the Internet economy will be no worse than neutral in the transportation sector, but could well have a large positive impact. In general, we believe one label commonly used for e-commerce, "frictionless," has a useful analogy here. Friction causes energy to be lost. Frictionless commerce saves energy.

- If, indeed, the Internet is already reducing energy intensity, then it is likely to have a very big impact in the years to come. The Internet economy is projected to grow more than ten-fold—from its current level of tens of billions of dollars today to more than $1 trillion in a few years. Moreover, while the Internet economy remains a small share of the total U.S. economy, it represents a much higher fraction of the *growth* in the economy. That is the essential point for this paper, which explores the likely impact of the Internet on the relationship between the growth in the economy and the growth in energy use.

- We believe the combination of trends described above makes it likely that the years 1997 to 2007 (and probably beyond), will not see the same low-level of energy intensity gains that the previous 10 years saw, which were under 1% per year. *We expect annual improvements in energy intensity of 1.5%—and perhaps 2.0% or more*. If this comes to pass, most major economic models used in the country will need to be modified. For instance, the government's main energy forecasting arm, the Energy Information Administration, uses a figure of 1.0% or less for its projection of annual energy intensity improvements. If the actual number is closer to 1.5% to 2%, then a

number of related forecasts may need to be changed, such as the number of power plants the United States will need to build in the next decade, and the cost to the nation of achieving greenhouse gas reductions. Already, *preliminary data suggest that energy intensity in 1999 will likely drop by more than 2.0%.*

- It may be that many other factors widely used in economic models—building construction per GDP, paper use per GDP, and the like—also need to be changed. This might in turn affect the impact of GDP growth on the inflation rate. The Internet economy could well allow a very different type of growth than we have seen in the past. In other words, the scenario we are presenting in this paper is that if there is a so-called "New Economy," as many apparently now believe, there is also a "New Energy Economy," which would have profound impacts on energy, environmental, and economic forecasting.

- At the level of the firm, one company has already integrated traditional energy efficiency with Internet efficiency to achieve remarkable improvements in energy intensity. IBM is one of the leaders in corporate energy management, with major successes using technologies like efficient lights and motors in its office buildings and factories. At the same time, it has had one of the most ambitious programs in corporate America to use laptop computers and other information technologies to allow a significant fraction of its sales and service organizations to work outside IBM's buildings (i.e. to telework). In addition, the company has been using its electronic network to improve inventory management and production planning, which has allowed it to better utilize existing manufacturing capacity and thereby lower investment and operating costs. Together, all of these efforts have allowed IBM to reduce corporate energy consumption by 4% per year throughout most of the 1990s. Moreover, IBM projects that it will be able to continue reducing energy consumption for the foreseeable future, even as it continues to experience significant growth.

# I. INTRODUCTION

Two very remarkable, though seemingly unrelated, changes have taken place in the U.S. economy in the past two years. The first is well known—the remarkable growth of the Internet. The second is not well-known—that in 1997 and 1998, while the U.S. economy grew by some 8%, U.S. energy consumption hardly grew at all, about 1%. Had the historical relationship between U.S. economic growth and energy consumption been the same in those two years as it had in the previous 10, we might have expected 6% growth in energy consumption. This is potentially very important because the vast majority of air pollution in this country come from the production and use of energy. In particular, virtually all of the emissions of carbon dioxide, the principal greenhouse gas emitted by human activity, come from fossil fuel combustion. Indeed, U.S. emissions of greenhouse gases rose only 0.2% in 1998, the smallest rise since 1991, a recession year.[3]

If the relationship between energy use and economic growth is changing, that would have profound implications for long-term economic and energy forecasting in this country. It would affect key national issues such as how costly it will be for the United States to reduce its emissions of heat-trapping gases that scientists believe contribute to global warming and climate change. Since the science of global warming has been the subject of thousands of studies, we will not discuss it here.[4]

There are, as we will see, a variety of reasons why U.S. energy intensity may be changing. The question of primary interest in this paper, however, is whether there is any connection between the growth of the Internet and energy trends. Energy use in the United States divides roughly evenly between buildings, manufacturing, and transportation. 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 CDs into electrons, and to turn trucks into fiber optic cables. After the Introduction, and a section on recent trends affecting energy consumption, the paper will focus on how the Internet may affect energy usage in those three sectors of the economy.

We recognize that the quality of the numbers and metrics available on the current and future state of the Internet economy leave much to be desired. Indeed, much of the data and forecasting come from firms engaged in e-commerce, market research, or management consulting, who all have an incentive "to build momentum" for the activity they are analyzing.[5] Even the terms electronic commerce and Internet economy, which are achieving widespread usage, do not have agreed-upon definitions.[6]

Very few energy or environmental analyses of the impact of the Internet have been done.[7] Environmental life-cycle analyses are very hard to do well and engender much skepticism.[8] The recent literature attempting to determine the net energy and environmental benefits of telecommuting is particularly sobering (see Section 5). Predicting the future is notoriously difficult in the technology arena. As Federal Reserve Board Chairman Alan Greenspan, one of the IT optimists, told Congress in June: "Despite the remarkable progress witnessed to date, we have to be quite modest about our ability to project the future of technology and its implications for productivity growth and for the broader economy."[9] This is doubly true in the energy arena, where flawed predictions are the norm. That is why it we have labeled this paper a scenario, borrowing the approach used by the most widely respected strategic planner in the energy business, Royal Dutch/Shell. Indeed, a major reason we are writing this White Paper is to raise issues that we believe deserve far more rigorous analysis than we have been able to perform, particularly by those who have made energy predictions without considering the impact of the Internet.

While the precise future impact of the Internet cannot be known today, one thing is already clear—the Internet is poised to have a powerful effect. As Federal Reserve Board Chairman Alan Greenspan told Congress in June:

> Something special has happened to the American economy in recent years.
>
> An economy that twenty years ago seemed to have seen its better days is displaying a remarkable run of economic growth that appears to have its roots in ongoing advances in technology….
>
> [I]nnovations in information technology—so-called IT—have begun to alter the manner in which we do business and create value, often in ways that were not readily foreseeable even five years ago.[10]

## THE EXPLODING INTERNET ECONOMY

The number of Internet users in the United States alone has soared from 5 million in 1993 to 62 million in 1997 to over 100 million as of mid-1999. According to the Department of Commerce's first major report on e-commerce, published in April 1998, "The Internet's pace of adoption eclipses all other technologies that preceded it. Radio was in existence 38 years before 50 million people tuned in; TV took 13 years to reach that benchmark. Once it was opened to the general public, the Internet crossed that line in four years."[11] Internet traffic doubles every 100 days.[12] Over 2 billion orders will be placed over the Internet in 1999.[13] Already, the Web is used by people representing some 60% of the total purchasing power of U.S. households.

The rapid growth of the Internet makes it difficult to understand its current impact, let alone its future impact. In part this is due to Metcalfe's Law of Networks, which states that the usefulness of the network equals the square of the number of users. In other words, while the number of users grows arithmetically, the value and impact of the Internet grows exponentially. The authors of the 1998 book, *Unleashing the Killer App*, explain that "the more people who use your software, your network, your standard, your game, or your book, the more valuable it becomes and the more new users it will attract, increasing both its utility and the speed of its adoption by still more users."[14] They note that having one phone is useless, a few phones are of limited value, and one million phones create a vast network. Indeed, the Internet makes possible an even more powerful network than telephones, as noted in a report by the University of California's E-conomy Project: "Unlike prior communication systems, such as telephony, which established a dedicated connection between two (or sometimes more) nodes, the Internet allows the simultaneous exchange of information in digital form among an unlimited number of nodes…. To this is added the innovation of hypertext, that is, the ability to almost effortlessly move from node to node at a whim."[15]

Online auctioning is a particularly potent example of the Internet's network effect. The Internet is beginning to create almost a virtual nationwide barter economy for a wide variety of goods and services. Not just Beanie Babies and Pez Dispensers are being auctioned but, as we will see, basic commodities like steel and paper, and even empty space on cargo trucks, which alone could potentially save a great deal of energy.

Many if not most Americans have become familiar with the brand-name business-to-consumer e-commerce sites, such as Amazon.com, Ebay, Blue Mountain, and Travelocity. The far bigger economic impact lies elsewhere, as explained in the September 1999 issue of *Business 2.0* by Mohanbir Sawhney, who heads the e-commerce and technology group at the Kellogg Graduate

School of Management at Northwestern University, and Steven Kaplan, faculty director of the entrepreneurship program at the University of Chicago Graduate School of Business:

> The great untold story of online commerce is that business-to-business sales have already eclipsed the higher-profile business-to-consumer market by a long shot. Annual B-to-B e-commerce is projected to soar from $43 billion in 1998 to $1 *trillion* by 2003, according to Forrester Research, while the consumer market swells from $7.8 billion to $108 billion in the same period.[16]

We will see in later sections the power of Metcalfe's Law as it applies to businesses like IBM, Cisco Systems, and GE—the exponential impact achieved as more and more companies put their supply chain on the Internet. GE, for instances, estimates that streamlining purchases via the Internet could save the company between $500 and $700 million annually.[17] CEO Jack Welch told *Business Week* in June, "I don't think there's been anything more important or more widespread in all my years at GE. Where does the Internet rank in priority? It's number one, two, three, and four."[18]

The Internet has an astonishing ability to eliminate inefficiency and increase capacity utilization across the entire economy. It may be helping to create a so-called "New Economy" with much higher rates of productivity growth than in the past two decades.

While the Internet economy remains a small share of the total U.S. economy, it represents a much higher fraction of the *growth* in the economy. In July 1999, the Department of Commerce's second major study on *The Emerging Digital Economy* presented a detailed analysis of the industries that produce Information Technology (IT), such as computers, semiconductors, telephone equipment, software, programming, computer services.[19] The Commerce Department said those IT-producing industries had reached nearly an 8% share of the U.S. economy by the end of 1998, but that they were responsible for 28% to 29% of the contribution to real growth during 1997 and 1998.

Further, those numbers do not include everything that is typically included in a definition of the Internet Economy: all of the additional sales over the Internet during those two years by traditional industries that were taking advantage of the output of these IT-producing industries and creating Web sites, intranets (internal networks) and extranets (networks extended to a limited number of participants outside the company, such as suppliers). One preliminary effort to capture the combined impact of all facets of the Internet Economy has been done by the Center for Research in Electronic Commerce of the Graduate School of Business at the University of Texas at Austin. They concluded in October:

> "U.S. GDP is projected to grow $340 billion in 1999. The projected $200 billion growth in Internet Economy in 1999 plays a significant role in the health of the economy, although differences between GDP and revenues make a precise comparison difficult."[20]

So, the Internet Economy is playing an increasingly dominant role in the nation's overall growth. It is the issue of incremental growth that is most relevant for this paper, since we are exploring whether information technology and the Internet allow a different kind of economic growth, one that does not require as much growth in energy consumption as traditional economic growth.

## A WEIGHTLESS AND FRICTIONLESS WORLD?

> "Computers in the future may … perhaps weigh only 1½ tons."[21]
>
> *Popular Mechanics*, 1949

Dematerialization is a long-standing and well-studied trend in the economy.[22] The idea that information technology (IT) and electronic commerce in particular can reduce our material and energy consumption is also not a new one. In an October 1996 speech, Federal Reserve Board Chairman Alan Greenspan said,

> Virtually unimaginable a half century ago was the extent to which concepts and ideas would substitute for physical resources and human brawn in the production of goods and services. In 1948 radios were still being powered by vacuum tubes. Today, transistors deliver far higher quality with a mere fraction of the bulk. Fiber-optics has replaced huge tonnages of copper wire, and advances in architectural and engineering design have made possible the construction of buildings with much greater floor space but significantly less physical material than the buildings erected just after World War II. *Accordingly, while the weight of current economic output is probably only modestly higher than it was a half century ago, value added, adjusted for price change, has risen well over threefold.*
>
> The displacement of human physical effort by ideas is, of course, also evident in changed production processes. Word processors have markedly reduced the effort required to produce a manuscript. Turn-of-the-century steel mills, and even those operating in 1948, valued the physical brawn that could move coiled sheets from one segment of a plant to another. Today, we perform these tasks with devices whose mechanical leverage is designed and guided by the insights coded into a computer program.
>
> Radical transformations in what we produce in the way of goods and services and how we produce them occur perhaps once or twice in a century, at most.[23]

Inspired in part by Greenspan, Diane Coyle, economics editor of *The Independent*, wrote a book titled, *The Weightless World: Strategies for Managing the Digital Economy*.[24] The digital world, she notes, is about as close to weightless as is possible, allowing "nearly costless reproduction." Danny Quah, a professor at the London School of Economics uses the term, "infinite expansibility," meaning that the use of a dematerialized object by one person does not stop another person from using it also.[25]

In 1994, *Wired* magazine explained, "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."[26] Similarly, Nicholas Negroponte, founder of MIT's Media Lab, wrote in his 1995 book, *Being Digital*, "The information superhighway is about the global movement of weightless bits at the speed of light."[27]

Some have even calculated the increasing weight loss of the U.S. economy. Chris Meyer, director of the Ernst & Young Center for Business Innovation, reported in April 1999 the results of an analysis by the Center. *"The value-to-weight ratio of a pound of GDP has gone from $3.64 in 1977 to $6.52 today, a 79 percent increase."*[28] While U.S. GDP rose 70% in those two decades, the total weight of that gross domestic product actually declined slightly.

In a similar vein, McKinsey consultant Lowell Bryan has calculated that today U.S. companies "require 20% less in the way of tangible assets to produce a dollar's worth of sales than they did a

generation ago."[29] The Internet, as we will see repeatedly throughout this paper, is likely to accelerate these trends.

A concept related to weightlessness is the way in which the Internet can dramatically reduce transaction costs.[30] "The conventional wisdom regarding Internet competition," according to an August 1999 paper on "Frictionless Commerce," from the E-commerce division of MIT's Sloan School of Management, "is that the unique characteristics of the Internet will bring about a nearly perfect market … where retailer 'location" is irrelevant, consumers are fully informed of prices and product offerings, and retailers all make zero economic profit."[31]

For consumers, getting good information on products and price is a key transaction cost. In the past, this might have involved such energy intensive activities as going to a library or a book store, visiting several different furniture stores or auto dealers, looking at several catalogs, and the like. Consumers in theory also benefit from the lower overhead of online merchants who don't have to build and operate expensive retail space.

The MIT study concluded, "We find the prices on the Internet are 9-16 % lower than prices in conventional outlets, depending on whether taxes, shipping and shopping costs are included in the price." They conclude, "There is lower friction in many dimensions of Internet competition."[32]

For businesses, frictionless commerce and nearly cost-free transactions may be even more valuable, as major companies increasingly are using the Internet to get the lowest prices for their supplies. For instance, General Electric has developed a Web-based Trading Process Network linked to its suppliers; it features "electronic catalogs, the ability to make electronic purchases and the option of paying online with an electronic credit card." The system has cut procurement cycle time *in half*, processing cost by *one third*, and the cost of goods purchased by 5% to 50%. As of mid-99, GE was doing over $1 billion worth of Web-based business annually.[33]

We think that the terms frictionless and weightless are apt analogies here. Friction causes energy to be lost. Frictionless commerce saves energy. Similarly, the more weight an object has, the more energy it typically takes to manufacture and transport.

## ROYAL DUTCH/SHELL SCENARIO

Consider a "world in which new technologies, systems and lifestyles would deliver continuing improvements in energy efficiency so that average *per capita* consumption rises by only some 15% by 2060" even as the world sustained annual GDP growth of 3% (and population roughly doubles).[34] A techno-fantasy? No, that's one of two planning scenarios developed in the mid-1990s by Royal Dutch/Shell Group, the world's largest, publicly-traded oil company, widely viewed as a benchmark for strategic planning.[35]

Shell labels this scenario "Dematerialization." It is "driven by convergent and mutually enhancing developments in information technology, telecommunications, materials and biotechnology which in turn could have considerable potential to change social values and with them lifestyles. If this indeed happened, we would experience a transition phenomenon as profound as that brought about by the invention of the automobile and subsequent developments in individual mobility during this century."

In the dematerialization scenario, energy intensity (energy consumed per dollar of GDP) decreases 1.7% per year until 2030, and then 2% per year after that, a rate, Shell notes, "admittedly has only been seen for limited periods in the past." As difficult as this possibility may be to achieve, it is

worth noting, as the *Economist* magazine has written, "The only oil company to anticipate both 1973's oil-price boom and 1986's bust was Royal Dutch/Shell."[36]

So large drops in energy intensity in the coming years, driven in part by IT and the Internet Economy, are certainly imaginable.

## OUR SCENARIO

For the purposes of this paper, the scenario we are assuming is that, in the words of Chairman Greenspan, "something special has happened to the American economy" and the something special is IT and the Internet Economy. If there is a "New Economy," as so many have speculated, then we believe there is a New Energy Economy, and we will explore it here. A goal of the paper is to see whether plausible estimates for the impacts of the Internet would be sufficient to have a noticeable impact on U.S. energy intensity.

The key issues that need to be understood in more detail are

- How many standard economic activities can be made weightless and/or frictionless?
- Of those that can, what fraction will?
- How will business and consumer behavior change when they do?
- How will those changes affect energy consumption?

We can think of a great many that might to greater or lesser extents: commuting; shopping; information gathering for items ranging from homes to cars; banking and bill paying; education; conferencing; photography; inventories; construction of new retail stores and commercial office buildings; printing encyclopedias, catalogs, newspapers, phone books, and ultimately books; manufacturing software and CDs.

E-commerce experts have uncovered a great many unexpected opportunities for generating "Internet efficiency," which have begun saving some energy today and have the opportunity to save vast quantities of energy in the future. The Internet holds the potential to eliminate waste from needless overproduction or mistaken orders. Consider under-utilization: online auctions, popularized for the public through eBay, allow companies to hold auctions for excess capacity, including airline seats, empty space on trucks, manufacturing capacity, and such energy intensive goods as steel and paper.

After a discussion of recent trends affecting energy consumption, this paper will examine these issues and opportunities and discuss their possible impact on present and future energy consumption trends.

## II. TRENDS AFFECTING ENERGY INTENSITY

In the era of low-energy prices preceding the early 1970s, the energy efficiency of many household, transportation, and industrial technologies in United States improved little.[37] As a result, energy demand and gross domestic product (GDP) in United States grew in lockstep: a 3% increase in GDP meant nearly a 3% increase in energy demand. As Figure 1 shows, the energy intensity of the economy (energy consumed per dollar GDP) declined only very slowly from 1950 to the early 1970s. There was a widespread view in the country that this linkage was unchangeable, that energy was essential for economic growth. There was little recognition that energy efficiency could break that trend without sacrificing economic growth.

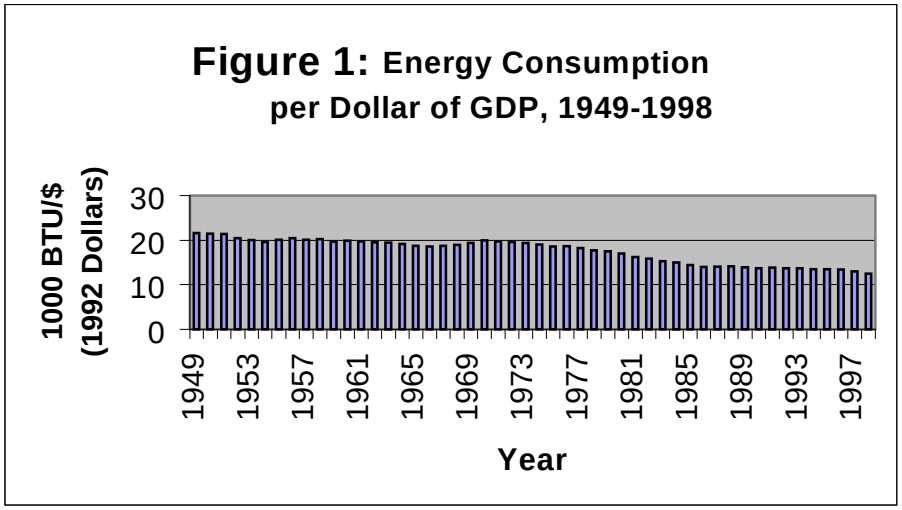
The inextricable connection between energy and economic growth came to abrupt end with the Arab oil embargo of 1973-1974. From 1973 to 1986, GDP grew 35% in real terms while the nation's consumption of primary energy remained frozen at about 74 quadrillion BTUs (or quads).[38] During this period, Americans bought more fuel-efficient cars and appliances, insulated and caulked their homes, and adjusted thermostats. Businesses retrofitted their buildings with more efficient heating and cooling equipment and installed energy management systems. Factories adopted more efficient manufacturing processes and purchased more efficient motors for conveyors, pumps, fans, and compressors. These investments in more efficient technologies were facilitated by higher energy prices and by federal and state policies that were enacted and implemented to promote energy efficiency.

Fully two thirds of the freeze in energy use during this period was due to increases in energy efficiency whereas one third was due to structural changes such as declines in energy-intensive industry and increases in the service sector. These efficiency improvements were caused by higher energy prices, government policies and programs, the availability of more efficient technologies, and other factors, such as behavioral changes resulting from concern about availability of energy and dependence on Persian Gulf oil. Through 1981, it has been estimated that higher prices might have been responsible for about two thirds of the energy savings. The Department of Energy estimates the country is saving $150-$200 billion annually as result of these improvements in efficiency.

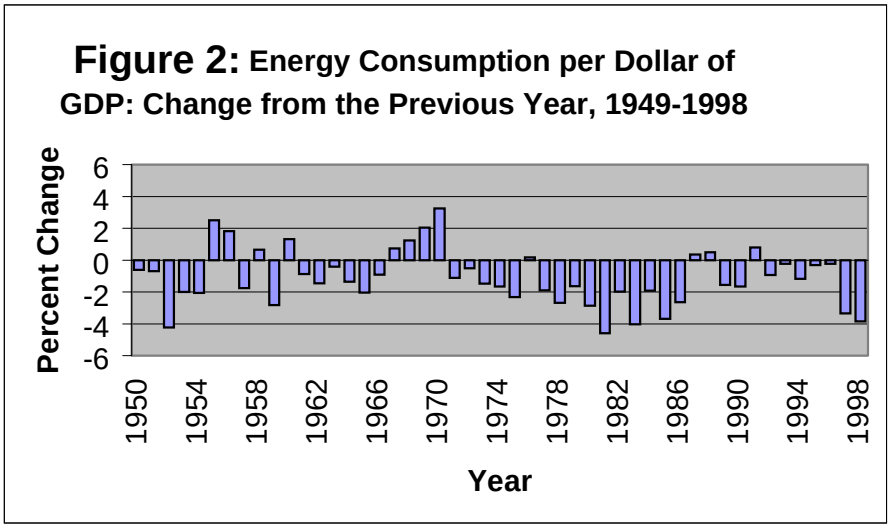
The gains in energy productivity achieved by United States during this period represent one of the great economic success stories of this century. The extent that the U.S. economy improved its energy productivity can be quantified by examining the relationship between total energy consumption and GDP. In 1970, nearly 20,000 BTU of energy were consumed for each (1992) dollar of GDP. By 1986, the energy intensity of the economy had dropped to 14,000 BTU of energy per (1992) dollar of GDP. As can be seen in Figure 2, the nation's energy intensity routinely declined by 2% per year during years from 1973 to 1986, and some years even declined by over 3%.

Starting in 1986, energy prices began a descent in real terms that has continued to the present, and government investments in energy R&D and deployment programs have declined. These trends have contributed to a growth in energy demand from 74 quads in 1986 to 94 quads in 1996. Because of the comparable growth in GDP over the same period, the energy intensity of the economy declined only slightly (under 1% per year) over the ten-year period.

[]




[The source for these two figures is the U.S. Energy Information Administration.[39]]




[These figures are not corrected for revisions to GDP calculations announced by the Department of Commerce in October. In Figure 2, that would add about -0.2% (negative two-tenths of a percent) to the percent changes from 1973 to 1986, and about -0.4% to the percentages from 1987 on.[40]]

The nation's energy intensity dropped 3.4% in 1997 and 3.9% in 1998—and the figures are closer to 4.0% for both years using the Commerce Department's recent revisions to GDP.[41] It is unprecedented for the U.S. economy to see such improvements in energy intensity during a period of low energy prices and relatively low public awareness of energy issues. The nation has had two years of economic growth totaling 8% (9% with recent revisions), but energy use is still just slightly over 94 quads, hardly different from its 1996 levels. While two years do not make a long-term trend, *already preliminary data suggest that energy intensity will likely drop by more than 2.0% in 1999* and that GHG emissions will continue to grow at a relatively slow pace.[42] The recent remarkable declines

in U.S. energy intensity have motivated us to think about what big changes might be happening in the U.S. economy that could be having such a big effect and whether those changes are likely to continue and possibly grow.

The EPA and Argonne National Laboratory have pursued a preliminary analysis to try to understand at a big picture level what is happening.[43] This analysis concluded that roughly one-third of the recent improvement in energy intensity is "structural." Structural gains traditionally occur when economic growth comes in sectors of the economy that are not particularly energy intensive, such as the IT-producing sector, which includes computer manufacturing as opposed to more energy-intensive sectors, such as the pulp and paper industry.

The remaining two thirds improvement comes from gains in the energy efficiency of all sectors. Energy efficiency gains may be divided into two categories. First, traditional energy efficiency occurs through the application of a variety of energy-saving measures, such as better lights and motors. Second, the economy itself can get more efficient in the use of all resources, through gains in total factor productivity. This might be called a gain in energy productivity or, when caused by IT and the Internet economy, we use the term *Internet efficiency*.

It is not our purpose here to explain in detail all of reasons for the sharp drop in energy intensity over the past two years. As can be seen from Figure 2, there is a great deal of year-to-year fluctuation in the change in energy intensity, which is due to a variety of factors.

Weather, for instance, can play a big role. In 1998, the country experienced both a very warm winter (which reduces the consumption of natural gas and other heating fuels) and one of the hottest summers on record (which increases the consumption of electricity for air conditioning). The reduction in heating has a bigger effect on total energy consumption than the increase in cooling, so the weather was responsible for perhaps 0.7% out of the 3.9% improvement in energy intensity in 1998.[44] If, however, global warming is occurring, then over time we should expect both warmer winters and warmer summers, which may positively impact U.S. energy intensity. The EIA announced in September that it "is adopting weather premises that reflect a three-decade long warming trend identified by the National Oceanographic and Atmospheric Administration." EIA notes that "Adopting the warming trend in place of long-term averages for the period October 1999 to September 2000 lowers total annual projected energy consumption by about 0.3 percent."[45]

Another possible factor is the rebound in federal investment in energy efficiency in the 1990s. Particularly significant was the launch and/or expansion in the mid-1990s of a variety of programs developed in partnership with business aimed at getting energy-efficient technologies quickly adopted by businesses and consumers. These programs were designed to have greater near-term impact than more traditional government programs aimed at long-term research and development. They were projected to have a significant impact by the late 1990s.

Also, the growth in the trade deficit in recent years is likely having an impact, though it is difficult to quantify. If, for instance, a manufacturer outsources an energy-intensive component of a product, that would represent a structural shift in the economy that improves our energy intensity. A sudden increase in steel imports, such as occurred in recent years, would also have an impact.

Unfortunately, the Energy Information Administration (EIA) requires a considerable amount of time to collect and analyze key data on energy consumption trends by sector (such as buildings and manufacturing), so it will be a few years before we have a detailed understanding of what is going on.

In any case, disentangling all of these factors is beyond the scope of this paper. Our interest here is in examining some key trends that may well be having an impact today and are likely to play an important role in the next decade. The impact of Information Technology and the Internet economy is the key trend we will focus on. But first, it is worth briefly discussing some important new trends related to energy efficiency and global warming that will also impact energy intensity.

## FUTURE TRENDS IN TRADITIONAL ENERGY EFFICIENCY

From 1987 through 1996, energy intensity in the U.S. economy improved at a low rate, under 1.0% per year. As noted earlier, there were a variety of causes, including the sharp drop both in energy prices and in federal efforts to reduce energy intensity (including the end of requirements for increased fuel efficiency gains in cars).

Yet energy technologies have continued to improve dramatically over the past decade and a half. In particular, the application of IT to traditional energy technologies has resulted in quantum improvements even in the two classical technologies that are responsible for most electricity consumption, lighting and motors. We have seen steady advances in solid-state electronic ballasts for running fluorescent lamps; they not only save considerable energy compared to magnetic ballasts, but also eliminate the annoying flicker and hum. Further, these ballasts can be run with sophisticated but low-cost controls, that allow them to automatically dim when there is more daylight. These lamps can now be controlled even at the desktop by remote controls or through a PC. Greater control over the workplace environment in general, and lighting in particular, has been linked to productivity increases.[46] Similarly, computer-controlled adjustable speed drives for motors can simultaneously reduce energy consumption and improve process control, achieving significant direct cost savings as well as productivity gains.[47] Even boilers and hot water heaters can cut energy consumption 25% or more through the installation of microprocessor-based controllers.[48] Also, a digital energy management control system (EMCS) can now continuously gather data about what is taking place in a building and how its equipment is operating, which can then be fed into a central computer that can be used to control the building and optimize its energy performance. Energy experts at Texas A&M have shown in two dozen Texas buildings that using such an approach can cut energy use 25% with an 18-month payback in buildings that have already received on upgrade with the latest energy-saving equipment.[49]

Some companies have instituted corporate wide policies to adopt these technologies, such as IBM and Johnson & Johnson. They have been able to sustain steady improvements in their corporate energy intensity (energy per dollar of output) of 4% per year and 3% per year respectively throughout the 1990s (IBM is discussed further in the next section). Though virtually every company could do what IBM and J&J have done, they are still the exceptions. *Fortune* magazine noted in 1998, "Only a third of U.S. manufacturers are seriously scrutinizing energy usage, where savings in five areas can move billions to the bottom line."[50] As energy became a much lower fraction of the cost of doing business in the mid-1980s (because of lower prices and a decade of successful investments in energy efficiency), businesses naturally reduced investments in energy-saving technologies. During the corporate downsizings of the early 1990s, many corporate energy staffs were sharply reduced or eliminated entirely. Thus for most of this period, most companies have lacked both the motivation and the management expertise to improve energy performance. Many companies, including some of our largest and most energy intensive, were making investments in energy-savings technologies only if they paid for themselves within about a year.

There had been a great deal of promise in the possibility that electric utilities would help their customers become more efficient because of regulations established in some states designed to encourage such action. These so-called demand-side management (DSM) programs began to grow in

impact in the early 1990s. But as the restructuring of the electric utility industry became more and more a reality throughout the country, the funding for such programs was cut back sharply. DSM spending for large utilities reached $2.7 billion in 1993, and has declined to $1.6 billion in 1997.[51] Electricity savings from such DSM peaked in 1996 at about nearly 62 billion kilowatt-hours (kWh), which is roughly 2% of all electricity sales that year, declined to 56 billion kWh in 1997, and were projected to decline again in 1998.[52] While reductions are likely to continue, DSM savings will not disappear entirely, since many states are setting aside public benefits funds to support traditional DSM activities as part of their utility restructuring legislation.

OUTSOURCING: A new trend, however, has emerged that is revolutionizing corporate energy efficiency investments. Companies are starting to outsource their power needs altogether. In March 1999, Ocean Spray announced a $100 million deal with the energy services division of Enron, a major natural gas and utility company based in Houston. Enron will use its own capital to improve lighting, heating, cooling and motors and to invest in cogeneration (the simultaneous generation of electricity and steam onsite, which is highly efficient). Ocean Spray will save millions of dollars in energy costs, have more reliable power and cut pollution, without putting up any of its own capital. In September, Owens Corning, the fiberglass insulation manufacturer, announced a similar $1 billion deal with Enron. Many other energy service companies are taking a similar approach. Pacific Gas and Electric (PG&E) Energy Services announced a deal last year with Ultramar Diamond Shamrock, to cut the oil refiner's energy costs by $440 million over the next seven years. Most of the savings would come from capital investments by PG&E in energy efficiency and cogeneration. Some companies, like Sempra Energy Solutions, have even gone so far as to finance, build, own and manage the entire energy system of a customer. For instance, Sempra did this for the energy system of a new animation campus of the entertainment company, DreamWorks SKG, including an onsite central plant for heating and air conditioning. DreamWorks pays a monthly lease fee for conditioned air that meets its specifications. This financial arrangement takes the cost of the energy system out of the capital budget, saving DreamWorks money it can use for making movies.

The potential impact of this trend is enormous. Companies like Ocean Spray, Owens Corning, Ultramar Diamond Shamrock, and DreamWorks would typically make investments in energy-efficient equipment only with a payback of a year or so. The energy companies they signed a long-term contract with, Enron, PG&E, and Sempra, however, will make much longer term investments, typically with a five- to seven-year payback, but sometimes as high ten years. This allows a great deal more energy efficiency to be achieved.

These energy outsourcing deals are quite new. Few engendered much investment in new capital before 1998. We believe that these deals will grow very rapidly in the next few years, and are likely to ultimately achieve savings well beyond that of DSM programs. This is particularly true for two reasons. First, traditional DSM often focused on retrofitting individual electricity-using components, whereas outsourcing encourages a whole systems approach to efficiency covering all fuels, an approach that can achieve deeper savings at lower cost. Second, traditional DSM did not in general encourage cogeneration, as the outsourcing deals do. And cogeneration combined with energy efficiency can cut the energy consumption of a building or factory by 40% or more in a period of just a few years.[53] If this scenario comes to pass, then energy outsourcing will have a major impact on improving the nation's energy intensity in the next decade.

CORPORATE CLIMATE COMMITMENTS: Another important trend begun in the last few years is for major corporations to make corporate-wide commitments to reduce their greenhouse gas emissions. This trend has accelerated since the industrialized nations of the world agreed in December 1997 in Kyoto, Japan to reduce greenhouse gas emissions below 1990 levels by 2008 to 2012. As the *Wall Street Journal* noted in an October article on the trend:

> In major corners of corporate America, it's suddenly becoming cool to fight global warming.
>
> Facing significant shifts in the politics and science of global warming, some of the nation's biggest companies are starting to count greenhouse gases and change business practices to achieve real cuts in emissions. Many of them are finding the exercise is green in more ways than one: Reducing global warming can lead to energy-cost savings.[54]

For instance, in September, DuPont, one of the biggest energy users in the United States, pledged that by 2010 they would reduce greenhouse gas emissions 65% compared to 1990 levels. While two thirds of those savings will come from reducing process-related greenhouse gases, the rest will come from energy. DuPont pledged to keep energy consumption flat from 1999 to 2010 even as the company grows, and to purchase 10% renewable energy in 2010. Kodak announced in 1999 that they would reduce their greenhouse gas emissions 20% by 2004.

The Center for Energy and Climate Solutions is working with World Wildlife Fund and a number of companies to generate similar commitments as part of the "Climate Savers" program. We anticipate that over the next several months, and in the years to come, a number of major companies will pledge to cut greenhouse gas emissions by making major investments in energy-efficiency (as well as cogeneration and renewable energy). [Visit cool-companies.org at the end of January for the first round of pledges.]

It may well be that these two trends—energy outsourcing and corporate climate commitments—combine. The Center is working with a major energy service company to demonstrate that virtually any Fortune 500 company can make an outsourcing deal to reduce its energy bill, its energy intensity, and its greenhouse gas emissions, without putting up any of its own capital. Should concern over global warming continue to grow, this type of deal may become commonplace.

## INTERNET EFFICIENCY

While these two trends will clearly be important in the future, they are at best a small part of the remarkable gains in energy intensity in the last two years. Since at least one third of the gain in energy intensity in the past two years comes from structural changes in the economy, one obvious place to look to is any segment of the economy that has been rapidly growing and is not very energy intensive. That describes the IT-producing industries, which includes computers, semiconductors, telephone equipment, software, programming, and computer services. While semiconductor manufacturing is moderately energy intensive, it is far less so than that of the process industries—such as pulp and paper, steel, and chemicals—which account for most industrial energy consumption. The other IT-producing industries are light manufacturing and services, which are not very energy intensive at all.

As noted earlier, the Commerce Department said in July that those IT-producing industries were responsible for 28% to 29% of the contribution to real growth during 1997 and 1998. One recent analysis by EPA suggests that continued rapid growth of the IT-producing industries may decrease the demand for energy compared to economic projections that do not properly reflect such changes in the economy, while increasing overall U.S. economic growth.[55] Based upon a "first approximation" of the potential impact of structural changes driven by double-digit growth of the IT-producing industries, EPA economist Skip Laitner indicates that *mainstream projections of U.S. energy and carbon dioxide emissions in the year 2010 may be overestimated by up to 5 quads and 300 million metric tons of carbon dioxide*. This is about 5% of the nation's projected energy use and GHG emissions.

Further, the EPA analysis does not attempt to incorporate everything that is typically included in a definition of the Internet economy: all of the additional sales over the Internet during those two years by traditional industries that were taking advantage of the output of these IT-producing industries and creating Web sites, intranets, and extranets.[56] Moreover, while the IT-producing industries are likely to keep producing a significant though probably relatively steady share of the nation's real growth, the additional sales spawned by the rest of the Internet Economy are growing at an almost exponential rate.

The two together are having a disproportionate impact on the economy as a whole, according to early analyses that attempt to count everything, such as that by the University of Texas discussed in the Introduction. Indeed, the impact of the entire Internet Economy on energy intensity almost certainly goes beyond the purely structural gain of having growth from industries that are not very energy intensive. Recent work suggests that the IT-producing industries and the Internet economy spawned by those industries, may be creating a so-called "New Economy," which can sustain higher levels of productivity growth than in the past two decades.

A September 1999 report by the influential consulting company, Macroeconomic Advisers, LLC, *Productivity and Potential GDP in the 'New" US Economy*, noted

> From 1973, when postwar productivity growth slowed dramatically, through 1995, output per hour in the private nonfarm business sector grew just 1.0% per year on average. However, from 1995 through 1998 that rose to 1.9% and, over last four quarters, productivity expanded at a 2.9% pace, rivaling rates last enjoyed consistently during the 1950s and 1960s. This acceleration is unusual so deep into a business expansion. If even part of it is sustained, the implications for the U.S. economy are far-reaching.[57]

In spring 1999, Macroeconomic Advisers "undertook a comprehensive and remarkably successful effort to explain the recent episode within a single, cohesive econometric equation for productivity growth over the entire period since World War II." Here is their explanation for the recent 2.9% growth in "potential productivity," which they define as "the level of productivity consistent with sustainable utilization rates of capital and labor":

> Nine tenths of a percentage point of the *explained* acceleration in potential productivity since 1994 are attributable to an increase in the *rate of technical advance*. Another 1 percentage point is attributable to an increase in the rate of *capital deepening*. The remaining 0.6 percentage point is an *unexplained residual*.

What is capital deepening? Federal Reserve Board Chairman Alan Greenspan explained the term to Congress in June:

> But the recent years' remarkable surge in the availability of real-time information has enabled business management to remove large swaths of inventory safety stocks and worker redundancies, and has armed firms with detailed data to fine-tune product specifications to most individual customer needs….
>
> For example, since 1995 output per labor work-hour in the non-farm business sector—our standard measure of productivity—has grown at an annual rate of about 2 percent. Approximately one third of that expansion appears to be attributable to output growth in excess of the combined growth of inputs….

> As lead times have declined, a consequence of newer technologies, firms' forecasts of future requirements have become somewhat less clouded, and the desired amount of lead-time insurance in the form of a reserve stock of capital has been reduced. In addition to shortening lead-times, technology has increased the flexibility of capital goods and production processes to meet changes in the demand for product characteristics and the composition of output. This flexibility allows firms to deal more effectively with evolving market conditions with *less physical capital* than had been necessary in the past.
>
> Taken together, reductions in the amount of spare capital and increases in capital flexibility result in a saving of resources that, in the aggregate, is reflected in higher levels of productivity. The newer technologies and foreshortened lead-times have, thus, apparently made capital investment distinctly more profitable, *enabling firms to substitute capital for labor and other inputs far more productively than they could have a decade or two ago.* Capital, as economists like to say, has deepened significantly since 1995. The surge in investment not only has restrained costs, it has also increased industrial capacity faster than the rise in factory output.[58]

So, capital deepening allows economic growth without as much increased resource use as typically occurs. This is a growing trend. A September 1999 PricewaterhouseCoopers survey of 449 CEOs concluded, "America's fastest growing companies are in the midst of an offensive to use less capital in their business and, in the process, to improve their financial productivity over the next 12 months."[59] Most of their strategies center around e-business applications. In the coming sections, we will see how the Internet economy is shortening lead times, improving forecasting, reducing inventories, and improving capacity—and discuss why these trends will probably accelerate throughout the next decade.

The central conclusion of study by Macroeconomic Advisers is that capital deepening is likely to continue in the near future and productivity growth could remain high for the next decade. Yet, if the overall productivity of the U.S. economy is significantly increasing, why should not the energy productivity of the U.S. economy also significantly increase? Such gains could be undermined if the Internet were itself a huge user of energy, which it does not appear to be (see below). They could also be undermined if the Internet drove new behavior patterns that led to increased energy use by certain sectors. In the rest of this study, however, we will see how the Internet economy has certain special attributes, such as the ability to foster dematerialization, that may well increase energy productivity even faster than average productivity. And any significant gains in traditional energy efficiency through the widespread adoption of energy outsourcing deals and corporate greenhouse gas mitigation actions will only spur further gains in energy intensity.

## THE INTERNET'S OWN USE OF ENERGY

In May 1999, *Forbes* magazine published an article arguing that the Internet has become a major energy *consumer* because it supposedly requires a great deal of electricity to run the computers and other pieces of hardware that make the Internet economy work.[60] The authors of the article appear to have significantly overestimated the energy consumption of most critical pieces of equipment, according to a number of leading energy analysts.[61]

Scientists at Lawrence Berkeley National Laboratory (LBNL) recently examined in detail the numbers underlying the *Forbes* analysis.[62] *LBNL found that the estimates of the electricity used by the Internet were high by a factor of eight.* Large overestimates were found in every category, including the calculations of how much energy was used by the major dot-com companies; by the

nation's web servers; by telephone central offices; by routers for the Internet and local networks; and by PCs used by businesses and residences.

The *Forbes* authors assumed, for instance, that a "typical computer and its peripherals require about 1,000 watts of power." In fact, the average PC and monitor use about 150 watts of power; this dips to 50 watts or less in energy-saving mode. Printers and peripherals tend to be spread over a great many users and don't increase this average very much. Laptop computers, a key growth segment, are particularly low energy users; some new laptops use under 30 watts. Moreover, computers are getting more energy-efficient every year because of steady improvements in technology driven in part by the growing market for portable equipment (and by the IT sector's desire to reduce its environmental impact).[63] For instance, Intel's Instantly Available Personal Computer "is designed to improve the capacity of a PC to stay connected to information networks while providing much more effective management of PC energy use and reducing the lengthy boot-up times PCs currently need."[64] It consumes "less than 5 watts of power while maintaining connections to the outside world." Similarly, new flat screens typically use about a quarter of the energy of traditional video display terminals with cathode ray tubes. As far back as mid-1997, one computer industry observer quoted in a Harvard Business School case study said, "the corporate PC business is becoming a replacement business."[65] Since new PCs tend to be more efficient than the ones they replace, many if not most companies are unlikely to see corporate energy consumption from computers rise sharply. For some it may even decline: Companies like Pratt & Whitney have instituted programs to cut the energy consumption of their computer systems (see case study at www.cool-companies.org).

Indeed, we believe that the argument of the *Forbes'* authors is almost completely backwards. We suspect that one of the reasons why energy intensity declined so slowly from 1987 through 1996 is that businesses in particular purchased a great many computers and other IT equipment that consume electricity, yet generated little accompanying productivity gains to offset that increased energy use. The Internet, however, is the killer application for PCs, in terms of reducing corporate energy intensity, especially for manufacturers, because it deepens capital, dematerializes, and the like. The incremental energy consumption from shifting PCs from traditional uses toward the Internet is apparently modest compared to its overall benefit. Put another way, as the 1999 OECD report explained, "One of the drivers of the Internet is the fact that it exploits all of the existing [information and communications technology] infrastructure, so that it can be used with a minimal amount of new investment."[66]

The *Forbes* piece claimed, for instance, that from 1996 to 1997, the increase in electricity consumed by all computers used for the Internet represented more than 1.5% of all U.S. electricity consumed that year. Yet total electricity consumption for all purposes grew slightly less than 1.4% from 1996 and 1997. That would imply the entire rest of the economy had no growth in electricity consumption even though economic growth was nearly 4% (4.5% with the recent Commerce Department revisions). That would be a startling improvement in electricity intensity. And while we believe that the Internet reduces energy intensity, we don't believe it has quite that dramatic an effect, so it is far more likely that the *Forbes* analysis is flawed.

We have no doubt that computers and the Internet will lead to more home electricity consumption. This is a long-standing trend, as homes have for some time been getting bigger and more stocked with electronic equipment. But the question is, if people spend *more* time on the Internet, *what are they spending less time doing*? Some will be watching television less; others reading newspapers less; some may be printing individual items of interest to them rather than receiving entire printed catalogs or directories in the mail; others will be working at home rather than at a commercial office building; and, potentially, some may be not be driving to work, to the grocery store, to their bank, and to malls

as much as before. These are all activities that would normally consume a great deal of energy and their potential displacement by home Internet use is the subject of a good deal of the rest of the report.

Also, although it is not a major factor today, we believe that in the very near future the Internet will itself be used to save energy directly. For instance, the computer-controlled energy management control systems referred to above, can be accessed and run over the Internet. We know of one major energy service company that is pursuing the installation of digital EMCS's in the buildings they manage, so they can operate them over the Internet very efficiently and at low cost; the Internet is already being used in Singapore for this purpose.[67] Similarly, many utilities have begun exploring Internet-based home energy management systems, which would give individual homeowners more control and feedback over their home energy use, or the ability to have an outside energy company or expert software system optimize their energy consumption. This could lead to significant energy savings in homes. Early trials of remote controlled home energy management systems suggest the savings in energy bills could be as high as 10%.[68] Finally, a number of groups are raising money to launch e-commerce Web sites that will allow homeowners to easily get information on energy savings home appliances and strategies, and to aggregate purchases in order to lower the price of those appliances. One of the barriers to greater penetration of energy-efficient technologies in homes is a high initial cost, even for technologies that pay for themselves in energy savings in a few years.

# III. THE INTERNET AND THE BUILDINGS SECTOR

The buildings sector is responsible for about one-third of U.S. energy consumption, roughly evenly divided between commercial buildings and residential buildings. This section will explore the ways in which the Internet Economy will affect building energy consumption.

For tangible goods, business-to-consumer e-commerce can replace retail stores with Web sites and warehouses. For intangible goods, it may replace facilities like banks entirely. Business-to-business e-commerce is projected to dramatically reduce inventories. If the Internet is increasing the percentage of workers who work at home, particularly full-time, it will substitute incremental residential energy consumption for probably much larger commercial energy consumption.

## BUSINESS-TO-CONSUMER E-COMMERCE

The 1999 OECD report on electronic commerce listed many of the ways that it increases economic efficiency by reducing the cost of owning and operating a physical establishment:

> In general, it is less expensive to maintain a cyber-storefront than a physical one because it is always "open," has a global market, and has fewer variable costs. For exclusively e-commerce merchants who maintain one "store" instead of many, duplicate inventory costs are eliminated.[69]

Further savings in inventory can be achieved by using the Internet to foster “just-in-time” inventory control (discussed below).

Another advantage of the Internet for retailing comes during Christmas. For many retailers, the last two months of the year represents a third of their sales (and even more of their profits), according to Craig Schmidt, vice president of real estate research for Merrill Lynch.[70] And Christmas is a time when people are more frustrated with the crowds in traditional stores, and, in many cases, were planning to have their gift purchases shipped to friends and family. The Internet is thus well designed to benefit from such surges, yet doesn’t have to maintain expensive real estate for the remaining 10 months of the year where profitability for many traditional retailers is low.

Probably the best known and most widely studied consumer e-commerce activity is book purchasing, popularized first by Amazon.com. Consider these statistics from a 1998 case study on Amazon.com by the J.L. Kellogg Graduate School of Management of Northwestern University:

Comparison of Operating Models of Land-based Versus Online Bookstore[71]

| | Traditional Book Superstore | Online Bookstore (Amazon.com) |
|---|---|---|
| Titles per Store | 175,000 | 2,500,000 |
| Revenue per Operating Employe | $100,000 | $300,000 |
| Annual Inventory Turnover | 2-3X | 40-60X |
| Sales per square foot | $250 | $2,000 |
| Rent per sq. ft. | $20 | $8 |
| Energy costs per sq. ft.[72] | $1.10 | $0.56 |
| Energy costs per $100 of sales | $0.44 | $0.03 |

*So a plausible estimate for the ratio of commercial building energy consumption per book sold for traditional stores versus online stores is 16 to 1.*[73] This is particularly remarkable given that a very good energy efficiency retrofit can cut building energy consumption 30% to 50% with a payback of a few years.[74] So Internet energy efficiency appears to be a very powerful tool for improving energy intensity. (The more complicated issue of the net impact of e-commerce on the energy used to transport the books to the consumer will be discussed in Section 5.)

While this 16-to-1 ratio is a remarkable ratio, it is comparable to other estimates. For instance, the president of one Internet seller of used books based in Sparks, Nevada, was quoted in July as saying, "It costs a dealer $1 to keep a book in a store. In Sparks, it costs a penny a month."[75] Similarly, chumbo.com, an online software retailer, estimates a cost of 50 cents to either carry a software CD or burn it on demand, whereas it costs the average steel and concrete retailer $43 to carry the same program on its shelf, according to *Wired* magazine.[76]

E-commerce is so new that many online retailers have not yet resolved the issue of whether they will build and use their own warehouses or will be able to rely on the warehouses of existing distributors or even the manufacturers whose product they are selling. A number of e-commerce companies are building new warehouses.[77] On the other hand, some distributors, like Ingram in the book industry, have responded to the e-commerce challenge. In 1998, Ingram announced, "it would introduce a new 'drop-shipping' service to reduce online booksellers' operating costs. Ingram would offer its customers the option of shipping orders directly to consumers. Drop-shipping would cost more than the current wholesale shipping service, but would still be cheaper than repackaging and reshipping."[78] And as will be seen in the business-to-business e-commerce discussion below, some companies, like Home Depot, have dramatically reduced the need for the middleman warehouse entirely, which is even better from an energy perspective. Indeed, the Internet allows the consumer to bypass a retailer entirely. For instance, the *New York Times* reported in October that some 30% of the PCs bought by U.S. households in the last six months were purchased directly from the manufacturer.[79]

Besides retailing, most aspects of the service sector will be affected by e-commerce. Consider hotels. Tad Smith, Senior Vice President for E-Commerce at Starwood Hotels & Resorts (which includes Sheraton and Westin hotels) says:

> The Internet represents the most powerful force known for maximizing the utilization of hotel rooms. Whether through one-to-one collaborative filtering techniques, auctions, email-based direct marketing, pricing optimizers, or any other new product, there will be more heads in beds. And that means less waste and greater efficiency.[80]

We will briefly explore two services that currently operate a great many buildings: banks and post offices.

ONLINE BANKING: The Internet is likely to significantly affect banking and other financial services, which include stock trading, insurance, and provision of financial information. The following chart from a 1998 Department of Commerce report shows the potential savings just in the area of bill payment:[81]

**Online Bill Payment Can Save Billions of Dollars**

**(cost to process each bill)**

| | Today | Online |
|---|---|---|
| Cost to biller | $1.65 - $2.70 | $0.60 - $1.00 |
| Cost to customer | $0.42 | $0 |
| Cost to bank | $0.15-$0.20 | $0.05-$0.10 |
| U.S. annual cost* | $38 B - $57 B | $11 B - $18 B |

**Potential savings: $19 B - $46 B**

*Total U.S. annual cost is determined by multiplying the processing cost by 17 billion checks a year.

As the Commerce Department report concluded, "Using the Internet for bill presentment and payment could dramatically reduce the amount of paper-based processing, resulting in a potential savings of up to $19 to $46 billion each year."

According to research published by International Data Corporation (IDC) in June, "There were nearly 6.6 million households banking online in United States alone in 1998." IDC projects that number will increase to more than 32 million by 2003.[82]

For consumers, the benefits include "convenience of day or night access," "getting up-to-date information" and ability to "balance accounts more easily." Wells Fargo, one of the country's largest banks, has also found benefits from its move to online banking. For instance, "Wells has been able to keep online customers at higher rates than other customers." Wells sees benefits from real-time response to its new product offerings and from one-to-one marketing to individual customers. Perhaps most important, "As its customers move from high-cost channels like the branch to low-cost channels like the Internet, Wells expects to recognize significant savings per transaction." Wells expects to have more than one million online customers by the end of 2000.[83]

Finland's banks are leaders in the use of electronic payment systems and thus offer a "rough indication of what may happen to financial services in the OECD area." From 1984 to 1996, Finland saw a 54% annual growth in productivity (measured by transactions per employee) and a 3.5% annual

decline in employment, resulting in a cut of more than a third of the jobs during that time period.[84] The OECD report notes that this one-third figure may be a good estimate for the number of U.S. bank branches closing in the near future.

The benefit of not having buildings is being touted by some online banks. One Internet bank took out a full-page ad in the *Wall Street Journal* in August that blared in large type: "Sure, we could build expensive branches (but, we figured you'd just rather have the money)." The ad boasted "Lower overhead, higher rates. Any questions?"[85]

POSTAL DELIVERY: In 1998, then Postmaster General Marvin Runyan estimated that business-to-business first-class mail dropped by over a third in the late 1990s because of email.[86] In April 1998, he told the National Press Club, "Research tells us that within the next 10 years, the infrastructure, security, and public acceptance issues that now limit electronic diversion (of communications currently sent as first class mail) will be solved."[87] It seems likely that online bill payment is going to grow because of the cost savings and convenience. For that reason, *The Industry Standard*, a magazine devoted to the Internet economy, opined in September: "Be glad you're not in the envelope business."[88] As more and more Americans gain access to the Internet, and email and online billing and grow, the threat to postal delivery will increase.

Postmaster General William Henderson told Congress in October that the Post Office's "market research suggests that first-class mail volumes may actually decline over the next five years" because of the growth of electronic transactions. He testified that of the Post Office's $62 billion in revenues, "We believe nearly $17 billion is at risk."[89] Testimony from the U.S. General Accounting Office at the same hearing noted that "although the Service's mail volume increased in the 1990s to record levels, the rate of growth has slowed." A GAO study concluded that first-class mail service will peak in 2002 and decline steadily by 2.5% every year until 2008. As more people go online and become familiar with email, the demand for ordinary letter delivery will drop sharply.[90] The Postal Service "might have to close some of its 38,000 post offices or reduce hours."[91]

Moreover, as we will see in the discussion in the next section on dematerialization, a number of other mainstays of the postal delivery business will be threatened. Catalogs may be the first to see a decline; Merrill Lynch expects them to suffer considerably as online retail sales grow.[92] Direct (i.e., junk) mail is also going to suffer as advertising increasingly moves online, though that may occur more slowly than the shift away from catalogs. Forrester Research projects that "Over the next five years, the Internet will siphon $27 billion—or 10% of all US ad spending—away from traditional media." They project that direct mail may lose up to 18 percent of its revenue by 2004.[93] Ultimately, magazine sales are also likely to peak and decline in the next decade. Greeting cards, too, may suffer. In September 1999, the online marketing research firm, Greenfield Online reported that "13 percent [of consumers on the Internet] plan to buy cards online and most will avoid writer's cramp by sending them electronically."[94]

It is too soon to say whether post offices will see a decline, or will be able to shift their mission. They might be able to turn into central warehousing and load consolidation centers. As discussed in Section 5, this would avoid the problem of numerous delivery trucks coming to the same address, but in that arena they are likely to face tough competition from UPS and other delivery firms, both new and emerging. If the U.S. Post Office doesn't develop a successful Internet strategy, the impact on energy consumption could be large, since the organization has 36,000 local post offices and 200,000 vehicles.[95]

## IMPACT

Is business-to-consumer e-commerce going to have a significant impact on retail building usage? Many think it will. For instance, John Quelch, dean of the London School of Business, told the *Harvard Business Review* this summer, that even if the Internet accounts for just an average of 5% of retail sales across all categories, "that shift will still create tremendous pressure on physical retailers, particular in the United States."[96] He notes:

> The United States has more square meters of retail space per capita than any other developed country in the world even adjusting for purchasing power. Essentially, the United States is "overstored." Space is more readily available there [in the U.S.], so stores tend to be larger. Increased and sustained use of online shopping will spawn more intense competition among physical retailers, and some stores will close.

A March 1999 study by Merrill Lynch on "Internet's Potential Impact on Retail Real Estate," concluded, "the Internet tends to disperse and decentralize human activity, while the value of real estate stems from the economy's need to concentrate and centralize human activity. Thus, the Internet will tend to 'cannibalize' retail sales away from store-based retailers, thereby reducing the underlying value of retail real estate."[97] One factor that will slow this trend somewhat is that Merrill Lynch anticipates that perhaps 40% of the growth in Internet sales of goods will come at the expense of catalog shopping.

Because of the rush to invest in Internet-related companies, retail real estate investment trust (REITs) are already having difficulty raising capital, according to Craig Schmidt. Schmidt says, "I don't have a meeting today about a real estate company where the Internet doesn't come up."[98]

It appears we've already begun to see an impact in software, which is increasingly being sold and even delivered through the Internet. According to MIT's 1999 "Frictionless Commerce" study:

> The software market provides even more striking evidence that consumers are switching channels…. By the beginning of our sample in February 1998 we had a difficult time finding software stores who sold a wide selection of software titles exclusively through conventional outlets and had to abandon our plans to include this product category in the study. Indeed, several industry commentators, using Egghead Software's January 1998 decision to close its conventional outlets, have argued that the presence of the Internet distribution channel has severely hurt the viability of conventional software outlets. For example, Chris Stevens of Aberdeen Group has been quoted as saying "At some point, you'd have to be an idiot to go down the street to [a conventional retailer] to buy software."[99]

Bookstores are next. Albert Greco, a Fordham University business professor who studies book retailing says that the market for books is barely expanding. Greco has undertaken a five-year statistical outlook on the book industry, and his preliminary findings show that business will expand only enough to keep up with inflation. "We're not going to have significantly more books sold," Greco told *Wired* magazine in June. The growth of online retailers, in other words, "is going to be a cannibalization" of brick-and-mortar stores.[100] Similarly, Danielle Fox, a J.P Morgan analyst who covers book retailing, told *Fortune* magazine in June, "early on, we thought that online sales could be incremental. But now the industry data suggest that online sales are coming at the expense of someone else's market share."[101]

*Fortune* noted that Amazon's sales already appear to having an impact: "Analysts had expected Barnes & Noble to add 50 new stores last year and another 55 this year; instead, just 37 were added in

1998, with another 30 promised for 1999."[102] Some conventional book retailers have attributed declines in book sales to Internet competition; others have identified the Internet as the reason they went out of business.[103] Craig Schmidt says that he's beginning to see a reduction of bookstores in smaller mall stores. Waldenbooks is scaling back expansion plans. This trend is likely to continue, and even accelerate in the coming decade, if electronic books prove as successful as some believe (see next section).

Mark Borsuk, Executive Director of the Real Estate Transformation Group, believes that in the next couple of years, "there is going to be a financial crisis for one or more traditional retailers."[104] Borsuk cites a PricewaterhouseCoopers analysis that "found that a 5% decline in sales can lower store profits by 20%. A sales shift of 10 percent can cause profits to plunge by 40 percent."[105] In most retail categories, Internet retails sales are still quite small. Total retail sales over the Internet were estimated in 1998 to be only 0.5% of total retail sales, though Internet retail sales clearly represent a much higher percentage of *growth* in retail sales. The most recent Forrester Research projections are for online retails sales in the United States to hit $185 billion in 2004, a remarkable 7% of total retail sales.[106] This could be a quarter of all the growth in retail sales during the next five years, and a much larger fraction for certain categories. Borsuk has developed a "space reduction timeline" for key retail categories. He sees books, music, and computers being hit first, in 1999; then consumer electronics and toys in 2000; drugs, grocery, and office supplies in 2001; and sporting goods, video, and pet stores in 2002.[107]

The great unknown question at this point is whether the Internet will make possible a critical mass of activities that fundamentally change the buying behavior of a significant portion of the American public. In short, will people ultimately go to malls less often? After all, one of the original motivations behind shopping malls, and one of their reasons for success, was an understanding "that consumers did not want to stop in several different places to run all their errands," in the words of Ragnar Nilsson, chief information officer of Europe's biggest department-store chain.[108]

What will happen when a large number of people can do their banking, a variety of different kinds of retail shopping, comparison shopping, grocery shopping, and the like on the Internet? The mall shopping experience is far from an ideal one for many people, particularly during the holiday crush, a key time for retail profitability. Because this could have a large potential impact on individual transportation, which is very energy intensive, this question will be discussed at greater length in Section 5. As for the impact on real estate, Schmidt gives as an example Chicago, which has about three dozen malls. He suspects that the Internet may ultimately lead to 6 to 8 of those malls no longer being fashionable, leading merchants to band into fewer malls.

What is the ultimate impact likely to be? The 1999 OECD report on the impact of e-commerce did a "rough estimate" of the potential "economy-wide efficiency gains" from a "business-to-consumer scenario" where e-commerce replaced some traditional wholesale and retail trade:

> Based on an input-output model, electronic commerce was assumed to reduce total wholesale and retail trade activity for consumer expenditures by 25 percent.... It was assumed that this reduction would lead to a decline in the use (cost) of buildings and related services (construction, real estate, utilities) by 50 percent, or a 12.5 percent decline in total for retail and wholesale trade. The smaller size of the wholesale and retail sector would lead to less use of labor and capital by the sectors both of which were assumed to decline by 30 percent for these services, or 7.5 percent for the total retail and wholesale sectors. The partial equilibrium resulting from these changes in cost leads to a reduction in aggregate distribution cost of about [5.2 percent for the United States] and in total economy-wide cost by about [0.7

> percent for the United States]. While small, this is still a considerable gain, since a reduction in these costs is a rough proxy for productivity gains [total factor productivity].[109]

It is interesting that so much of the cost savings in this estimate are in the energy area: construction and utilities. So, if total economy-wide cost is reduced of the order of 0.7% from business-to-consumer e-commerce, then it seems plausible to estimate a concomitant reduction in energy costs of the same fraction. That would mean energy cost savings of $4 to $5 billion, most of which would be in the commercial buildings sector and manufacturing sector (i.e. construction).[110] *A 12.5% decline in the use of retail buildings alone represents about 1.5 billion square feet of commercial building space no longer needed.*[111] Moreover, though speculative, these numbers may even be conservative, since, as we have seen, the reduction in utilities and other building costs may be much greater than 50 percent (a factor of two); the reduction may in some cases be greater than 90 percent (a factor of ten). In any case, even a 0.7% "Internet energy efficiency" gain, if anywhere close to being realizable, is huge. If realized over a seven-year period, for instance, it would by itself improve energy intensity an additional 0.1% per annum.

The OECD report notes, "Given that the cost savings due to business-to-business e-commerce are significant and the business-to-business segment represents a much larger portion of the overall total, these estimates based on a business-to-consumer scenario are conservative." Let's examine the business-to-business segment, which is projected to be at least five times the size of the business-to-consumer segment and thus is likely to have a far greater impact on energy intensity.

## BUSINESS-TO-BUSINESS E-COMMERCE

Some estimates for business-to-business e-commerce project it to exceed $1 trillion in 2003. As in many areas of e-commerce, those numbers are anything but definitive. A range of estimates from five different market research firms for what business-to-business e-commerce was even in 1997 varies by a factor of five. Projections for 2001 range from $88 billion to $499 billion. Whatever the number is, it seems clear that it is larger than business-to-consumer e-commerce and growing rapidly.[112]

Most of its impact on energy use likely will come in reducing manufacturing energy intensity, from the need for less building construction to better capacity utilization to e-materialization of paper. But significant savings are likely to be generated from companies using the Internet for supply chain management, thereby reducing inventory warehousing. The potential savings are large given that it has been estimated that 10 cents of every dollar spent in the nation goes toward moving and warehousing products.[113]

For instance, Home Depot uses information technology and the Web throughout its supply chain to largely bypass the warehouse. As *Informationweek* reported:

> The Atlanta-based building supplies retailer now moves 85% of its merchandise--nearly all of its domestic goods--directly from the manufacturer to the storefront. Product no longer languishes in warehouses, saving both suppliers and Home Depot money. "We're treating each of our stores as if it were a distribution center," says CIO Ron Griffin. Because of Home Depot's high volume--its stores average $44 million in sales and 5-1/2 full inventory turns a year--the products frequently ship in full truckloads, making the system even more cost-effective.[114]

The OECD has noted, "the general tightening of supply chains as business-to-business e-commerce becomes more pervasive is likely to have a significant effect on inventories and associated cost."

Ford Motor Company has deployed an intranet that connects 120,000 workstations at offices and factories around the world. Paul Blumberg, director of product development, told *Fortune* magazine in 1998 that sharing such information widely has helped the company cut the time it takes to get new models into full production from about 36 months down to 24 months. CIO Bud Matheisel says that while in 1996 it took seven weeks for customers to get their new Mustang delivered from the plant to the dealer, by 1998 that was down to slightly over two weeks. The company's goal is to manufacture most of its cars and trucks on an "on demand," basis, delivering vehicles less than two weeks after the order. That would save the company billions of dollars in inventory and fixed costs.[115]

This trend may merge with the growing popularity of websites that allow comparison shopping and purchasing of automobiles (see Section 5). That would allow automakers like Ford to sell cars with far fewer and/or smaller retail establishments (i.e. dealerships).

In the Mid-1990s, the Automotive Industry Automation Group (AIAG) tested its Manufacturing Assembly Pilot (MAP) program, which integrates an electronic data interchange system with e-commerce for automakers and their suppliers. [116] The results of the pilot included a 58% reduction in lead times, a 24% improvement in inventory levels, and a 75% reduction in error rates. The AIAG concluded, "This project proved that industry-wide use of electronic commerce (EC) technologies to improve communication throughout a multi-level supply chain could save the automotive industry an estimated $1 billion per year."

Toyota announced in August it is using a next-generation just-in-time system to allow it to produce a car within five days of receiving a custom order in North America.[117] Toyota is using an advanced computer-based system to create a "virtual production line" two weeks in advance of actual production. The system determines how many of which parts are required and what time—at every point on the production line—which are then almost instantly turned into provisional orders for the plant's 300 suppliers. Real Tanugay, a vice president for manufacturing at Toyota, said the system is cutting in-house inventories by 28% and storage requirements in the plant by 37%, freeing space for manufacturing.

The freeing up of inventory space for manufacturing may have a big impact on energy use in buildings, since the ultimate potential of the Internet to reduce inventories is enormous. As explained in the 1999 OECD report on electronic commerce:

> A key factor in reducing the costs of inventories is improving the ability to forecast demand more accurately. Electronic commerce merchants who allow consumers to customize their order or select from a wide variety of choices obtain valuable information on customer preferences. They should improve their ability to forecast demand. In a traditional store, a consumer might buy a computer with unwanted features or lacking certain features because that model was available. In such a situation, the merchant is ignorant of the consumer's true preferences. The electronic commerce merchant who offers a "built-to-order" computer, instead, knows exactly what consumers prefer and can adjust the product line accordingly. In addition, the links that electronic commerce provides along the supply-chain make it possible to pass this information on to partners, thereby lowering their costs and probably the overall price.[118]

The practice of having companies work together for better forecasting and restocking is called Collaborative Planning Forecasting Replenishment (CPFR). *Ernst & Young has estimated that CPFR could lead to an inventory reduction of $250 billion to $350 billion across the economy, roughly a 25% to 35% cut in finished goods inventory across the supply chain.* IBM is touting projected

reductions in inventories from e-commerce solutions as high as 50% for some of its customers, such as Robinson Brick.[119]

Federal Express (FDX) is working to go even further and "enable some companies to dispense with warehouses altogether."[120] Consider how FDX is teaming with Cisco Systems Cisco Systems, the multi-billion dollar company that sells routers, switches, and other network interconnect devices, as described in a November *Wall Street Journal* article:

> FDX is scheduled to begin coordinating all of Cisco's shipping over the next two years—and in the following three years, gradually eliminate virtually all of the company's warehousing.
>
> Here is how that ambitious plan would work: The company relies on factories in the U.S., Mexico, Scotland, Taiwan and Malaysia to make the dozens of finished parts its customers want. Now, Cisco often holds on to each part at a warehouse near the factory so the whole order can be shipped to the customer at once.
>
> But Cisco's business is booming—its revenue has grown 40% annually over the past three years—and the company doesn't want to continue building warehouses, paying for reshipping, and owning tens of millions of dollars of inventory while it awaits transit. Beyond that, the company needs more flexibility to be able to drop or add manufacturers at a moment's notice. So Cisco wants a far more advanced system for moving products.
>
> The idea: Merge the orders in transit. As many as a hundred different boxes destined for a single customer would be shipped independently as soon as they are manufactured—and they would all arrive at a customer's door within hours of each other. The parts could be assembled right there, never spending a moment in a central warehouse.

The Department of Commerce noted in 1998, "By reducing inventory levels, businesses will realize substantial savings in materials handling, warehousing, and general administrative costs."[121]

*The net result might be to eliminate the need for another one billion square feet of commercial warehouses and on-site storage at manufacturing facilities.*[122] So business-to-business e-commerce, like business-to-consumer e-commerce, holds the potential to generate significant "Internet energy efficiency" savings in the buildings sector. The implications for energy intensity in the manufacturing sector other than in buildings is a complex subject, which will be discussed in the next section.

## TELEWORK AND COMMERCIAL BUILDINGS

As one 1998 journal article noted, "definitions and measurement are problematic, but home-based work in all its forms appears to constitute a sizable and growing component of the labor market."[123] The emergence of the Internet, coupled with downsizing and outsourcing, has created an accelerating trend. "Just as home office growth has contributed to expanding Internet use, Internet availability has contributed to the growth and success of home offices," according to Raymond Boggs, director of IDC's Home Office Market research program.[124] "The Web enables a small business operating out of the home to establish a worldwide presence to promote itself and transact business online."

The rapid growth of the Internet is significantly increasing the opportunities for people to work out of their home for two reasons. First, as the Internet provides more access to more information, it, coupled with advances in IT technology such as high-speed connections, gives people working out of their home far more capability. Second, as e-commerce itself grows, both business-to-consumer and

business-to-business, more jobs will involve spending a considerable amount of time on the Internet, jobs that can perhaps be done as easily from home as from a traditional workplace.

International Data Corporation (IDC) has estimated that the number of home offices of all kinds is growing by about three million a year. IDC projects the number of home offices with PCs on the Internet will grow from 12 million in 1997 to 30 million in 2002.[125]

Since a considerable amount of the likely energy benefits from telework involve reducing transportation-related energy by eliminating trips, telework will also be discussed in Section 5. Telecommuting that involves office workers working at home only a fraction of the time has only a modest impact on building energy consumption. The Internet, however, makes it possible for far more office workers to telecommute a significant fraction of the time, what we call here "Internet telecommuters." It also creates whole new jobs that are completely home-based, "Internet entrepreneurs." These two together make the potential impact on office space and hence building energy consumption much greater.

Two companies in particular are leading the way toward this next generation of telecommuting—AT&T and IBM.

**AT&T:** AT&T has "consciously sought to reduce the cost of providing office space for workers who spend a great deal of time with customers outside the office," as one recent study concluded.[126] AT&T's first shared office was at AT&T's Global Systems Division in Morristown, New Jersey. Using their laptops, employees who need office or meeting space remotely connect to a company computer to reserve it. Once at the office, they wheel their own mobile file cabinet to their reserved space. The workstations are six feet square and arranged so the two people can work apart privately or move their chairs together to work side-by-side. This system allows workers to come to the office only when they need to.[127] This approach is made easier for the company as it becomes more Internet-based and thus increasingly "paperless" (see next section), so that less workstation space is needed to accommodate filing cabinets and the clutter of paper-based information storage.[128]

The savings have been large. By mid-1998, total square footage used by the division in Morristown has dropped from 45,000 to 27,000 and square footage per person has dropped from 230 to 120. An investment of $2.1 million is saving the company $464,000 a year.

AT&T is expanding this strategy company-wide, where square footage per person averaged 300 in 1998. Their five-year plan aims to generate savings of almost $50 million a year. By 2003, AT&T estimates that some 34,000 employees—a quarter of the total—could be taking advantage of alternative work settings. Two-thirds of those would be shared-office workers, using 1/3 as much corporate space as in traditional offices. One-third would be "virtual" averaging as little as 1/10 the square footage of traditional offices. With roughly the same number of total workers in 2002 as in 1998, the company expects to cut total square footage from about 32 million square feet to 21 million square feet.

Clearly, this strategy delivers significant energy savings in their commercial buildings for AT&T. The typical office building in this country uses about 20 kWh per square foot and another 35,000 BTUs per square foot of natural gas.[129] For larger office buildings packed with computer and telecommunications equipment, such as AT&T has, the numbers, particular the electricity numbers, would be higher. As a rough approximation, this strategy seems likely to reduce electricity consumption by 200 million kWh and natural gas consumption by 350,000 MBTUs (million BTUs) per year.

The question of the *net* energy savings of this strategy is much more difficult to determine. Transportation fuel savings are likely though, as will be seen in Section 5, the specific amount of fuel savings is difficult to project (particularly since this type of "Internet telecommuting" is so new). Certainly, by having their employees work at home more, home energy consumption, especially electricity consumption, will rise. Just how much is difficult to know. There are few recent, rigorous analyses that show how much incremental energy use a home-based worker will experience (incremental over what their home would have consumed anyway had they not been there).[130] Moreover, the workers who telecommute the most are also the ones who travel the most and so they aren't at home much of the time. At Morristown, for instance, it was "estimated that at least 60% of the sales and technical people would be out of the office with customers at any given time."[131]

With all the above caveats said, we would expect that the incremental home-based electricity consumption would be lower than the reduction in work-based electricity consumption. We would not be surprised if the incremental home electricity consumption were 500 kWh and 1,000 kWh for the shared-office worker and virtual worker respectively.[132] Each shared-office worker saves about 175 square feet per worker times 20 kWh per square foot or 3500 kWh a year. Each virtual office worker saves 270 square feet per worker, or 5400 kWh a year. So it seems likely there would be a large net electricity savings per Internet telecommuter of 3000 to 4400 kWh a year. This is clearly an area that deserves much more rigorous analysis and field research.

Finally, there is the issue of the energy saved from avoided construction, assuming that the 11 million square feet that AT&T no longer needs will be used by someone else in place of a new building. This e-materialization of office buildings will be discussed in Section 4, but it is worth noting now that the total energy used in constructing a building is several times the annual energy consumed by that building.

**IBM**: IBM launched a major alternative-workplace initiative program in the mid-1990s for its North America's sales and service organization, "an initiative designed to improve customer responsiveness, reduce cost, and increase productivity."[133] The goals were to reduce employee travel time, and "if they're not going to work in IBM office, we want to eliminate the dedicated space with all of its overhead and services," in the words of Lee Dayton, IBM's Vice President for corporate development and real estate.

Today, virtually all of IBM's sales force can operate "independent of a traditional workplace." Over 12,500 workers have given up their dedicated workspaces. An additional 13,000 are capable of mobile operation. Worldwide, roughly 17 percent of IBM's total workforce has the equipment and training to work in alternative-workplace arrangements.

The result has been that from 1992 to 1997, "real estate savings totaled $1 billion from mobility initiatives alone." Worldwide occupancy expenses dropped from $5.7 billion to $3.3 billion, a 47% reduction.[134] Worldwide cost per employee dropped from $15,900 to $9,800. Occupancy expenses as a percentage of company revenues fell from 8.8% to 4.2%.

In addition, as will be discussed in the next section, IBM has been using its electronic network to improve inventory management and production planning, which has allowed it to better utilize existing manufacturing capacity and lower investment and operating costs.

No doubt all of these efforts have contributed to IBM's remarkable success in reducing energy consumption by 4% per year for most of the 1990s. By coupling an aggressive traditional energy efficiency program, with an aggressive Internet energy efficiency program, IBM has achieved one of the greatest and largest sustained improvements in overall energy efficiency that we are aware of.

Moreover, they project that they will be able to continue significant annual energy reductions for the foreseeable future.

A number of European companies have adopted this strategy.[135] For instance, the Swedish telecommunications company, Ericsson, has designed a flexible workplace with 15 percent fewer desks than the number of employees, which is "based on the assumption that at least 1/4 of the workforce telework out of the office." If the Internet allows any significant portion of American companies to adopt a program similar to AT&T and IBM for a significant fraction of their workforce, the ultimate economy-wide energy savings could be very large.

## HOME-BASED WORK

Although it is difficult to determine the exact number of home-based self-employed workers and precisely what they are doing, it seems clear that this is a large and rapidly growing part of the workforce.[136] In October, the *Washington Post*, for instance, ran a front-page article headlined "Area Neighborhoods Buzz with Home Businesses," which noted that "legions of workers are redefining the rhythms and rituals of their neighborhoods by pitching the commute and working out of their homes."[137] The article notes that "this rapid expansion is being driven in large part by leaps in technology, as high-speed Internet access, inexpensive computers and sophisticated telephone equipment allow virtual offices to flourish." It cites the case of Tomas Point Court outside of Annapolis, Maryland, where "about half of the cul-de-sac's fourteen stately residences boasted home offices of one kind or another."

An August article in the *Washington Post* on eBay, the online auctioning site, illustrates how the Internet is changing the way people work.[138] It tells the story of Sandy Kleppinger of Leesburg VA who sells software online. She buys software wholesale, or, preferably for less, such as "the remainder bin at CompUSA, where boxes of a particularly good software title were on sale for 94 cents each." She stores the software in her basement and garage (which, in some sense, is increasing the warehousing capacity utilization of the country at exceedingly low incremental cost). "Seven days a week, she posts auctions on her computer, monitors them, closes them, takes orders, packages software and mail boxes. She updates her database, opens mail, sorts checks, fills out deposit slips, prints labels, sends emails, and does the books."

In the first seven months of 1999, Kleppinger sold $85,000 worth of product, with half that as profit. After spending $1,100 for a fast computer to launch her business, her main expense is a few thousand dollars a month to purchase software. She has now expanded from eBay to Amazon.com's auction site and the one run by Yahoo.

*If she were working in a traditional small office building generating the same type of revenue and profit, she would probably be consuming upwards of 6000 kWh a year. Her incremental home-based electricity consumption is perhaps 1500 kWh, which yields a net saving of more than 4000 kWh.*

While it is impossible to know exactly how many "Sandy Kleppingers" there are, the *Washington Post* noted "Kleppinger is one of roughly 15,000 'power sellers' turning over at least $2000 a month on the site of the world's largest Internet auction house." Ebay has seen registered users rise from under one million in early 1998 to 6 million by August 1999, with $6.8 million worth of goods and services changing hands every day electronically. A spokesman for the company says that more and more people have turned collecting and other hobbies into a full-time business. "Every desktop is a store," says Howard Rheingold, author of several books on the computers and the Internet.

## IMPACT

In 1996, two senior directors of Arthur Andersen's Real Estate Transformation Group estimated that the growth in telecommuting and telework could lead to "US companies ultimately shedding as much as 3 billion square feet of office space."[139] Three billion square feet is a large number—representing five percent of total commercial for space (which is about 60 billion square feet[140]). Nonetheless, it seems like a plausible order-of-magnitude estimate for the reduced need for commercial buildings created by the Internet economy for 1997 to 2007.

Suppose, for instance, that from 1997 to 2007, the Internet leads to an additional one million home offices each year.[141] Suppose that half of those are Internet telecommuters and half are Internet entrepreneurs and that they avoid on average 150 square feet and 300 square feet of office space respectively. That would avoid the need for more than 2 billion square feet of office space by 2007.

If Internet telecommuters save a net of 3000 kWh and Internet entrepreneurs save 4000 kWh, the electricity savings in 2007 would be 35 billion kWh (about 1.5% of the combined electricity sales in the commercial and residential sectors that year). [142]

This would be augmented by any reductions in commercial office space as a result of business-to-consumer and business-to-business e-commerce, discussed above. That might render 1.5 billion square feet of retail building space unnecessary in the same time frame, which would avoid 18 billion kWh and 67 million MBTUs.[143] Also, as noted above, there could well be a net reduction of perhaps 1 billion square feet in warehousing and storage in the commercial and manufacturing sectors, but the annual energy savings are likely to be small.[144]

The net savings from the Internet in this scenario come to about 50 billion kWh in 2007. This is about 13% of the projected growth in total sales of electricity to the residential and commercial sectors during that time: 400 billion kWh from 1997 to 2007.[145]

Potential Impact of Internet on Buildings[146]
(1997 to 2007+)

| Building Type | Sq. Ft. Saved | Electricity Saved (kWh) | Natural Gas Saved (MBTU) | GHG Saved (metric tons) |
|---|---|---|---|---|
| Retail | 1.5 Billion | 18 billion | 67 million | 14 million |
| Office | 2 Billion + | 35 billion | -- | 21 million |
| Warehouse | Up to 1 Billion | -- | -- | -- |
| TOTAL | 3 Billion + | 53 billion | 67 million | 35 million |

# IV. THE INTERNET AND THE MANUFACTURING SECTOR

The industrial sector is responsible for about one-third of U.S. energy consumption. This section will explore the ways in which the Internet economy might affect manufacturing energy consumption.

E-commerce holds the potential to have a significant impact on manufacturing. In particular, two key energy-intensive industries will face competition from the "e-materialization" made possible by the electronic marketplace: construction and the manufacture of pulp and paper. A much less energy intensive industry, printing, is also facing competition. And all manufacturers are likely to benefit from a reduction in inventories; better forecasting and online auctioning reducing needless overproduction and increasing capacity utilization; and superior supplier chains reducing mistaken orders and minimizing waste. Much of this is what Federal Reserve Chairman Greenspan called capital deepening, which has myriad benefits for the economy.

## E-MATERIALIZATION

Dematerialization is a long-standing trend in the economy, as noted in the Introduction. Many have concluded that the Internet in particular may accelerate the trend towards a weightless world, the conversion of atoms to bits, as Prof. Negroponte puts it, or e-materialization, as we are defining it here.

E-materialization is likely to be the source of some of the biggest impacts the Internet has on energy intensity and pollution. That is because the most energy intensive industries on the planet are the industries that extract raw materials and convert them into useful commodities, such as plastic and other chemicals, paper, and construction materials such as the famous "bricks and mortar." In addition, the transportation of these heavy materials engenders a great deal of energy consumption. If atoms can genuinely be replaced by bits, and distributed by the Internet, rather than trucks, trains and planes, the energy savings will be significant. Since the energy-intensive industries are also those responsible for the vast majority of hazardous waste and toxic chemical pollutants, e-materialization holds the potential to prevent the creation of that pollution in the first place. This is much better than disposing of or treating that pollution later.

## PAPER

The manufacture of paper is one of the most energy- and resource-intensive processes in the economy. Only the chemicals industry and petroleum refining surpass paper manufacturing in total energy consumed in the industrial sector.

Paper consumption is one of the likeliest targets for e-materialization. It is certainly easy to see that the long-heralded "paperless office" promised by the computer revolution has not occurred nor is it likely to anytime soon.[147] Indeed the consumption of standard office paper may well continue its rise, though, ironically, much of its growth may come in homes. Nonetheless, just as it appears that the Internet may be the killer application that finally is generating the productivity gains people had long anticipated for the widespread use of the computer, so too may the Internet be the application that kills paper in a number of traditional uses. Just as the CD ROM caused a remarkable decline in printed encyclopedias, the Internet is poised to have a similar impact on newspapers, catalogs, envelopes, and the like.

We don't see a paperless future, but we do see one in which paper consumption per dollar of GDP drops significantly.

The most comprehensive recent study done on the likely near-term impact of the Internet on paper consumption is a September 1999 report *Paper and the Electronic Media*, by the Boston Consulting Group, one of the world's leaders in strategy consulting.[148] This is an important study because it is the first systematic model aimed at predicting the impact of the Internet economy on a major resource. The BCG analysis projects that by 2003, the Internet will reduce demand for paper by *2.7 million tons*, compared to what it would have been without the Internet (some 30 million tons across several categories of paper), even with increases in cut-size office paper.

A reasonable estimate for the energy saved by avoiding the use of one ton of paper is 30 million BTUs.[149] Thus, under the BCG scenario, the Internet's impact on energy consumption just from e-materialization of paper by 2003 would be of the order of 80 trillion BTUs, *which is nearly a quarter of one percent of all industrial energy consumption*. As discussed below, it would not be surprising to us if the actual savings were larger than BCG projects, and in any case the reduction in paper use and energy will only accelerate after 2003, so the impact on energy intensity is likely to grow throughout the next decade.

The greenhouse gas savings for avoiding the use of a ton of paper is estimated at 3.3 metric tons of carbon dioxide equivalent for newspapers and 3.8 for office paper.[150] Under the BCG projection, the greenhouse gas savings from e-materialization of paper by 2003 would be some 10 million metric tons of carbon dioxide equivalent.[151]

The BCG ran their model out to 2008 at our request. Because it is so difficult to forecast anything so unprecedented as the growth and impact of the Internet, the model cannot provide reliable quantitative predictions that far into the future. However, the qualitative results do suggest that under the kind of scenario for growth in the Internet economy examined here, the net reduction in paper consumption in 2008 could more than double the 2003 reductions, which would bring energy savings to over 0.16 quads and GHG savings to over 20 million metric tons.

Because of the large potential savings in both energy consumption and greenhouse gas emissions, it is worth examining this issue and the BCG study in more detail. The BCG study looked at the likelihood of substitution of electronic media for traditional uses of paper based on an analysis of six drivers: Internet penetration, match of demographics, enhanced functionality, superior economics, reading habits, and emotional attachment.[152] The study also looked at the impact of what it calls indirect substitution, where the loss of advertising revenue to the Internet indirectly hurts a form of traditional media. Forrester Research projects that "Over the next five years, the Internet will siphon $27 billion—or 10% of all US ad spending—away from traditional media."[153]

NEWSPAPERS: The biggest single user of paper—newspapers—is the key loser in the BCG study (a conclusion reached by a number of analysts). As the study notes, "The considerable information content of most newspapers, combined with high fixed costs and the subsidizing of content by advertising, makes them particularly vulnerable to electronic substitution. When advertising revenues decrease, as a result of a rise in online classified marketplaces, for instance, the economic underpinnings of the entire industry are jeopardized."

The Internet is particular problematic for the industry because circulation, advertising, and time spent reading newspapers are already in decline. Even without the Internet, the BCG project that continuation of recent trends would reduce newspaper demand for newsprint by some one million tons. One recent survey found that over 90 percent of executives from 400 U.S. companies believe the Internet will soon be an essential source of business news, and only half believe they will obtain their news from traditional daily newspapers in the future.

There is a significant cost structure difference between the print and on line newspaper business. As the Department of Commerce noted in 1998, "the online business does not have to support the three largest expenses of the print business: the newsprint …, physical distribution, and the cost to manufacture and print the paper. Combined, these costs represent 30 to 40 percent of the total cost structure."[154] And they all have a high energy content.

Thus, online editions can have a significant economic advantage. [155] In addition they can provide more timely information, as well as information tailored for the individual user, what Negroponte called *The Daily Me*.[156] Thus, there is a large potential benefit for what the BCG calls direct substitution of electronic media for traditional newspapers.

On top of that is the likelihood of indirect substitution. Advertising is the source of about 80% of revenue for U.S. newspapers. Classifieds, the biggest single revenue source for newspapers (some 37% of total revenues), are widely believed to be the most likely to go online.[157] As the BCG notes, electronic classifieds are timely, searchable, and comprehensive, and offer sight, sound, and motion; as such, they are potentially superior from the consumer's perspective." BCG projects that about 15% of the U.S. classified market will be online in 2003. Forrester Research believes that the Internet will displace $4.7 billion in print classified ad revenue by 2003, costing the industry some 20% of their expected revenues in that year.[158]

As but one example, J.D. Power and Associates reported in August that over one-quarter of used-vehicle buyers already use the Internet for assistance during the shopping process.[159] Half of the Internet shoppers searched online classified Web sites in order to find sellers of the particular vehicle they wanted. "Despite the fact that online vehicle-locator sites are in their infancy, we were amazed to find that some of these sites already offer a wider selection of used vehicles than the typical newspaper classifieds," said Chris Denove, director of consulting operations at J.D. Power and Associates. "The online locators are so versatile that they could one day make traditional newspaper classifieds obsolete."

BCG projects that direct and indirect substitution will cut total newspaper demand for newsprint to 7.4 million tons in 2003 (down from 9.8 million tons in 1996) as opposed to their business-as-usual projection of 8.6 million tons. They believe "about 15 percent of the 1997 North American newsprint capacity will be superfluous by 2003."

MAGAZINES: The BCG study notes that magazines are "less threatened by electronic replacement, at least in the medium-term, for two reasons." First, they face less of an indirect substitution threat than newspapers because their advertising is more brand-oriented than classified. Second, most online magazines appear to lack the consumer appeal of online newspapers, "largely because timeliness is less critical and emotional attachment, reading habits, and handling are more so."

In certain segments, such as finance, substitution may occur sooner. The financial information services division of McGraw-Hill began distributing its products electronically before 1990, but initial sales of digital products "barely made a dent in the overall business." Up until 1995, print revenues made up 85 percent of the division's sales. Today, financial institutions such as brokerages and banks depend on these online publications for decision-making. By 1998, revenues from the online business exceeded 50 percent of total sales. McGraw-Hill projects that distributing many of its other products electronically "will drive down printing and distribution costs which can be as high as 50 percent of the retail price in some markets."[160]

CATALOGS: Catalogs, on the other hand, face stiff competition from the Internet. Consumers comfortable with catalog shopping have already accepted virtually all of the same conditions that dominate online purchasing, but with less convenience, less customizability, no interactivity, and lack of timeliness. A consumer has to worry with old catalogs that the item they desire is out of stock.

From the retailers' point of view, once they have devoted significant resources to setting up a Web site and maintaining it, mailing out catalogs every month becomes an expensive burden. The cost of paper alone is 10 to 15 percent of total expenses. Printing and distribution costs increase that significantly.

BCG projects that without the Internet, total demand for paper for catalogs would have risen from 1.9 million tons in 1996 to 2.6 million tons in 2003, but that electronic substitution will reduce that number to 2.2 million tons in 2003. Here BCG may be underestimating the impact of the Internet.

A March 1999 report by Merrill Lynch concluded that much of the rapid growth of Internet retail sales will come at the expense of the mail order business. Their analysis projected that in 2003 Internet sales of goods (not services such as stock trading or travel) will hit $100 billion, up from $8 billion in 1998. Of that, Merrill projects $40 billion will come at the expense of the mail order industry, which currently generates between $55 billion and $75 billion in annual sales. Almost every major catalog has set up a Web site, and the report argued "one of the strongest predictors of future nonstore retailing use is whether a consumer has ever used mail order or some other shopping method which requires delivery of goods. Thus, mail order shoppers are already predisposed for Internet retailing."

Bloomberg News reported in March 1999 that "Catalog retailer Lands' End wants to increase its Internet business to cut costs and help shore up its earnings…. Last year, online sales more than tripled to $61 million from $18 million. But earnings overall are being chewed up by higher catalog costs and bulging inventories, despite rising sales company-wide. Web sales could help lower those costs, the company hopes."[161] The company mailed 259 million catalogs in 1998, and intends to start cutting back on catalog sales and pages per catalog by the end of 1999. Charlotte LaComb, Lands' Ends' investor relations manager, said in September that the company's Internet success is helping to change its strategy.[162] "The big nut is when we get to the point of moving the catalog customer over to the Internet," LaComb said. "We need to reduce the costs of the mailings. The cost to produce and mail is about 17 percent of sales, and that's something we'd like to cut."

By having product and pricing information on the Web and web-based CD-ROMs, Cisco is saving $50 million in printing and distributing catalogs and marketing materials to customers; this is a small part of the savings from Cisco's broad-based Internet strategy, discussed below. Digital Equipment Corp. has estimated that putting its promotional materials online is saving $4.5 million annually in catalog and mailing costs.[163]

Some online companies tout the environmental benefits of being catalog free. HardwareStreet.com, a 100% "Virtual Internet Reseller" brags, "we have no expensive retail locations, we don't mail millions of catalogs, and we don't consume trees! ... and, as part of our environmental awareness program, we donate 1% of our profits to The National Forest Foundation to plant trees in a U.S. national forest![164]

Craig Schmidt, Vice President of Real Estate Research for Merrill Lynch, posed the question to us, "Why would someone with Internet access shop with a catalog?"[165] He sees ultimately almost a 100% conversion from catalog users to online for those with access to the Internet. He believes

catalog production is likely to be lower in 2003 than it is today, not higher. If so, that would mean hundreds of thousands of tons of reduced paper consumption beyond what the BCG study projected.

DIRECTORIES: The advantages offered by electronic directories include "timeliness, searchability, and breadth of information." Advertisers can gain from the ease of collecting and updating information and the opportunity for cross promotion (connecting people who are buying homes to movers). Publishers can save on the large cost of paper, printing, and distribution. BCG projects that the Internet will reduce total demand for directories by 25% compared to projected levels for 2003, a savings of 300,000 tons of paper. Environmental analyst Nevin Cohen noted in his essay "Greening the Internet" the great benefit that would result from putting telephone books online: "Approximately 470,000 tons of telephone books are discarded each year, yet only ten percent are recycled."[166]

INSERTS AND DIRECT-MAIL: Paper used for inserts and direct-mail consumed nearly 6 million tons in 1996. BCG believes substitution will threaten direct mail more than inserts, because electronic forms of advertising have more advantages for more targeted audiences. They believe, however, "overall substitution effects in the next five years will be limited." In contrast, Forrester Research believes that direct-mail will take a pretty big hit, perhaps as much as 18% of revenues by 2004.[167] If so, paper savings in this area might be larger.

INFORMATION-BASED BOOKS: The potential for information technology to replace information-based books has already been demonstrated by the rapid replacement of hard-bound encyclopedias with CD-ROMs, particularly Microsoft's *Encarta*. Since 1990, for instance, *Encyclopedia Britannica* has seen sales of its printed sets plummet 80%. In October, the company made the entire encyclopedia—32 volumes and 44 million words—available for free on their website.[168]

While traditional books have obvious benefits, the state of the art in electronic books is improving both in the areas of portability and readability. Because they eliminate the costs of the paper, printing, and distribution, it is likely that electronic books will have a lower cost than traditional books. While this transition may take a number of years, even in the short term so-called eBooks offer large enough advantages that they are likely to start substituting very soon for certain types of books, including education, reference, technical, and scientific. Unit sales of science and technology books have already declined from a peak of about 80 million copies in 1995 to 74 million copies in 1998, in large part because of the impact of electronic media.[169]

BCG results suggest that by 2003 electronic substitutes will displace 300,000 tons of U.S. paper consumption by books.

In addition, traditional booksellers typically have a large rate of returned books, which can exceed 30%, many of which are destroyed (or sold at deep discount). Online sellers appear to have lower returns, thus demonstrating a typical feature of the Internet, the ability to minimize waste. Even traditional booksellers are pursuing the implementation of printing books on demand using the Internet and IT technology. In June, Borders announced that it will install Sprout, Inc.'s digital print-on-demand technology in the distribution center that services its bookstores and its Internet site.[170] This technology, which Sprout is also marketing to other publishers and book retailers, makes it possible to produce single copy production of paperback books at distribution centers and at in-store production facilities after the book has been sold to the consumer. This just-in-time strategy for book manufacturing "reduces the cost of storing and shipping books for publishers and retailers, lowers the threshold for keeping slow-moving titles in print, increases the in-store exposure of titles not already on the shelf, and eliminates the risk of returns."

Publishers "can't wait until they go electronic," says Fordham University business professor Albert Greco in the June edition of *Wired*.[171] Greco explains that "by going electronic they can change the text instantly. Their cost of doing business will disappear because there's nothing to print." The magazine notes that, "If books exist as stored data, then no work will ever go out of print…. Returns, the bane of the business, would cease to exist. Inventory, a damaging cost, wouldn't have to be warehoused."

The combination of all these trends suggests that the opportunity in the coming years for reducing paper consumption by book publishers is large.

OFFICE PAPERS: Determining the future impact of the Internet on consumption of different types of office paper is the most difficult. As but one example, BCG notes "an increase in the amount of available information coupled with the tendency to reprint documents as needed rather than store paper versions implies a rise in paper used, while the ability to preselect information indicates a drop in consumption." Overall, the study concludes that the gains in cut-size paper "will not compensate for overall substitution losses in publication papers." That is to say, the volume of paper reductions caused by substitution to e-newspapers, e-catalogs and the like is greater than the additional volume that will be required because some of this electronic information is likely to be printed on a desktop printer several times.

In homes, for instance, increased penetration of computers and printers will lead to increases in individual printing, which will represent a shift in volume away from large-scale offset printing. People can print out the page or two they are most interested in from an online catalog or directory, rather than receive the whole thing in the mail.

In offices, the forecasting is particularly difficult. While there has been a steady rise in recent years in the consumption of cut-size paper, the largest segment within office papers, growth in this area has already started to slow in the United States. According to Kirsten Lange, one of the report's authors, the reason for this slowing is that the United States is further along in Internet use. So Americans, who once routinely printed out their emails, do so far less often, and we have become more comfortable reading text in electronic form than even a few years ago.[172] She expects that trend will continue in United States, and eventually spread to other regions of the world as they become more accustomed to the use of the Internet and electronic media.

The BCG report notes that while use of cut-size office paper will grow, other types of office paper "are likely to deteriorate: for example, our findings indicate a rise in email will result in a one-million-ton loss of envelopes [worldwide]. Demand for forms will also drop."

The report concluded that total demand for cut-size paper in the United States would grow from 3.8 million tons in 1996 to 5.4 million tons in 2003 just due to increased use of paper in offices, and that increased use of paper for print-on-demand in homes will bring the total in 2003 to 5.7 million tons.

We would not be surprised if we began to see a decrease in office paper consumption over the next several years, as a number of companies have begun to use the Internet and intranets to dramatically reduce paper consumption. Two of the leading companies who provide technology that supports the Internet, AT&T and Nortel Networks, show what is possible. Nortel has a comprehensive program to reduce paper consumption, including "heightened employee awareness and increased use of electronic mail, Nortel Networks' Intranet, paperless recordkeeping and two-sided copying and printing."[173] From 1997 to 1998, they cut paper use by 1,140 metric tons, a 17% cut (and a 25% reduction in tons per dollar of sales). Since 1993, paper use has decreased 33% (64% in tons per sales dollar).

AT&T has cut paper consumption by more than 400 tons.[174] Their strategy has included:

- Shifting the AT&T personnel guide from a 1500-page paper document (copied and distributed at least 20,000 times a year) to an online resource. A number of other corporate directories were similarly e-materialized.

- Putting the Environment, Health & Safety organization online, including their monthly newsletter (which by itself saved 1.8 million pieces of paper).

- Enabling online requests for supplies via the Internet.

- Putting nearly 400 corporate forms online, so they can be printed only when needed.

- Distributing *AT&T Today* online, eliminating 10,000 daily copies, and saving 24 million pieces of paper.

IBM reports that its Internet-based supply chain management system has cut paper consumption by 5 million sheets.[175]

While reducing paper consumption clearly helps the environment, the primary reason many companies will end up reducing paper use is because paper-based systems tend to be inefficient and require far more labor than electronic systems. For instance, General Electric is simultaneously achieving a variety of benefits, including productivity gains and paper reduction, from its Trading Process Network (TPN), a suite of Internet-based purchasing and supplier productivity solutions.[176] Prior to e-materializing its procurement system, GE's system was exceedingly inefficient, as described in the Department of Commerce's 1998 report on electronic commerce:

> More than one-quarter of its invoices (1.25 million invoices) had to be reworked because the purchase order, receipt, and invoice did not match.
>
> Factories at GE's lighting division used to send hundreds of request for quotations (RFQs) to the corporate sourcing department each day for low-value machine parts. For each requisition, the accompanying blueprints had to be requested from storage, retrieved from the vault, transported onsite, photocopied, folded, attached to paper requisition forms with quote sheets, stuffed into envelopes and mailed out. This process took at least seven days and was so complex and time-intensive that the sourcing department normally only sent out bid packages to two to three suppliers at a time.

GE Lighting decided to pilot the company's first Internet-based procurement system, TPN Post, which is an online service that allows for electronic RFQ distribution and bid receipt:

> Now, the sourcing department receives the requisition electronically from its internal customers and can send off a bid package to suppliers around the world via the Internet. The system automatically pulls the correct drawings and attaches them to the electronic requisition forms. Within two hours from the time Sourcing started the process, suppliers are notified of incoming RFQs by email, fax, or EDI [electronic data interchange] and are given seven days to prepare a bid and return it over the Internet to GE Lighting. A bid can be awarded the same day GE receives and evaluates it.

The benefits GE Lighting has experienced are large.

> Cycle time has been cut in half
>
> There has been 100% removal of paper and mail costs
>
> The sourcing department has had a huge gain in productivity. They have at least six to eight extra days a month to concentrate on strategic activities, rather than the paperwork, photocopying, and envelope stuffing the department did when the process with manual.
>
> While the labor costs involved in procurement declined 30%, materials cost declined 5 to 20% because the company could now reach a wider base of suppliers online.
>
> Because the transaction is now handled electronically from beginning to end, invoices are automatically reconciled with purchase orders and reflect any modifications that happened during the process. The error rate has dropped sharply.

In 1997, eight GE divisions used TPN for some of their procurement, buying over $1 billion worth of goods and supplies via the Internet. By 2000, the company plans to have all 12 business units purchasing its nonproduction and maintenance, repair and operations (MRO) materials via the Internet, a total of $5 billion. Streamlining these purchases alone, the company estimates, could save GE between $500 and $700 million annually.

Businesses spend about $250 billion each year on materials, services, and supplies apart from the production process. For most of them, it is a manual process, as costly and inefficient as GE's was.[177]

Considering all of the benefits of electronic media, it seems particularly plausible that the Internet will significantly reduce paper consumption per dollar GDP, thereby reducing the nation's energy intensity and greenhouse gas intensity. A secondary impact will be in the printing industry, which is far less energy intensive than the pulp and paper industry. Should newspapers, catalogs, and directories decline in the near term, and then magazines and direct mail in the medium-term, printing energy consumption per dollar GDP will also probably decline.

CARDBOARD PACKAGING: Another area closely related to paper consumption is the use of cardboard packaging. Like projections about the use of cut-size paper, however, there are many potentially offsetting factors. For business-to-consumer e-commerce, we might expect to see an increase in the use of packaging, as companies like Amazon.com ship books directly to the consumer in boxes. On the other hand, to truly understand this area would require a more comprehensive life-cycle analysis than is possible in this report. Here are some key issues.

If some consumer e-commerce results in shipping directly from the manufacturer to the homeowner, it could well bypass at least one stage of bulk shipping that involves placing the product in large cardboard boxes or other similar containers. Also, as noted above, perhaps 40% of the expected growth in consumer e-commerce over the next five years will simply displace catalog shopping, so the products will be delivered in exactly the same packaging. Similarly, to the extent that consumer e-commerce is particular successful during Christmas, where a significant fraction of items purchased were going to be shipped anyway, some of its impact during this time will again be offset.

Probably more significant is the rapid growth in business-to-business e-commerce. As inventories are slashed, the use of packaging and even crating may decline. Further, as supply chains are put on the

Internet or an extranet, shipments of blueprints and other items requiring cardboard packaging, may decline sharply. Also, companies like GE and Cisco (discussed below) are using the Internet to reduce the fraction of mistaken orders from 25% down to with low as 2%.

Finally, shippers themselves have an incentive to reduce one of their principal costs, shipping materials, and many have taken steps to reduce their consumption. Consider, for instance, UPS, the world's largest express carrier and package delivery company. In 1998, they partnered with the Alliance for Environmental Innovation, a nonprofit organization, to cut packaging waste.[178] Their results, announced in November of that year, were:

- Nearly doubling the amount of post-consumer recycled material in the UPS box, and using at least 80 percent post-consumer recycled material in the Express Letter.
- Eliminating the use of bleached paper in all express packaging.
- Reducing overall waste and pollution from production of shipping materials by an average of 13 percent.
- Introducing post-consumer recycled material into UPS's plastic PAK and reducing each PAK's weight by almost 10 percent.
- Market testing reusable options for UPS's box, tube, and plastic PAK.

A key innovation was the introduction of a reusable envelope. The project summary noted that "Together, the new packaging improvements along with the reusable envelope reduce air pollution by almost 50 percent, cut wastewater discharge by more than 15 percent and use 12 percent less energy than previous UPS packaging. In addition, the initiatives save the company more than $1 million annually." Overall, this effort will reduce solid waste by 5000 tons and cut energy use by some 40,000 million BTUs per year.

UPS is now exploring making more of its packaging reusable. If there is a significant growth in the delivery of packages to residences, it seems likely that more retailers and shippers will explore reusable packaging, which could be picked up by the same vehicles that are dropping the packages off.

For all of the above reasons, it is difficult to determine the impact of the Internet on cardboard and other packaging. We would not be surprised if the impact were roughly neutral.

## OTHER E-MATERIALIZATION

Besides paper, a great many other products can be e-materialized, including software, music, and film.

SOFTWARE: Perhaps the most obvious target for e-materialization is software. As the speed and memory of computers increases, and the number of high-speed connections increase, more and more software will be delivered over the Internet. Forrester Research predicts that soon half of all software distributed by Microsoft, Netscape, and Oracle will be done over the Internet.[179] International Data Corporation projects that by 2003, $33 billion dollars of software will be sold *on* the Internet, and nearly half of that, $15 billion, will be delivered *by* the Internet.[180]

Many companies are pursuing web-based versions of their software. Microsoft is "working aggressively to develop an Internet-based version of its market-dominating Office software," according to Reuters.[181] Brad Chase, a Microsoft vice president for Internet operations, said in September that the company planned to offer an online version of Office over its new business Web

portal, but not for free. ``It will happen probably sooner than you would expect, not in the far distant future," he said. Reuters reported that “Industry analysts are divided on how fast a transition to Web-hosted applications will occur, with some expecting more than half of all software to be run off a network within three years.” Sun Microsystems has made its StarOffice 5.1 suite of programs available for free on the Internet. In the first month, a million copies were downloaded and it continues to be downloaded at the rate of 40,000 a day.[182] They are in the process of redesigning it so that it can be run on the web.

Again, for many companies, the primary driver for e-materializing software and other information products isn’t saving energy, but rather increasing productivity. For instance, Dell Computer Corporation went online for a variety of reasons, one of which was to lower service and support costs. By mid-1998, some 30,000 software files each week were being downloaded from Dell’s site. Answering those requests by phone and then mailing each customer the software would have cost the company $150,000 a week.[183]

Similarly, Cisco Systems has achieved a variety of benefits by going online.[184] It builds virtually all of its products to order, so there are very few off-the-shelf products, and, prior to their website, ordering a product was very complicated. Like GE, roughly 25% of their orders had to be reworked, meaning that the original order was rejected, the customer was recontacted, and the entire procurement cycle would begin again.

In the mid-1990s, Cisco put its technical support system on the Web. By 1997, Cisco’s customers and reseller partners were logging onto their Web site nearly one million times a month to receive technical systems, check orders, or download software. The service has been so well received that today 80% of all customer service inquiries are satisfied online. About half of Cisco’s orders pass through its system without being touched by anyone. “We just collect the money,” CFO Larry Carter told the *Economist* in June. *The error rate has dropped to 2%.*

By 1998, Cisco estimates that the online system was saving it $360 million per year, or approximately 17% of total operating costs. The company has achieved half of those savings, $180 million, in distribution, packaging and duplicating costs made possible because customers download new software releases directly from Cisco site. By having product and pricing information on the Web and web-based CD-ROMs, the company saves an additional $50 million in printing and distributing catalogs and marketing materials to customers. Most of the rest of the savings come from reduced technical support staff costs. Thus, most of the savings come from relatively energy-intensive activities, printing and distributing catalogs as well as manufacturing, packaging, and distributing software. By 1999, Carter estimates the savings had risen to $500 million.

MUSIC: Music is another area where there is great potential for dematerialization. As Nevin Cohen has speculated, “In the next decade, compact discs will probably go the way of vinyl LP, replaced by music stored and transmitted electronically over the Web.”[185] A number of programs have been developed recently to digitally encode music; perhaps the best known is MP3.

In a survey released March 1999, the Recording Industry Association of America (RIAA) claims that MP3 files may be a contributing factor to the decline in music purchases by 15- to 24-year-olds.[186] According to the RIAA, "The continuing drop-off in the proportion of purchases accounted for by 15- to 24-year-olds (32.2% in 1996 versus 28% in 1998), once the mainstay of the market, is puzzling. Potentially the rise of the Internet as a free entertainment center, and the accompanying availability of free MP3 music files, could be contributing factors." Net measurement firm Media Metrix reported in August that an estimated 4 million people in the United States listened to digital music in the month of June.

FILM: Similarly, digital photography can take and record pictures electronically, rather than chemically, and can store the information in computer format rather than on paper. Also, the pictures can be transmitted over the Internet instantaneously to a large number of people at no incremental cost. Cohen notes that "digital photography avoids the major environmental impact of film manufacturing and photo processing."[187]

The digitizing of film has broad applications. As one small example, dentists' offices have begun going "filmless."[188] Now dental x-rays can be recorded directly on electronic receivers, which require one-tenth the amount of x-rays. The information is then stored on a computer, where it can be transferred to insurers or other doctors, at virtually no cost. Some dentists are integrating this into an overall strategy to make their dental offices "paperless," and have all patient records be electronic, which also saves a significant amount of space

## CONSTRUCTION

Construction is one of the most energy intensive industries, consuming more energy, for example, than agriculture.[189] It is also an industry that recent projections have suggested would be growing much faster than other more energy intensive industries, such as petroleum refining and steelmaking.[190] Moreover, the materials used in construction, such as steel and concrete, have a high degree of embodied energy: That is, it takes a great deal of energy to produce them. Therefore, avoiding their use saves considerable energy.

We will not repeat the complete discussion of Section 3, which noted a number of impacts that business-to-consumer and business-to-business e-commerce may have. It seems plausible, if not likely, that the U.S. is entering a time when it can have economic growth without the same amount of construction that it has needed in the past. This may be true in the retail sector, as Web sites substitute for new retail construction (and perhaps ultimately replace old retail stores). It also seems likely that e-materialization could have a big impact in a few specific areas such as banking and perhaps post offices.

Also, we may see reduced demand for new office construction for number of reasons. If more and more companies adopt the model developed by information technology leaders such as IBM and AT&T, than the average square footage needed per worker will decline. Also, if Internet based commerce allows more economic growth to come from home-based businesses, that will also reduce the demand for new office construction.

The manufacturing sector is also likely to see a reduced need for construction. Recall Federal Reserve Board Chairman Greenspan's testimony in June on the impact of information technology, "The surge in investment not only has restrained costs, it has also increased industrial capacity faster than the rise in factory output."[191] And while business-to-consumer e-commerce may require more warehouse space, business-to-business e-commerce is likely to dramatically reduce the need for manufacturing warehouse and storage space. Companies like Toyota have already found that improving their just-in-time process has freed up space for manufacturing expansion. Astonishingly, Cisco has been able to generate more than $12 billion in revenues with "*only 500,000 square feet of its own manufacturing space*."[192] And, as discussed in the previous section, Cisco is working with Federal Express to reduce warehousing space even as it continues to grow.

The Department of Commerce elaborated on the potential benefits in its first report on the *Emerging Digital Economy* in 1998:

> Managing inventory properly results in better service for the customer and lower operating costs for the company. Increasing the frequency of inventory "turns" (number of times inventory in existing warehouse or store space is sold or used for production each year) reduces inventory-related interest, handling and storage cost. Reducing inventory levels also means that existing manufacturing capacities are more efficiently utilized. More efficient production can reduce or eliminate the need for additional investments and plant equipment."[193]

In short, the Internet allows better utilization of existing manufacturing capacity and that should slow the need for construction of new manufacturing plants. Indeed, we may actually see the "bartering of manufacturing capacity," according to business professors Sawhney and Kaplan writing in the September 1999 issue of *Business 2.0*.[194] Other examples are discussed later in this section.

The need for construction will not disappear. Far from it. Economic growth requires construction. However, it seems plausible that the amount of incremental construction required for an increment in economic growth may change. This will lower the nation's overall energy intensity because the construction sector is one of the more energy intensive parts of the industrial sector and is a major consumer of resources such as lumber and steel, whose production is also relatively energy intensive.

Because the Internet may render some existing retail space unnecessary, it is likely that some new construction in the future will be rehabbing existing retail stores, bank branches, warehouses, and other commercial buildings. This is adaptive reuse, and retail analysts such as Mark Borsuk, believe it will become increasingly common.[195] Like all forms of recycling, this requires less energy than manufacturing a new building from scratch. Both trends—reducing the amount of incremental construction and increasing the recycling of buildings—would lower energy intensity.

IMPACT: In our scenario of significant Internet impact, one estimate for reduced demand in the area of commercial buildings was 3 billion square feet. This seemed plausible for the time frame of 1997 to 2007, as discussed in Section 3. We saw the possibility of Internet telecommuters and Internet entrepreneurs avoiding the need for more than 2 billion square feet of office space and business-to-consumer e-commerce avoiding the need for 1.5 billion square feet of retail space. One could also add to that a considerable amount of net warehouse space saved (though there will clearly be some new construction here).[196] Finally, better manufacturing capacity utilization could avoid the need for constructing hundreds of millions of square feet of manufacturing plants in the coming decade.[197]

Let us suppose that 3 billion square feet represents the net reduction in all building space from 1997 to 2007 as a result of the Internet economy: telework, business-to-consumer e-commerce (teleshopping), and business-to-business e-commerce. Therefore, starting in 1997, the need for building construction is reduced by 300 million square feet each year for ten years. This represents about 20% of the new additions projected for commercial floor space during that time, according to EIA.[198]

It has been calculated that the total energy consumed in constructing office buildings is about one million BTUs (MBTU) per square foot.[199] *Avoiding the need for 300 million square feet of new construction each year would thus save 0.3 quads of energy, nearly 1% of all industrial energy consumption.* This is a very significant amount of energy, especially since this energy is saved every year for ten years (or longer, if the trends continue). This would also represent some 40 million metric tons of GHGs avoided each year.

Clearly this scenario is very speculative and omits many complicating factors. For instance, while some of the 3 billion square feet represents avoided new construction (i.e. Barnes & Noble not

building as many stores as they had planned or IBM not building as many new factories or office buildings as it grows), some of it represents current buildings made unnecessary (banks, malls). Of those unneeded buildings, some will be occupied by new tenants, which will avoid new construction. Others will be adaptively reused, which will save energy, but not 1 MBTU per square foot. Others will be abandoned, saving no energy. Finally, in many cases, developers will perceive the land as more valuable than the buildings, so some unneeded buildings will be destroyed and rebuilt completely, which will require extra energy for demolition and removal of the old building.

For all these reasons, the 1% reduction in industrial energy consumption is at best a very crude approximation. Nonetheless, this analysis shows that e-materialization of buildings and factories has enormous potential to improve manufacturing energy intensity. This is an important area that deserves far greater study.

**Potential Impact of E-materialization (by 2008)**

| | Energy Saved | GHG Saved (metric tons) |
|---|---|---|
| Paper | 0.16 Quads | 20 million |
| Construction | 0.3 Quads | 40 million |
| TOTAL | 0.46 Quads | 60 million |

## CAPITAL DEEPENING and WASTE MINIMIZATION

The Internet allows vastly superior supply chain management, which can dramatically reduce inventories, improve forecasting, and eliminate mistakes and wasted production. It also allows sophisticated bartering, which also increases capacity utilization, and holds the potential for increased material reuse. All of this fosters capital deepening and "a saving of resources that, in the aggregate, is reflected in higher levels of productivity," to repeat the words of Chairman Greenspan.[200] The key point is, "The newer technologies and foreshortened lead-times have, thus, apparently made capital investment distinctly more profitable, enabling firms to substitute capital for labor and other inputs far more productively than they could have a decade or two ago."

Avoiding overproduction, waste, and mistakes, and fostering material reuse, can have disproportionately large energy and environmental impacts. This is particularly true because for many manufacturers, the energy used to create and transport the raw materials they buy (the so-called "embodied energy") vastly exceeds the energy they purchase. For instance, Interface Flooring Systems has calculated that *the embodied energy in the raw material it uses to make carpet tile exceeds the process energy needed to manufacture it by a factor of 12*.[201] So avoiding 4% mistaken production, for instance, would save the equivalent of roughly half the energy used in manufacturing.

We have seen large productivity and other Internet-related benefits in the Cisco, GE, AT&T, and IBM examples. The efforts of IBM's Personal Systems Group are particularly illustrative. The case was described by the Department of Commerce's 1998 report:

> Each month, the group's marketing departments report information on how many PCs they think will be sold. The production planning departments identify manufacturing and materials capacity in each factory. Armed with inputs from across the company on demand and supply, production schedules are assigned to each factory. The procurement staff uses the same information to negotiate with suppliers. As new information comes in each week, the process is repeated and the production schedule fine-tuned.
>
> Electronic communication between factories, marketing and purchasing departments have made this quick response possible. Problems are communicated as they arise and the appropriate adjustments are made. If demand suddenly rises or if one factory cannot meet its production schedule, IBM is aware of it in time to increase production at another factory.
>
> The Personal Systems Group has been phasing in this Advanced Planning System (APS) since 1996 and already reports significant results. During the first year of APS, inventory turns increased 40 percent over the previous year, and sales volumes increased by 30 percent. The group anticipates another 50 percent increase in turns and a 20 percent increase in sales volume in 1997. By better utilizing its existing manufacturing capacity, IBM has avoided having to make additional investments to meet the increased volume requirements. The lower investment and operating costs due to improved inventory turns have resulted in savings of $500 million.[202]

Ultimately, most manufacturers will want these kinds of savings. If they do, we may well see the realization of the prediction by Ernst & Young—inventories reduced $250 billion to $350 billion across the economy.[203] This would also significantly increase manufacturing capacity utilization.

The Internet makes it possible to imagine truly unexpected increases in the efficiency of the manufacturing sector. Consider the example of PaperExchange.com, an online exchange that is working to change the way paper is bought and sold globally.[204] In the exchange model, sellers can easily find buyers and the price is transparent to everyone. One of the key investors and directors is Roger Stone, who had previously turned his company Stone Container into a $7.8 billion paper company. According to Stone, "Paper is a tremendously inefficient industry, especially globally, and because the agent and distributor hold the information, the seller AND the buyer often do not know what the real price is. The middleman takes a big cut and keeps the information." Stone notes that paper mills often base production decisions on unreliable information from sales staff in the field. That can lead to overproduction, which in turn drags down prices. "People are making production decisions on levels of sales that they wish and hope for, and not on real information. With an exchange, they will know real levels of production and real prices across the industry."

A paper mill can cost $500 million. For that reason, mills typically keep them running 24 hours a day, producing paper that is put into inventory, hoping it finds a buyer. Often that doesn't happen, and the paper that is left in warehouses is just churned back into pulp and produced again, a monumental waste of energy. Exchanges can help minimize that. Material exchanges can also be integrated into transportation exchanges that auction off empty space on trucks to help maximize the capacity utilization of the transportation system (See Section 5). There are now, or soon will be, exchanges for most commodities.[205]

MATERIALS REUSE AND WASTE MINIMIZATION: We have already seen a number of instances where Internet-based systems have allowed companies to dramatically reduce their mistakes, such as Cisco and GE. Also, returns in the book business are likely to steadily decline with the growth of Internet-based businesses, print on demand, and, ultimately, electronic books. In general, better forecasting and just-in-time production methods minimize waste and mistaken

production. Indeed, the majority of the fasting growing U.S. businesses are pursuing a "just when needed" product strategy as part of their overall effort to "conserve capital and enhance their financial performance," according to a September report by PricewaterhouseCoopers.[206] As Dell notes, "Building-to-order ensures that each Dell system produced has a buyer, which reduces excess and obsolete inventory that can end up in the landfills."[207]

Online auctioning also promotes material reuse. As Nevin Cohen has written, "thrift stores and yard sales have always been a better alternative for items otherwise destined for the dump."[208] Now e-commerce auctioning sites like the wildly popular eBay are creating "a global yard sale, matching people cleaning out their attics in one part of the world with bargain hunters everywhere." On the consumer side, the Internet is filled with used goods, from cameras to computers to CDs. Steven Landsburg, an associate professor of economics at the University of Rochester in New York who writes the "Everyday Economics" column for the online magazine *Slate*, explains the societal benefit:

> Take the $2.7 billion goods moving through eBay. The important thing about that figure is that it's not like a corporation that earns $2.7 billion a year and has $2.6 billion in costs. In that case, the corporation is only adding $100 million to the economy. Here you've got $2.7 billion a year for stuff that basically cost nobody anything because it was sitting in their garage and they weren't using it. So it's a full-fledged $2.7 billion contribution…. *I expect that there will be fewer CDs made, because everybody will take turns owning them.*[209]

On the business side, the industrial secondary market can now be found on the Internet. FastParts auctions off excess electronic components, typically getting sellers about 50% of the value of their components, with buyers receiving a 30% to 50% discount on prices.[210] Another site, iMark.com, auctions used capital equipment. Their goal is to increase an organization's ability to track, transfer, and sell idle assets, thus improving capital cost avoidance, reducing losses, and maximizing investment recovery.[211] Another site, chemconnect.com, is a chemical and plastics exchange, which can minimize the loss of perishable chemicals, and also facilitate a waste exchange, whereby one company's output can be used as another company's input. There is even a solidwaste.com, which auctions off items like a "40-foot long once-used cargo container."

Given how much energy is required to manufacture many of the above products, it seems inevitable that these auctions sites and exchanges will save a considerable amount of energy. From an analytical perspective, it will be difficult to determine the direct impact of these business-to-business e-commerce activities. Many of the sites allow participants to remain anonymous, and it is, in any case, difficult to determine what both buyers and sellers would have otherwise done. This is an area that merits further analysis.

# V. THE INTERNET AND THE TRANSPORTATION SECTOR

The transportation sector is responsible for about one-third of U.S. energy consumption today. This section that will explore the ways in which the Internet economy might change the contribution of transportation energy consumption to the nation's overall energy intensity.

The Internet holds the prospect of reducing transportation energy intensity by

- replacing some commuting with telecommuting
- replacing some shopping with teleshopping
- replacing some air travel with teleconferencing
- enabling digital transmission or e-materialization of a variety of goods that are today shipped by truck, train and plane, including formerly printed material, software, construction materials, and the like
- improving the efficiency of the supply chain
- increasing the capacity utilization of the entire transportation system.

On the other hand, the Internet holds the prospect of increasing energy intensity by

- Increasing delivery of products by relatively inefficient means, including overnight delivery by air and/or truck
- Increased shipping in general, as the globalization fostered by the Internet makes it easier to purchase objects from very far away
- Increasing personal (and business) travel, as people seek to meet in person the widely dispersed people they have met on the Internet

This sector is particularly difficult to analyze. For instance, some of the above effects are interactive and potentially offsetting: some personal shopping by car is likely to be replaced by small-package shipping. Also, as we will see below, even well studied areas, such as the impact of telecommuting on vehicle miles traveled (VMT), are exceedingly complicated. Further, it will be particularly difficult to disentangle trends that have been ongoing for many years—such as the rapid growth in international trade, air travel, and VMT— from any impact the Internet may have. The Energy Information Administration is currently projecting that, for the next decade, transportation energy use will grow at more than twice the rate of either the building sector or the manufacturing sector.[212] Also, there are information gaps for many relevant aspects of transportation, including transportation by businesses and travel by self-employed home-based workers.

We do not believe we can predict with high confidence which of the above sets of trends will prove dominant. It is entirely possible that the above effects will roughly cancel out, and that transportation energy consumption will continue to grow at the rate it has in the recent past. On the other hand, we also view it as very plausible that the Internet's impact on the shipping of goods is roughly neutral, but with a significant positive impact on personal travel (and, to lesser extent, business travel). In either case, the information technology sector is not transportation intensive, and information is increasingly being delivered through the Internet. Thus, to the extent that much of the growth of GDP continues to come from the IT sector, the Internet economy is likely to allow some incremental economic growth that does not require the same amount of incremental transportation energy that traditional economic growth had required.

## TELEWORK

As noted in Section 3, "definitions and measurement are problematic, but home-based work in all its forms appears to constitute a sizable and growing component of the labor market."[213] A number of studies have shown telecommuting reduces commuting transportation, as would be expected.[214] Studies have shown that the benefit from reduced consumer trips is *not* reversed by an increase in other trips; two large U.S. studies actually showed that "the total travel savings are greater than commute travel savings alone," which "implies that non-commute travel actually decreases as a result of telecommuting." This is, however, a small effect.[215]

On the surface, then, telecommuting seems to clearly and significantly reduce transportation energy consumption. There are a number of indirect effects, however, that make the analysis of the energy benefits of telecommuting far more complicated. For instance, there is the impact of "latent demand": people who had previously chosen not to travel because of congestion, might change their minds if telecommuting reduces crowding on the roads. On other hand, by reducing peak congestion and improving traffic flow, the remaining traffic on the road might reduce their fuel consumption. Also, in the long-term, telecommuting may lead to more urban sprawl: more people moving farther away from centrally-located businesses into less crowded and less expensive homes farther away from cities.

A 1994 study by the U.S. Department of Energy that included all of these effects still found a substantial net saving in petroleum by the year 2010 due to telecommuting.[216] The direct benefit of telecommuting was reduced by slightly less than 50% when the benefit of improved traffic flow and the losses from latent demand and urban sprawl were all factored in.

On the other hand, one of the leading authorities in the field, Prof. Patricia Mokhtarian of the University of California, Davis, has argued that because of "counteracting forces," the "aggregate travel impacts will remain relatively flat into the future, even if the amount of telecommuting increases considerably."[217] For instance, she argues that early telecommuters have had longer commutes than the population as a whole, so that as telecommuting grows, there will be a reduction in the average commuting distance avoided. Also, she argues there are other increases in travel that may occur, particularly "demand for travel induced by telecommunications capabilities themselves." This so-called "induced demand," includes "an increased awareness of activities of interest," "stimulation of economic growth, which stimulates travel," and "an expanding network of personal and business relationships."[218]

Fundamentally, it is argued that there is a historical correlation between travel and communications.[219] That is, better communications technologies (such as phones and faxes) have not substituted for transportation, but indeed have served to stimulate transportation. The question for the next decade is whether the Internet represents a sufficiently qualitative improvement in communication—both because of technological superiority and because of the network effect discussed earlier—that it will break this historical relationship. Some analysts believe that it may.[220]

Moreover, insofar as the "Internet changes everything," as many have said, we believe it fundamentally changes telework, for several reasons. First, the Internet is forecasted to be a central technology for home offices. International Data Corporation (IDC) has estimated that the number of home offices is growing by about three million a year. IDC projects the number of home offices with PCs on the Internet will grow from 12 million in 1997 to 30 million in 2002.[221]

Second, as the Internet provides more access to more information, it, coupled with advances in IT technology such as high-speed connections, gives people working out of their home far more

capability. In particular, it gives home-based workers greater ability to perform "the applications they are most interested in, such as remote accessing of corporate data, collaborative working, and file sharing," according to Raymond Boggs, director of IDC's Home Office Market research program.[222] To the extent that multi-party teleconferencing qualitatively improves because of the Internet (discussed below), that will further increase the ability of people to work at home. Ernst & Young uses desktop videoconferencing to connect full-time home-based software consultants with both coworkers in corporate offices and clients.[223] Previously, the company was flying consultants to corporate offices once a week and paying their hotel bills.

Third, as e-commerce itself grows, both business-to-consumer and business-to-business, more jobs will involve spending a considerable amount of time on the Internet, jobs that can perhaps be done as easily from home as from the workplace. Much traditional telecommuting is only one or two days a week, which affords only modest opportunity for transportation savings, as Mokhtarian has noted. The Internet increasingly allows employees who work at home to stay connected both with their office and with customers and so it will increasingly make possible the kind of telecommuting practiced by a large number of workers at IBM and AT&T, where time at the office is substantially reduced (see Section 3).

The fourth reason the Internet fundamentally changes telework: Since business-to-consumer e-commerce is growing rapidly, teleworkers with sophisticated Internet technology are likely to be at the forefront of those who replace travel for shopping, banking, and the like with use of the Internet. Thus, while traditional telecommuters might substitute some of their saved telecommuting travel with travel for errands, Internet telecommuters may not. We will return to this important issue below.

Fifth, the Internet economy is fostering pure home-based work.

HOME-BASED BUSINESSES: “Just as home office growth has contributed to expanding Internet use, Internet availability has contributed to the growth and success of home offices," according to IDC’s Boggs.[224] "The Web enables a small business operating out of the home to establish a worldwide presence to promote itself and transact business online."

In Section 3, we saw the example of the Washington, DC area where “legions of workers are redefining the rhythms and rituals of their neighborhoods by pitching the commute and working out of their homes,” according to the *Washington Post*.[225] The article notes that “this rapid expansion is being driven in large part by leaps in technology, as high-speed Internet access, inexpensive computers and sophisticated telephone equipment allow virtual offices to flourish.” The DC area is the most connected in the country, with nearly 60% online as of fall 1999.

The growth in primary home-based business (HBB) workers (full-time workers with no second job) due to the Internet is especially important from an energy perspective. While “little or no study has been performed on the travel behavior of HBB workers,” Mokhtarian and Henderson published in 1998 the “first known U.S. study of HBB travel,” analyzing nearly 1000 workers surveyed by the California State Department of Transportation (Caltrans).[226] As might be expected, the analysis concludes that HBB workers spend less time traveling in cars (for all purposes) per day than either home-based telecommuters (HBT) or non-home-based (NHB) workers (i.e. conventional workers). HBB spent 1.23 hours a day traveling in cars, whereas HBT spent 1.39 and NHB spent 1.61.

As a crude calculation, suppose that each year from 1997 to 2010, there are 1 million additional HBBs because of the Internet economy (i.e. above and beyond the pre-Internet rate of growth in HBBs).[227] Assume each HBB avoids 0.38 hours a day in car travel for 250 work days (compared to what they would have traveled had they joined the work force as conventional works, NHBs). This

would avoid more than 15 million metric tons of carbon dioxide emissions in 2010, or about 0.7% of the emissions projected for the transportation sector in that year.[228]

Far more research needs to be done in this area.[229] For instance, anecdotal evidence suggests that HBBs fostered by the Internet may be even less transportation intensive than traditional HBBs. The *Washington Post* noted in October, "new home businesses also tend to be quiet and white-collar, a far cry from the busy walk-in clinics and noisy backyard repair shops that so riled neighbors in the past. In Herndon [Virginia], town officials are considering relaxed zoning rules for home businesses now that most of them don't bring increased traffic and clamor."[230] On the other hand, many HBBs will be using pick-up and deliver systems that rely on increased use of trucks and planes.

Also, if telework does in general promote sprawl, that has less impact on net transportation saved for HBBs than for traditional telecommuters. That is, if you are telecommuting one or two days a week but you move farther away from your work (and from an urban center), then your commutes will be longer, which, as noted earlier, undercuts the net transportation benefit of telecommuting (and may also increase travel time for shopping and errands). On the other hand, if you are an HBB (or Internet telecommuter who spends very little time at the office), moving farther from an urban center will not undercut the net transportation benefit of working at home. And if you are able to do many of your errands over the Internet, then sprawl will not increase your travel for those purposes as much either.

Overall, it seems likely that any significant growth in telework in general and HBBs in particular holds the potential to slow the rate of growth of transportation energy consumption. To expand on this point, telework will probably not reduce congestion nor vehicle miles traveled in an absolute sense. The United States has a growing economy and, unlike most of the other industrialized nations, significant projected growth in population (in large part due to immigration). What Internet-driven telework should make possible is more economic growth without as much incremental congestion and transportation energy consumption. In that sense, like much of the impact of the Internet on other sectors described earlier, the Internet economy should improve the capacity utilization of the existing transportation system.

## TELESHOPPING

> "The Internet has done for electronic commerce what Henry Ford did for the automobile – converted a luxury for the few into a relatively simple and inexpensive device for the many."[231]
>
> OECD, 1999

"The Internet is in some sense the ultimate mall," Russell Roberts of Washington University in St. Louis told National Public Radio in October.[232] It uniquely combines convenience, flow of information, selection, and cost. As noted in Section 3, one of the original motivations behind shopping malls, and one of their reasons for success, was an understanding "that consumers did not want to stop in several different places to run all their errands," in the words of Ragnar Nilsson, chief information officer of Europe's biggest department-store chain.[233]

Early analysis suggests that Internet shopping is largely substituting for rather than augmenting traditional retail shopping. A report released in August by Jupiter Communications, concluded that "only 6% (or $720 million of the expected $11.9 billion) of online commerce in 1999 will represent incremental sales— those that would not have occurred otherwise." Jupiter expects that the percentage of incremental sales will grow only slightly, to 6.5% in 2002.[234] Similarly, in May 1999, NFO Interactive, an online market research firm, reported that "online shoppers say they plan to decrease the amount of money they spend off-line retail stores in favor of spending more at online

retailers."[235] A March 1999 study by Merrill Lynch also concluded, "the Internet will tend to 'cannibalize' retail sales away from store-based retailers."[236] One factor that may somewhat slow the impact of this trend on personal transportation is that Merrill Lynch anticipates that perhaps $40 billion of $100 billion in Internet sales they project for 2003 will come at the expense of catalog shopping.

In March 1999, the online marketing research firm, Greenfield Online, announced that "a major new shopping study finds that 39 percent of those with access to be Internet say they go to the store or mall less often now that they can easily shop for and buy a wide variety of products online."[237] Greenfield's CEO, Rudy Nadilo, notes that "these results are significant to retailers, since Americans who use the Internet are 60 percent of the buying power the total U.S. population."

In September, Greenfield reported that "seventy percent of consumers on the Internet plan to do some or all of their holiday shopping online. But when surfing for gifts hits high gear in October, November and December, nary a major department store nor big-name catalog retailer is likely to be among the top online destinations for holiday e-commerce. The top Web sites online gift buyers say they plan to visit are virtual businesses only, with no physical store presence."[238]

Over the next few years, the Internet will increasingly provide alternatives to a large quantity of traditional errands. As noted in Section 3, Internet banking and other financial services are expected to see sharp growth. Many services that provide grocery shopping over the Internet are planning significant expansions over the coming year, including Webvan, HomeGrocer, and Peapod.[239] Already, as of the first quarter of 1999, 40% of new vehicle shoppers are using the Internet to help them shop, and that is projected to grow to more than 65% by the end of 2000, according to an August report by J.D. Power and Associates.[240] This may already be reducing trips (slightly). "More than one-third of the Internet shoppers surveyed report that they crossed at least one vehicle off their shopping list as a direct result of information they found online," said J.D. Power's Chris Denove. "This is bad news for manufacturers and retailers who want customers to test drive vehicles and not narrow their vehicle selections based on cold hard facts alone."

Sir Richard Greenbury, chairman of British department store Marks and Spencer, told *Harvard Business Review* in mid-1999:

> Right now, not many appliances are sold over the Net. But why couldn't and wouldn't consumers prefer to buy washing machines, say, or dishwashers, from the convenience of their own homes? Once channels are established -- and consumers' confidence grows -- why wouldn't the picture change accordingly? Most consumers do not purchase a dishwasher and walk out the store with it. So if they can get a dishwasher just as fast, or faster, by buying over the Internet, and the Net offers satisfactorily complete information about the product, why wouldn't they shop online?
>
> Why not buy wine on-line? Or dog food? Or water? Any product you don't need to look it carefully or touch is fair game.[241]

Many online retailers are working to improve the experience. For instance, "Lands' End is trying to make shopping online more like going to the mall with a friend," CNET News.com reported in September.[242] Lands' End has added two new features. One, "Lands' End Live," allows a customer to request the help of a personal assistant as they peruse the site together. The Lands' End assistant can help mix-and-match outfits and answer questions, either over instant chat (if the customer has only one telephone) or over a cell phone or telephone while viewing the same Web pages. The second,

"Shop With a Friend," allows two friends in separate locations to browse the same pages, while comparing prices and exchanging opinions over instant chat.

## TRAVEL TIME IS ENERGY

As the 1999 OECD report noted, “people have a limited amount of leisure time, and new activities will necessarily come at the expense of old.”[243] It seems likely that as more and more people spend more and more time using the Internet to “run errands,” gather information, and the like, one of the activities that some of them will spend less time doing is driving the car. If people switch from some traditional transportation to the Internet, they will primarily do so because of perceived benefits such as convenience and time saving, not to save energy. The energy savings will be a secondary benefit.

But the energy savings are large. As one major study of energy use and lifestyles noted, “a minute spent traveling uses 8 and 12 times as much energy, respectively, as a minute spent in service buildings or at home.”[244] Moreover, one's home is always using a fair amount of energy, even when one is traveling, whereas the family car uses energy only when it is being driven. Therefore, the incremental energy benefit of spending an extra minute online rather than traveling is likely to be even greater than 12 to 1.

The potential time savings from using the Internet are significant for both commuting and shopping. According to *Harvard Business Review*, in one AT&T unit, the typical alternative work participant “gained almost five weeks per year by eliminating a 50-minute daily commute.”[245] In one classroom exercise, MIT’s Sloan School of Management “asked seventy MBA students to compare ‘shopping experiences’ when shopping for CDs at Internet and conventional retailers. Including travel, search, and purchase times, our results showed that it took 35 minutes longer to shop in conventional outlets that it did in Internet outlets.”[246]

While many people enjoy the shopping experience, others do not. John Dodge made this point in his Internet column in the *Wall Street Journal* interactive edition, “Harried Shoppers Are Ready To Buy Groceries on the Web”:

> “Going to the grocery store with my two-and-half-year-old son is a tantrum waiting to happen," says Allison Martin, a 34-year-old mother of two in Portland, Ore. For the past few months, Ms. Martin has been doing her weekly $100 worth of shopping at HomeGrocer.com via her personal computer. As a result, her weekly shopping has been transformed from two hours of hell to a relatively placid 15 minutes on the PC. Add 10 minutes to put away the groceries once they're delivered -- there's free delivery for orders of more than $75 -- and Ms. Martin is free to go on to the other fires that parents of young children invariably have to extinguish.

He concludes that while shopping for groceries in cyberspace is far from perfect, “for stressed-out shoppers who'd just as soon never see the inside of a supermarket again, the advantages of the Internet are hard to beat.”

Mark Borsuk, Executive Director of the Real Estate Transformation Group, makes a similar point. Writing about shopping at Wal-Mart, which was touted by its Chairman in mid-1998 as "a social experience for many people in the world," Borsuk notes, “what is experiential about pushing a shopping cart through a 100,000 sq. ft. building to restock cereal, toilet paper, soap and buy name brands when they are available online?”[247] Wal-Mart, of course, now has its own Web site.

Merrill Lynch's Craig Schmidt believes that people won't stop going to malls completely, but that it is entirely likely that they will perceive "less reason for travel every weekend" and travel only every second or third weekend.

## NET IMPACT ON PERSONAL TRANSPORTATION

If people substitute time on the Internet for time spent in their car, that is a big energy saver as we have seen. On the one hand, we agree with those, such as Mokhtarian, who argue that people travel for more purposes than merely getting to a final destination or accomplishing some activity.[248] On the other hand, far more people appear to be either neutral toward or dislike certain short-distance travel— such as grocery shopping or commuting— than like it.[249] So while we would not be surprised if some of the travel time reduced by the Internet is replaced with other travel (such as walking, or long distance travel by car or plane), we would be very surprised if it were completely replaced.

We also believe the Internet changes telework, and that previous work on the subject of telecommuting, while important, will probably need to be redone completely for Internet-based teleworkers. The Internet is likely to substantially change telecommuting, to allow a significant number of workers to go beyond the traditional one or two days a week of telecommuting, and be come "Internet telecommuters," such as at IBM and AT&T.

Perhaps more important, the Internet is likely to substantially change self-employed home-based work, creating a large category of "Internet entrepreneurs." Both of these new classes of workers, and particular the latter, seem likely to have substantially less work-related transportation than traditional workers. Equally important, they will also have the skills and tools to perform online a substantial amount of shopping, banking, and other non-work transportation-intensive activities. For these reasons, it seems plausible that the Internet could break the historical relationship between communications and travel. And while personal transportation is likely to continue to grow in the future, it seems likely to grow at a slower rate than in the past.

Telework is not for everyone, and may be an undesired change for long-time traditional employees, "who are accustomed to a structured office environment," particularly middle managers, as *Harvard Business Review* has noted. On the other hand, Lorraine Fenton, VP of information technology for IBM North America points out that most "twenty-somethings" who are entering the labor force "have never had a private office, so to begin their work life without one is not a dramatic change."[250] The same point could be made about shopping online. An October study by Greenfield Online found that "Generation X" is doing the most buying online.[251] As their wealth grows, so too will the amount of online shopping.

Perhaps the most likely scenario is one described by Shelley Morrisette, Group Director for Quantitative Research, at Forrester Research:

> By 2003, consumers will bifurcate by technology attitude, income, education, and digital lifestyle. One group will constantly turn to the Net from multiple platforms to meet an ever-increasing variety of needs -- shopping, banking, investing, education, entertainment, and work. The other group will grudgingly adopt technology when necessary. This divide will exist for 10 years -- until Generation Next begins to form new households.[252]

Even if the Internet reduces personal transportation, that does not necessarily mean it will reduce total transportation. After all, the goods that consumers purchase over the Internet still need to be transported to consumers' homes, and only a few of them will be delivered over the Internet itself.

How business transportation is affected by business-to-consumer e-commerce and business-to-business e-commerce will determine the net impact of the Internet on transportation.

## BUSINESS TRANSPORTATION

While it is difficult to know with confidence the likely impact of the Internet on personal transportation, it is even harder in the case of business transportation. Fundamentally, this is a poorly studied and poorly understood area, as was made clear in a February 1999 Congressional hearing on "Present and Future Trends in Ground Transportation." Transportation consultant Alan E. Pisarski testified that "the areas where tremendous information gaps exist" include:

- Just-in-Time patterns and trends
- Current and Prospective NAFTA flows
- Intermodal freight movements
- Urban goods movement distribution
- Inland movements of goods moving in foreign trade
- Travel and tourism requirements, both intercity and international
- Major new trade corridor flows[253]

Many of these are critical to understanding the ultimate impact of the Internet on transportation. The rest of this section will try to touch on some of the key points in an area that will require far more research before definitive conclusions can be drawn.

BUSINESS-TO-CONSUMER TRANSPORTATION: It is, as we have seen, entirely possible that people will travel less for a variety of traditional errands. This change would have a net positive impact on energy intensity only if it did not result in extra energy being consumed by businesses to provide the end product of those errands. There are a variety of offsetting impacts on net business transportation resulting from business-to-consumer e-commerce: greater e-materialization and goods that would have been shipped anyway, on the one hand, and greater use of more energy-intensive delivery forms (such as overnight mail) and longer distance shipping (especially internationally), on the other hand.

First, those goods and services that are e-materialized will see a dramatic drop in shipping energy consumption. As the OECD noted in its 1999 report, "distribution costs are significantly reduced (by 50% to 90%) for electronically delivered products such as financial services, software, and travel."[254] Traditional software distribution costs drop from $15 to $0.20 - $0.50 for Internet delivery. Section 4 described a variety of items that will likely become e-materialized in part or in whole, including newspapers, catalogs, directories, magazines, direct mail, bills, greeting cards, and increasingly, books and music. By 2003, reductions in shipped paper goods alone (compared to what they otherwise would have been without the Internet) may reach 2.7 million tons. If the Post Office, with its 200,000 vehicles, cannot find alternatives to the many paper-related goods they are shipping, that by itself would have a big impact on transportation energy.

Also, in some sense, comparison shopping done on the Internet represents the e-materialization of the delivery of information about products that has traditionally required personal transportation. In the case of trying to find the best price for an automobile, this can be a considerable savings in transportation compared to visiting often widely dispersed auto dealers to acquire the same information.

Second, in many cases, business-to-consumer e-commerce displaces a purchase that would have been shipped anyway. This category includes many gifts purchased during the holiday season at other

times. It also includes products that are too large to carry out of the store (appliances, furniture, exercise equipment). Here, the personal transportation is saved, while there is little incremental increase in business shipping. Indeed, in some circumstances, there might be a reduction in business shipping. For instance, if you live in Virginia and buy a Christmas gift online for a relative in California, the e-tailer might be able to ship it from a West Coast warehouse or supplier. If you traveled to the store in Virginia, bought it, and had it shipped to California, the retailer would have had to ship the product from the warehouse or supplier to the store, and then it would be shipped again to California. In this case, the online purchase would probably save both personal and business transportation. (In the case where the Internet purchase displaces a purchase made over the phone or through a catalog, there will probably be very little change in either personal transportation or business shipping.)

Third, much of business-to-consumer e-commerce relies on more energy-intensive shipping modes, such as overnight mail. As environmental analyst David Rejeski has written, "when we opt for trucks instead of boats or rail, energy use goes up by a factor of four to five (from 400 or 500 BTUs per ton-mile to over 2,000). Moving the same package by air freight again increases the energy use dramatically (to over 14,000 BTUs per ton-mile). A life-cycle analysis by the clothing retailer Patagonia found that with traditional shipping, transportation accounted for 6% of the total energy needed to create and deliver its product. Using overnight mail raised that figure 28%.[255]

A key point is that *consumers can maximize the energy and environmental benefits of e-commerce by choosing the slowest delivery mode that circumstances allow*. A 20-mile round-trip to purchase two 5-pound products at one or more malls consumes about one gallon of gasoline. Having those packages transported 1000 miles by truck consumes some 0.1 gallons (and much less than that if railroads carry the packages for a significant fraction of the journey). Shipping the packages by air freight, however, consumes nearly 0.6 gallons. These numbers are only very rough approximations, but they make clear that overnight delivery of e-commerce purchases by air freight can offset a large fraction of the transportation energy benefits of teleshopping.[256]

This third factor is complicated by the fact that we do not know which e-commerce model will ultimately win in the marketplace and how efficient existing retailers are in their own transportation system. In the case of products delivered over a long distance, such as books, for instance, online purchases may allow drop-shipping directly from a primary distributor to a consumer, whereas traditional shopping would mean that the book might first travel from the distributor to the traditional bookstore's warehouse and then to the bookstore where the consumer buys it. While the net impact in this case is probably still an increase in business transportation energy, the ultimate impact is much more difficult to calculate.

For short-distance delivery, such as groceries, there is clearly an increase in business transportation, but the degree will probably depend on how much of the final deliveries become bundled. If a variety of different trucks all show up at the same house or in the same neighborhood over the course of a week, each making individual deliveries, that will decrease energy productivity. On the other hand, many companies are seeking to bundle deliveries, though it is far from clear which model will win in the marketplace and there is likely to be a long shaking out period.[257] Peapod's Mike Brennan has said, "We can also leverage the distribution model to things like dry-cleaning and videos."[258] Others envision bundling a very broad range of products and services for direct delivery to customers' homes including "groceries, prepared meals, pet food and supplies, postage stamps, dry-cleaning, video and video game rentals, film processing, bottled water and cooler, as well as package pickup and delivery."[259] In the long-term, consumers may not require overnight delivery of many items they purchase regularly (pet food, home office supplies, vitamins and health care products, and so on).

What they will need is reliable delivery at regular intervals, which in theory should allow an efficient system to be set up.

This might also be a role for the Post Office, since they already have the infrastructure in place for home deliveries, and they are likely to suffer the most loss in business from the rise in electronic media. Brad Allenby, AT&T's Vice President for Environment, Health and Safety has written, "the U. S. Post Office passes virtually every home in the country on a daily basis, so piggybacking delivery of new t-shirts on the existing delivery system should be relatively efficient economically, energetically, and environmentally."[260] Amazon.com sends 65% of its good through the Postal Service.[261] The Postal Service will, however, face fierce competition from major shipping companies, like UPS. For such companies, energy is significant cost of doing business, so there is a great incentive to maximize efficiency; these companies are already early adopters of alternative-fueled vehicles and many plan to be early adopters of advanced efficiency vehicles. Also, for such companies, a 10 percent increase in package delivery might only mean a 5 percent increase in vehicle miles traveled, because of their sophisticated use of information technology to optimize delivery routes and times.[262] On top of all these complications, the Internet is, as discussed earlier and below, significantly affecting the delivery supply chain, severely complicating any life-cycle analysis.

The fourth major factor affecting calculations of the impact of business-to-consumer e-commerce on transportation energy is the impact the Internet will have on international trade. To the extent that it becomes easier to learn about and purchase products from faraway, that will tend to increase the overall energy intensity of the transportation system. In the United States, imports of foreign goods have been growing at a rapid pace for a long time. Transportation expert Alan Pisarski believes that is a key reason why ton-miles of freight per dollar of GNP, which had been declining slowly but steadily from 1950 to 1985, rose from 1985 through 1995.[263] Of course, so many consumer goods are produced overseas, it is far from clear that business-to-consumer e-commerce will have a noticeable impact in this area (though business to business e-commerce, discussed below, may).

Interestingly, one of the most important of all U.S imports as measured in both total value and total weight is oil. For the past decade, U.S. imports of oil have ranged between $50 billion and $70 billion a year, and now routinely exceed 10 million barrels a day. So if the Internet decreases transportation energy intensity, its biggest single impact on international trade may be to slow the rise in imported of oil, which is otherwise projected to grow as much as 50 percent in the next decade. On the other hand, if it leads to an increase in transportation energy intensity, oil imports would rise, further increasing energy intensity.[264]

BUSINESS-TO-BUSINESS TRANSPORTATION: We would expect the transportation energy impact of business-to-business e-commerce to far exceed that of business-to-consumer e-commerce, since the dollar value of the former by all accounts 5 to 10 times larger than that of the latter. Unfortunately, this is an area where, as noted above, there are key information gaps. We will briefly discuss the key areas of impact, all of which need much more study.

As discussed in Section 4, business-to-business e-commerce may exceed $1 trillion in a few years. Better supply chain management may ultimately reduce inventories by 25% to 35%, saving $250 billion to $350 billion across the economy. Since a significant part of the cost of inventories is related to transportation, reducing inventories should reduce transportation energy consumption.

Yet, one of the reasons inventories are reduced is because of greater use of just-in-time (JIT) manufacturing. And while the impact of JIT on energy consumption is poorly understood, it is widely believed that accelerating delivery times means using more energy-intensive forms of transport, particular trucks and planes.[265] It is also believed to lead to increases in deliveries by

trucks that are not completely full (and that return empty). This in turn may contribute to the astonishing industry estimate, reported in the *Economist* magazine, that "about half the lorries on America's roads at any one time are running empty."[266]

On the other hand, the real power of the Internet is its ability to improve manufacturing productivity overall. The previous section provided many examples of the Internet dramatically improving forecasting, and eliminating mistakes and wasted production. All of this "saving of resources," to use the words of Chairman Greenspan, is, in the environmental sense, the highest form of energy savings: pollution prevention. Few things save more transportation energy than *not* shipping products to warehouses or distributors that you cannot later sell. The Internet is fostering "just when needed" manufacturing among the majority of the fasting growing U.S. businesses, according to a September report by PricewaterhouseCoopers.[267] As one example, books often have a very high rate of returns. Reducing returns or preventing them completely (as can occur with Internet booksellers, print on demand, and ultimately electronic books) saves shipping in both directions. Similarly, we have seen that the Internet dramatically reduces mistaken orders, which are also a form of purely wasted transportation energy, often, again, in two directions. As companies dematerialize blueprints. invoices, and the like that too represents avoided transportation. The combined impact can be large, as the 1999 OECD report explained:

> Also the use of advanced forecasting systems and third-party as opposed to internal, transportation services means that trucks run fully loaded, do not incur empty "back-haul" journeys and more accurately deliver what is needed. In the case of one Japanese supermarket, this has resulted in a 20 percent reduction in the number of deliveries.

Equally important will be the extent to which the Internet allows so-called disintermediation—eliminating the middleman. To repeat the example from Section 3, Home Depot moves 85% of its merchandise directly from the manufacturer to its stores. Warehouses are bypassed. Also since Home Depot has such high-volume, "the products frequently ship in full truckloads, making the system even more cost-effective."[268] In general, shipping from a manufacturer to a distributor and then from a distributor to a retailer is likely to be less efficient than shipping from a manufacturer directly to a retailer (or even to a consumer).

Furthermore, as we have seen throughout this paper, the Internet has a great ability to increase capacity utilization in every sector the economy. The transportation sector is no exception. All of those empty or partially loaded trucks on U.S. highways are a particularly large opportunity. A number of companies are pursuing Internet-based systems for auctioning off that empty space, including UPS and The National Transportation Exchange (NTE). Ken Lyon, the head of information systems for UPS's Logistics Group told *Wired* magazine in September: "Globally, there's a vast number of trucks, ships, and aircraft that whiz around at less than full capacity. Let's sell that space. It would be a more dynamic market."[269] The NTE has already begun to connect shippers who have loads they want to move at low cost with fleet managers who have space to fill. The *Economist* described how NTE works:

> NTE helps a spot market by setting daily prices based on information from several hundred fleet managers about the destinations of their vehicles and the amounts of space available. It then works out the best deals. When a deal is agreed, it issues a contract and handles payment. The whole process takes only a few minutes. NTE collects a commission based on the value of each deal, the fleet manager gets extra revenue that he would otherwise have missed out on, the shipper gets a bargain price, at the cost of some loss of flexibility.[270]

If online auctions were to increase the overall load of cargo trucks on the road by even 10 percentage points over the next 10 years, the impact on transportation energy intensity would be enormous. This would be one of the best examples of eee-commerce: e-commerce that maximizes energy savings and environmental benefits

Some airlines have already been successful at this sort of auctioning. American Airlines, one of the industry leaders in yield management, still ends up with unsold seats in many markets. Prior to the Internet, the airline did not have a simple and profitable way to market these seats at the last-minute. Now, every week, over one million "NetSAAver" subscribers get email from the airline listing very low fares for certain undersubscribed markets for travel that weekend. Launched in March 1996, the program was generating tens of millions of incremental dollars for American by mid 1998.[271]

Certainly, even more than in the case of business-to-consumer e-commerce, business-to-business e-commerce is likely to foster international trade and transportation over greater distances, which will tend to increase transportation energy intensity. Given how rapidly international trade has grown in recent years, and how sharply U.S. imports have risen in particular, it will be difficult to disentangle the effect of the Internet from globalization in general. One benefit of the Internet in the area of long-haul shipping is that the Internet allows "bartering high-transportation cost assets (such as paper or steel)."[272] So if there were a company in California that was going to purchase paper from a Georgia company, and there were a New York company that was going to purchase the same kind of paper from an Oregon company, it would be possible to switch buyers. So instead of shipping cross-country twice, the net result would be two relatively short trips. Roger Stone says that Paperexchange.com is fostering exactly this type of efficiency gain. Indeed, material exchanges can also be integrated into transportation exchanges like NTE to help maximize the efficiency of both.[273]

Finally, there is e-materialization, which is also pure pollution prevention and thus also likely to have a big impact. If, as discussed above, manufacturers are better able to produce just what is needed and make fewer mistakes in manufacturing, they will need fewer raw materials (and fewer new manufacturing plants) per dollar of GDP. Given that raw materials are among the heaviest goods that are transported, even a very small savings here will have a very large impact on transportation energy intensity. And if e-commerce does reduce the amount of construction per dollar of GDP, that too will have a significant impact, since construction is very transportation intensive. The construction of commercial buildings (and manufacturing plants) in particular relies on a great deal of steel and cement, two of the heaviest items to transport.

TELECONFERENCING: A number of analyses have shown that video-teleconferencing has under one percent of the energy consumption and greenhouse gas emissions of airline travel.[274] Some hi-tech companies have begun to use teleconferencing to make a significant dent in business travel. For instance, Telia, one of Europe's leading telecommunications companies, had 34,400 teleconferences in 1998, up more than 300% during the past three years. This allowed the company to cut its business trips to 149,000 for the year, down 12% from 1997 levels.[275]

Prior to the rapid growth of the Internet, studies had suggested that the potential for teleconferencing to substitute for some types of business travel was large,[276] and that up to 25% of business travel could be eliminated due to high-technology substitution.[277] Teleconferencing experts point out a number of advantages that make the Internet "the medium of choice for telecommuting":

> The ubiquitous use of browser technologies, the escalating acceptance of Java language among programmers, the increasing sophistication of multipoint teleconferencing options, growing cooperation among vendors in developing meaningful standards, and the advent of

> new technology that allows the industry to meet customer demands far better and faster and deliver "real time" conferencing capability.[278]

According to IDC, "the evolution from $70,000 room-based videoconferencing dinosaurs to today's sleek, streamlined desktop, set-top, and compact videoconferencing solutions makes this technology more appealing and attainable to a wider range of users."[279] A number of commercial products today can deliver "truly real-time 'TV quality' video at 30 frames per second." IDC projects that the average sales price of commercial desktop videoconferencing equipment will drop to $850 by 2003.

Media accounts of the hassles and delays of air travel seem to be occurring with increasing frequency. Political leaders have introduced proposals for a "Passenger Bill of Rights." Yet just as air travel may be becoming less desirable to a significant number of business travelers, the alternative is dramatically improving in quality. Indeed, to the extent that businesses are driven by a desire to cut costs, increase the speed of communications, and improve teamwork, "desktop teleconferencing" offers unique benefits.[280]

It is too soon to say whether this next generation of teleconferencing will slow the growth projected for air travel in the coming decade. It is certainly plausible that it will have no net impact, and that any reduction in air travel due to teleconferencing is offset by the "induced demand" of improved communication—a desire to meet in person the many new people one meets through teleconferencing.

On the other hand, there are two network effects that might give a new boost to Internet teleconferencing. First, the rapid growth in the spread of advanced by IT equipment and high-speed connections to businesses and individuals is dramatically increasing the number of people who can video teleconference. According to IDC, desktop and compact videoconferencing shipments are projected to rise steadily from 400,000 in 1999 to 2.1 million in 2003, and the installed base of endpoints will rise from 600,000 in 1998 to more than 4.2 million by 2003.

Second, more and more of the people entering the labor force and management positions have been raised on PC-based interactive communications. Evan Rosen has written

> This generation does homework on a powerful PC while checking out the World Wide Web. Immediate information and results seem natural. So does leveraging collective knowledge through the Internet and corporate intranets. Visiting an internal Web site with a few mouse clicks makes more sense than placing a call to internal specialists and waiting for a call back. Since Webites grew up playing interactive video games, interacting with PCs becomes a breeze. After participating in on-line chat groups, adding a camera to a computer seems like a logical next step. Real-time video communication is more an evolution that a revolution.[281]

Should this generation embrace teleconferencing to any significant extent, the impact on transportation energy intensity would be enormous.

# VI. CONCLUSION: EEE-COMMERCE

Energy intensity in every sector could be significantly reduced over the next several years under plausible scenarios for the impact of the Internet economy on businesses and consumers. It may already be happening now, and is likely to accelerate because of improvements in technology, large expenditures by businesses, the network effect, and the growth in the labor force of a generation raised on electronic interaction.

While energy use will continue to rise throughout the next decade, the Internet economy appears to allow a certain amount of incremental growth that does not require as much energy and resource consumption as traditional economic growth. The impact of the Internet economy, coupled with other trends we have discussed (such as corporate energy outsourcing and corporate action on global warming), lead us to believe that from 1997 to 2007, the nation will experience annual declines in energy intensity (energy consumed per dollar of GDP) of more than 1.5%—and perhaps more than 2.0%.

We expect to see the biggest impact in the manufacturing sector. E-materialization is likely to have its greatest effect on some of the most energy intensive sectors, including pulp and paper, construction, and the production of the materials needed for construction. Also, if indeed the value of business-to-business e-commerce exceeds $1 trillion in a few years, it is certain to cut many energy-related costs in manufacturing, including inventories, overproduction, and mistakes. At the highest level, the information technology revolution and the Internet economy appears to be deepening capital and increasing total factor productivity, thereby improving energy and resource efficiency.

Commercial buildings, too, are likely to see large savings. Telework may significantly reduce the average amount of office space needed for each worker in the economy (as Internet telecommuters spend less time at the office and as there is sharp growth in purely home-based workers). Business-to-consumer e-commerce may significantly reduce the amount of retail space needed for each dollar of sales in the economy. Certain retail establishments, such as banks and perhaps post offices, may suffer large impacts. Some of these savings may be offset by the energy consumed by the equipment used to run the Internet, but early reports that this was a dominant effect appear to be seriously flawed.

Transportation is the most difficult area to analyze because there are so many complicating factors. We would not be surprised if, for instance, much of the transportation energy benefits from Internet shopping were offset by increased energy for delivering goods to the home (unless the Post Office, which already passes virtually every home daily, becomes the primary means of delivery). On the other hand, we think several areas hold large potential for net savings. An increase in telework would be among the most important. Internet telecommuters are likely to commute less than traditional telecommuters. Purely home-based workers may offset the most transportation energy. They are also far more immune to the counteracting effect of urban sprawl. Dematerialization is pure pollution prevention in the area of transportation. In the next several years we may avoid the transportation of millions of tons of paper and construction material. In some sense, there is a competition between e-materialization increasing the GDP per ton of shipped goods versus the desire for greater speed increasing the energy per ton-mile and greater international trade increasing the total miles of freight transport. Business-to-business e-commerce may increase the need for speed on the one hand, and eliminate the need entirely for some transportation on the other. There is also a large opportunities for greater use of real-time information to improve the capacity utilization of the transportation system. The transportation sector is the sector forecasted to have the fastest growth in energy

consumption over the next decade, and while the Internet economy will not stop that growth, it has great potential to slow it.

Residential buildings are likely to see increases in energy consumption. More people will spend more time at home using electricity-consuming equipment, such as PCs, to access the Internet for work, shopping, and other activities.

If the Internet economy does have these impacts, many factors widely used in economic, energy, and environmental models—energy per GDP, construction per GDP, paper use per GDP, and perhaps the impact of GDP growth on inflation—need to be changed. Important predictions, such as the number of power plants the United States will need to build in the next decade, and the cost to the nation of achieving greenhouse gas reductions, would need to be changed. Also, certain of the above trends are still in a sufficient state of flux that they could be influenced by companies and governments seeking to maximize environmental benefits. In particular, it seems worthwhile to figure out if there is a way to minimize the environmental impact of multiple deliveries of packages to the same residential neighborhood.

For all of these reasons, every one of the above trends merits far greater study. We would urge government agencies and major industry groups to examine baseline trends for the 1990s, and then start tracking relevant data. The Department of Energy, the Department of Transportation, the EPA, and the Department of Commerce should establish a Task Force on the Internet and the Environment. We would also hope that major IT and Internet companies would try to understand how they can better foster choices that improve the environment. We would urge all businesses seeking to reduce their environmental impact to explore how they can use IT and the Internet economy to achieve the kind of deep and ongoing emissions reductions that IBM and other companies have achieved.

Finally, we would urge consumers to see e-commerce as a way they can minimize their environmental impact. This study has made clear that e-commerce is likely to have myriad energy and environmental benefits. When consumers are shopping on the Internet, they can maximize those benefits by choosing the slowest delivery method that circumstances permit. That would truly create *eee-commerce*.

# ENDNOTES

[1]Alan Greenspan, "High-tech industry in the U.S. economy," Testimony Before the Joint Economic Committee, U.S. Congress, June 14, 1999**,** www.bog.frb.fed.us/boarddocs/testimony/1999/19990614.htm [Hereafter Greenspan, "High-tech," June 1999].

[2]Andrew Wyckoff and Alessandra Colecchia, *The Economic and Social Impact of Electronic Commerce*, Organisation for Economic Co-Operation and Development (OECD), Paris, France, 1999, www.oecd.org/subject/e_commerce/summary.htm. [Hereafter *OECD 1999*.] In terms of citations, this paper takes a similar approach to that of the OECD study (p. 26): "While this book tries to rely on scholarly work and solid statistical data as much as possible, to gain insight into the macroeconomic impact of a phenomenon that is changing as quickly as e-commerce requires relying on private data sources, expert opinion, the popular press and anecdotal statistics as well."

[3]Energy Information Administration (EIA), "Emissions of Greenhouse Gases in the United States 1998," U.S. Department of Energy, October 1999, www.eia.doe.gov/oiaf/1605/ggrpt/index.html.

[4]For those interested in the current thinking by the scientific community on global warming and its likely impact on the United States, a comprehensive paper on the subject is Tom Wigley, *The Science of Climate Change*, Pew Center on Global Climate Change, June 1999, Arlington, VA, www.pewclimate.org/projects/env_science.html.

[5]*OECD 1999*, p. 31. For an extensive discussion of the data problems involved in tracking the Internet economy, see John Haltiwanger and Ron Jamrin, "Measuring the Digital Economy," Center for Economic Studies, U.S. Bureau of the Census, Department of Commerce, May 1999, http://mitpress.mit.edu/UDE/haltiwanger.pdf

[6]For a discussion of the definitional issue, see *OECD 1999*, pp. 28-29.

[7]Two of the first articles on the subject are David Rejeski, "Electronic Impact," *The Environmental Forum*, July/August 1999, pp. 32-38 and Nevin Cohen, "Greening the Internet," *Environmental Quality Management*, Fall 1999. A good online survey of views on the broader subject, "Is IT [Information Technology] kind to Planet Earth?" can be found in the October issue of *iMP Magazine*, www.cisp.org/imp/october_99/10_99contents.htm. It includes the Cohen piece. See also European Commission Working Circle on Sustainability and the Information Society, *Contributions of the Information Society to Sustainable Development*, European Commission, Brussels, 1995**,** www.faw.uni-ulm.de/sust-info-society/.

[8]See, for instance, the discussion of cloth versus disposable diapers and paper versus plastic bags in Michael Brower and Warren Leon, *The Consumers Guide to Effective Environmental Choices* (New York: Three Rivers Press, 1999), pp. 128-133.

[9]Greenspan, "High-tech," June 1999.

[10]Ibid.

[11]Lynn Margherio et al, "The Emerging Digital Economy," Department of Commerce, April 1998 www.ecommerce.gov/emerging.htm [Hereafter *Commerce 1998*].

[12]Ibid.

[13]"Forrester Research: Over 2 Billion Orders Placed Online Annually," **www.nua.ie/surveys/index.cgi?f=VS&art_id=905355239&rel=true,** August 30, 1999.

[14]Larry Downes and Chunka Mui, *Unleashing the Killer App* (Boston, MA: Harvard Business School Press, 1998), pp. 23-28. The book contains a good discussion of Metcalfe's Law. Robert Metcalfe founded the 3Com Corp. and designed the Ethernet protocol for computer networks.

[15]Martin Kenney and James Curry, "E-Commerce: Implications for Firm Strategy and Industry Configuration," July, 1999. Paper No. 2, University of California E-conomy Project, http://e-conomy.berkeley.edu/pubs/wp/ewp2.html.

[16]Mohanbir Sawhney and Steven Kaplan, "Let's Get Vertical," *Business 2*, September 1999, p. 85.

[17]*Commerce 1998*, Appendix 3 (A3), pp. 27-28. These savings are just in purchases of nonproduction and maintenance, repair and operations materials.

[18]"Internet Anxiety," *Business Week*, June 28, 1999, www.businessweek.com/1999/99_26/b3635001.htm.

[19] David Henry, Sandra Cooke et al, *The Emerging Digital Economy II*, Department of Commerce, June 1999, www.ecommerce.gov/ede/report.html [Hereafter *Commerce 1999*]. For a list of all of the IT-producing industries see Table 2.1 of the report.

[20]Anitesh Barua and Andrew Whinston et al, "The Internet Economy Indicators," Center for Research in Electronic Commerce, Graduate School of Business, University of Texas at Austin, 1999, www.Internetindicators.com/key_findings_oct_99.html. The study was published with many important caveats, which are discussed at www.Internetindicators.com/qa.html.
[21]Andrew Hamilton, "Brains that Click," *Popular Mechanics*, March 1949, p. 168.
[22]For good historical discussions of dematerialization see Jesse Ausubel, "The Environment for Future Business: Efficiency Will Win," *Pollution Prevention Review* 8(1):39-52, Winter 1998, http://phe.rockefeller.edu/future_business/, and Iddo Wernick, "Materialization and Dematerialization: Measures and Trends," *Daedalus* 125(3):171-198 (Summer 1996), http://phe.rockefeller.edu/Daedalus/Demat/.
[23]Alan Greenspan, Speech at the 80th Anniversary Awards Dinner of The Conference Board, New York City, October 16, 1996, www.federalreserve.gov/boarddocs/speeches/1996/19961016.htm.
[24]Diane Coyle, *The Weightless World: Strategies for Managing the Digital Economy* (Cambridge, MA: MIT Press, 1998).
[25]Ibid., p. 3.
[26]Brad Cox, "Superdistribution," *Wired*, September 1994, www.wired.com/wired/archive/2.09/superdis.html.
[27]Nicholas Negroponte, *Being Digital* (New York: Vintage Books, 1996), p. 12.
[28]Chris Meyer, "What's the Matter," *Business 2.0*, April 1999, www.business2.com/articles/1999/04/content/newrules.html.
[29]As cited in Thomas Steward, *Intellectual Capital* (New York: Currency Doubleday, 1999), p. x.
[30]For a good discussion of the issue of the Internet and transaction costs, see Downes and Mui, *Unleashing the Killer App*, pp. 35-55.
[31]Erik Brynjolfsson and Michael D. Smith, "Frictionless Commerce: A Comparison of Internet and Conventional Retailers," MIT Sloan School of Management, Cambridge, MA, August 1999, http://e-commerce.mit.edu/papers/friction [Hereafter *MIT 1999*]. Other studies have found similar results, though some items for sale on the Internet can be more expensive, particularly those in high demand. See Jacob M. Schlesinger, "Wholesale Numbers Rattle Shares And Give Skeptics Fresh Ammunition," *Wall Street Journal Interactive Edition*, October 18, 1999, www.wsj.com.
[32]In the e-commerce literature, friction is a more complicated issue than has been focused on here. It typically involves the issue of whether the Internet will eliminate all intermediaries or whether there will be new intermediaries that themselves represent a transactional cost or will in fact be the source all of frictionless commerce. For a good discussion of this see, Mohan Sawhney "The Death of Friction," Kellogg Graduate School of Management, 1997, available at http://sawhney.kellogg.nwu.edu/ (this site requires sign-in).
[33]"The Net Imperative: A Survey of Business in the Internet," *The Economist*, June 26, 1999, p. 39 [Hereafter *Economist 1999*].
[34]John Jennings, "Sustainable Development," Shell International, London, April 17, 1997.
[35]For a discussion of Shell and its scenarios, see Joseph Romm, *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions* (Washington DC: Island Press, 1999), pp. 16-27.
[36]*Economist*, September 28, 1991. See also Peter Senge, *The Fifth Discipline* (New York: Doubleday, 1990), p. 181.
[37]This historical discussion is based on Brown, Levin, Romm, Rosenfeld, and Koomey, "Engineering-Economic Studies of Energy Technologies to Reduce Greenhouse Gas Emissions: Opportunities and Challenges," *Annual Review of Energy and Environment*, 1998, pp. 287-385.
[38]Primary energy use is the chemical energy embodied in fossil fuels (coal, oil, and natural gas) or biomass, the potential energy of a water reservoir, the electromagnetic energy of solar radiation, and other renewable resources, and the energy released in nuclear reactors. For the most part, primary energy is transformed into electricity or fuels such as gasoline, jet fuel, heating oil, or charcoal – called secondary energy. The end-use sectors of the energy system provide energy services such as cooking, illumination, comfortable indoor climate, refrigerated storage, transportation, and consumer goods using both primary and secondary energy.

[39]EIA, *Annual Energy Review 1998*, U.S. Department of Energy, Washington, DC, July 1999, Figure 1.5 and Table 1.5, pp. 12-13, www.eia.doe.gov/pub/energy.overview/aer98/graph/0105c.pdf and www.eia.doe.gov/pub/energy.overview/aer98/txt/aer0105.txt.
[40]Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC, October 1999, www.bea.doc.gov/bea/dn1.htm. These revisions include counting businesses' purchased software as a capital investment that increases GDP.
[41]Ibid.
[42] EIA, *Short-Term Energy Outlook*, Washington, DC, December 1999, www.eia.doe.gov/emeu/steo/pub/contents.html and personal communications with Skip Laitner and Howard Geller. EIA's most recent forecast is that energy intensity in 1999 will drop 2.3%.
[43]Personal communications with Skip Laitner of EPA and Gail Boyd of Argonne.
[44]Howard Geller and Jennifer Thorne, "U.S. Carbon Emissions Barely Increase in 1998," American Council for an Energy-Efficient Economy, Washington, DC July 1999, www.aceee.org/briefs/98score.htm.
[45]EIA, "Weather Assumptions Changed for EIA's Short-Term Energy Projections," September 1999, www.eia.doe.gov/neic/press/press136.html.
[46]Romm, *Cool Companies*, pp. 77-99.
[47]Ibid., pp. 28-30, 140-156.
[48]"Army Slashes Energy Bills," *Energy User News*, September 1999, pp. 34-40.
[49]Ibid., pp. 57-63.
[50]*Fortune*, May 11, 1998, p. 132C.
[51]EIA, *Electric Utility Demand Side Management 1997*, December 1998, www.eia.doe.gov/cneaf/electricity/dsm/dsm_sum.html.
[52]EIA, *Electric Power Annual - 1997* (Volume II), October 1998, www.eia.doe.gov/cneaf/electricity/epav2/html_tables/epav2t48p1.html.
[53]See, for instance, Romm, *Cool Companies*, pp. 117-118 and 159-162.
[54]Steve Liesman, "Dropping the Fight On Science, Companies Are Scrambling to Look a Little Greener," *Wall Street Journal*, October 19, 1999, p. B1.
[55]John A. "Skip" Laitner, "The Information and Communication Technology Revolution: Can it be Good for Both the Economy and the Climate?" U.S. Environmental Protection Agency, Washington, DC, December 1999.
[56]*Commerce 1999*, Chapter 2.
[57]Macroeconomic Advisers, LLC, *Productivity and Potential GDP in the "New" US Economy*, September 1999. The results cited in the text are from the "Executive Summary and Conclusions," of the report.
[58]Greenspan, "High-tech," June 1999.
[59]"Fast Growth Companies Conserving Capital to Boost Financial Productivity, PricewaterhouseCoopers Finds," PricewaterhouseCoopers press release, New York, September 21, 1999, www.pwcglobal.com/extweb/ncpressrelease.nsf/DocID/87741394208BD38F852567F300588DB8?OpenDocument.
[60]Peter W. Huber and Mark P. Mills, "Dig more coal—the PCs are coming," *Forbes*, May 31, 1999, pp. 70-72.
[61]Personal communications with Amory Lovins, Alan Meier, and Jon Koomey.
[62]Jonathan Koomey, Kaoru Kawamoto, Maryann Piette, Richard Brown, and Bruce Nordman. "Initial comments on *The Internet Begins with Coal*," memo to Skip Laitner (EPA), Lawrence Berkeley National Laboratory, Berkeley, CA, December 1999, available at http://enduse.lbl.gov/Projects/infotech.html (TK). The underlying analysis is Mark P. Mills, *The Internet Begins with Coal: A Preliminary Exploration of the Impact of the Internet on Electricity Consumption*, The Greening Earth Society, Arlington, VA, May 1999, http://www.fossilfuels.org. The LBNL analysis was able to provide corrected estimates for every calculation by Mills except the embodied energy, which as the LBNL authors point out, is a very complicated analysis and only rarely carried out.
[63]Typical home Internet users are online 5 to 10 hours a week (under 500 hours a year). So they consume under 100 kWh a year on the Internet, more than a factor of 10 *less than* the estimate of the *Forbes'* authors of 1000 kWh a year. And this does not even include any of the myriad potential offsets discussed in our study, such as a reduction in television watching, which would save a considerable amount of electricity. Long before the Internet was popular, PCs have been used at home for word processing, games, and the like. It is therefore methodologically flawed to ascribe all or even most of the electricity consumed for

home PCs in general to the Internet (for a discussion of this "boundary" issue, see Koomey et al, "Initial comments on *The Internet Begins with Coal*"). Internet telecommuters and home-based businesses use the Internet considerably more than the average home user, but, as discussed in section 3, they are probably displacing far more electricity consumption by not working in an electricity-intensive office building. The issue of the electricity consumed by business PCs on the Internet is discussed below.

[64]John B. Horrigan, Frances H. Irwin, and Elizabeth Cook, *Taking a Byte Out Of Carbon*, World Resources Institute, Washington D.C., 1998, p. 18. Many manufacturers of PCs and computer chips are also working to reduce the energy needed to make their products, as well as GHGs emitted during production. See, for instance, Joseph Romm, *Cool Companies*, pp. 100-112.

[65]"Dell Online," Harvard Business School Case Study 9-598-116, revised March 26, 1999, Harvard Business School Publishing, Boston, MA, p. 23. So if a business user seeking the latest technology for Internet access replaces an old, inefficient computer with a new laptop, for instance, that might actually result in a net *reduction* in the electricity consumed by that Internet user. When the home PC market saturates, the same will likely be true of home Internet use.

[66]*OECD 1999*, p. 28.

[67]Personal communications with Lee Eng Lock, Supersymmetry.

[68]Horrigan et al, *Taking a Byte Out of Carbon*, pp. 14-16.

[69]*OECD 1999*, p. 13

[70]Personal communications with Craig Schmidt.

[71]The non-energy parts of this table are from Mohan Sawhney and David Contreras, "Amazon.com—Winning the Online Book Wars," case study, J.L. Kellogg Graduate School of Management, Northwestern University, p. 26, http://sawhney.kellogg.nwu.edu/. The case study cites Morgan Stanley Research as the source of the data in the table.

[72]EIA, *A Look at Commercial Buildings in 1995*, October 1998, p. 218 [Hereafter, *CBECS*]. These are the building's utility costs. Modern warehouses are somewhat more energy intensive than the average. On the other hand, so are modern retail stores.

[73]We are taking the ratio of sales per square foot as the ratio of goods per square foot. By this calculation, online stores have roughly eight times the goods per square foot as traditional stores.

[74] Romm, *Cool Companies*, pp. 46-76.

[75]"Net gets used books new looks," *USA Today*, July 21, 1999, p. 5D. Part of the reason the ratio is so high in this case is that Nevada has no inventory tax or corporate income tax and land is cheap.

[76]"Keeping it Digital," *Wired*, September 1999, p. 68.

[77]"Online Boom to Benefit Storage Companies," www.nua.ie/surveys/index.cgi?f=VS&art_id=905355215&rel=true, Aug. 20, 1999.

[78]Sawhney and Contreras, "Amazon.com," p. 10.

[79]Steve Lohr, "The Web Hasn't Replaced the Storefront Quite Yet," *New York Times*, Oct. 3, 1999.

[80]Personal communications with Tad Smith.

[81]*Commerce 1998*, A4, p. 36. The cost to the customer of online bill payment is probably not strictly zero, as the table in the Commerce Report indicates, but it is likely to be negligible.

[82]"Over 32 Million U.S. Households Will Be Banking Online by 2003," IDC press release, Framingham, MA, June 1, 1999, **www.idcresearch.com/Press/default.htm**.

[83]*Commerce 1998*, A4, pp. 38-41.

[84]*OECD 1999*, p. 48.

[85]Ad for telebank.com, *Wall Street Journal*, Aug. 9, 1999, p. c7.

[86]As cited in *OECD 1999*, p. 48.

[87]As cited in Kevin Childs, "Internet Threatens Postal Service," *Editor & Publisher Interactive*, April 24, 1998.

[88]"Online Billing Set to Take Off," *The Industry Standard*, Sept. 13, 1999, p. 110.

[89]Statement of William J. Henderson before the Subcommittee on the Postal Service, House Committee on Government Reform, October 21, 1999, http://www.house.gov/reform/postal/hearings/henderson.pdf.

[90]Testimony of Bernard L. Ungar, Director of Government Business Operations Issues, before the Subcommittee on the Postal Service, House Committee on Government Reform. GAO/T-GGD-00-2, October 21, 1999, www.house.gov/reform/postal/hearings/ggd-73840.pdf.

[91]Mike Snider, "E-mail use may force Postal Service cuts," *USA Today*, October 20, 1999, www.usatoday.com/life/cyber/tech/ctg466.htm.

[92]Eric Hemel and Craig Schmidt, "Internet's Potential Impact on Retail Real Estate," Merrill Lynch, March, 1999 and personal communications with Craig Schmidt.
[93]"Online Advertising To Reach $33 Billion Worldwide By 2004," Forrester Research press release, Cambridge, MA, August 12, 1999, www.forrester.com/ER/Press/Release/0,1769,159,FF.html.
[94]"Most Online Holiday Gift Buying Will Be at E-Stores, Not Real Stores," Greenfield Online, Westport, CT, September 29, 1999, www.greenfieldcentral.com/default2.htm.
[95]Downes and Mui, *Unleashing the Killer App*, p. 18.
[96]"Retailing: Confronting the Challenges That Face Bricks-and-Mortar Stores," *Harvard Business Review*, July-August 1999, p. 163.
[97]Hemel and Schmidt, "Internet's Potential Impact."
[98]Personal communications with Craig Schmidt.
[99]*MIT 1999*, p. 14
[100]Warren St. John, "Barnes & Noble's Epiphany," *Wired*, June 1999, **www.wired.com/wired/archive/7.06/barnes_pr.html**.
[101]Nina Munk, "Title Fight," *Fortune*, June 21, 1999, p. 90
[102]Ibid.
[103]See, for instance, *MIT 1999*, p. 14.
[104]Personal communications with Mark Borsuk. His extensive writing on this subject can be found at www.mihalovich.com.
[105]Mark Borsuk, "Death at the Margin," *The Industry Standard*, October 4, 1999 http://thestandard.net/articles/display/0,1449,6556,00.html (the online version is dated September 24, 1999).
[106]Steve Lohr, "In E-Commerce Frenzy, Brave New World Meets Old," *New York Times*, October 10, 1999, p. wk5.
[107]Mark Borsuk, "Nowhere yet Everywhere," June 1999, www.mihalovich.com/columns/nowhere.htm#fn_15.
[108]"Retailing," *Harvard Business Review*, 1999, p. 166.
[109]*OECD 1999*, p. 73.
[110]This might be offset a few percent from increased home electricity consumption by those using the Internet for shopping. We don't think this will be a large effect by the time the OECD savings are achieved, perhaps 2007, since home PCs (or other Internet access systems) are likely to be low electricity users by then. Also, some of the increased time that households spend shopping on the Internet might well displace other electricity-consuming activities, such as TV watching.
[111]CBECS, p. 56. This assumes that retail space is approximated by using the figures for total mercantile and service floorspace, which was 12.7 billion square feet in 1995. The net impact on warehousing is discussed below.
[112]Kim Cross, "B-to-B, By the Numbers," *Business 2.0*, September 1999.
[113]Scott Kirsner, "Venture Verite: United Parcel Service," *Wired*, September 1999, pp. 83-96.
[114]Tom Stein and Jeff Sweat, "Killer Supply Chains," *Informationweek*, Nov. 9, 1998.
[115]Mary J. Cronin, "Ford's Intranet Success," *Fortune*, March 30, 1998, p. 158. See, also Mary J. Cronin, "The Corporate Intranet," *Fortune*, May 24, 1999, pp. 114+.
[116]*OECD 1999*, p. 63 and www.aiag.org.
[117]Robert L. Simison, "Toyota Unveils System to Custom-Build Cars in Five Days," Dow Jones News Service, Aug. 5, 1999 [retrievable at wsj.com].
[118]*OECD 1999*, p. 63.
[119]Advertisement in *Business 2.0*, November 1999, following page 154.
[120]Douglas Blackmon, "FedEx CEO Smith Bets His Deal Will Recast The Future Of Shipping," *Wall Street Journal*, November 4, 1999, pp. A1, A16.
[121]*Commerce 1999*, pp. 16, 57.
[122]Total commercial building warehouse and storage space in 1995 was 8.5 billion square feet (*CBECS*, p. 56). The drop in commercial warehouse usage could reasonably be estimated as somewhere between the 12.5% reduction in retail and wholesale building use discussed earlier and the 25% to 35% reduction in finished goods inventories. Using the lower figure of 12.5% gives a savings of 1 billion square feet. On the other hand, there would likely be an *increase* in warehouse space from the new e-tailers, of perhaps 1 square foot in 8, using the sales ratio from the bookstore example. This comes to 200 million square feet

out of the 1.5 billion square feet in reduced need for retail space (though as discussed in the notes to Section 5, many e-tailers are using existing warehouses, so not all of this would be new construction). Finally, the manufacturing sector had 12.3 billion square feet of enclosed floor space in 1994 (EIA, *Manufacturing Consumption of Energy 1994*, December 1997, p. 88). If 10% of that were used for warehousing and storage, a 25% reduction would free up 300 million square feet for other purposes. Thus, 1 billion square feet seems a plausible estimate for the net reduced need for warehouse and storage space.

[123]Patricia Mokhtarian and Dennis Henderson, "Analyzing the Travel Behavior of Home-based Workers in the 1991 CALTRANS Statewide Travel Survey," *Journal of Transportation and Statistics*, Vol. 1 No. 3, October 1998, pp. 25-41. As the authors explain, estimates for the precise number of home-based workers vary widely, in part because of different definitions used by different analysts and in part because of difficulties in measuring who is actually working at home (and the related question of how much one has to work at home to qualify as a home-based business).

[124]Ibid.

[125]" Internet Access Providers Should Prepare for Fierce Competition in the Home Office Market," IDC, March 22, 1999, and "IDC Reveals Home Office Internet Use Reaches Record High," IDC, Sept. 15, 1998, Framingham, MA, www.idcresearch.com/Press/default.htm.

[126]Horrigan et al, *Taking a Byte Out Of Carbon*, p. 25.

[127]Unless otherwise specified, the numbers in this case study are from Mahlon Apgar IV, "The Alternative Workplace: Changing Where and How People Work," *Harvard Business Review*, May-June 1998, pp. 121-136.

[128]Personal communications with David Malchman, AT&T.

[129]*CBECS*, pp. 239, 274.

[130]A number of the studies that were done suffer from methodology flaws (for instance, they use self reporting, which tends to be unreliable) and are more than ten years old (so they don't reflect more widespread use of computers that are more energy-efficient, particularly laptops, which are the preferred computer for many high-tech telecommuting and consume far less energy than desktop PCs). See, for instance, Patricia Mokhtarian, Susan Handy, and Ilan Salomon, "Methodological Issues in the Estimation of the Travel, Energy, and Air-quality Impact of Telecommuting," *Transpn. Res.-A*. Vol. 29A, No. 4, 1995, pp. 296-297.

[131]Apgar, "The Alternative Workplace," *HBR*, p. 126.

[132]We are approximating the incremental electricity consumption (primarily from air conditioning, home office equipment, and lighting) at 750 watts times 2000 work hours, or 1500 kWh. We are assuming that shared office workers spend about one-third of their time at home (and the rest with customers or in the office) and that virtual workers spend about two-thirds of their time at home. This is meant as an average number. In warm climates, the figure would be higher while in mild climates it would be lower. Also, workers who use a laptop would tend to consume less electricity. We also estimate that the net natural gas savings from telecommuting are low.

[133]Apgar, "The Alternative Workplace," *HBR*, pp. 129-130.

[134]These savings are for occupancy and voice-IT expenses (phone-based communication charges) combined; the former are much larger than the latter.

[135]Peter Arnfalk, "Information Technology in Pollution Prevention—Teleconferencing and Telework Used As Tools in the Reduction of Work-Related Travel," Licentiate Dissertation, International Institute for Industrial Environmental Economics, Lund University, Sweden, October 1999, pp. 69-70.

[136]For one recent discussion that touches on many of the complexities of this issue, see Susan N. Houseman, "Flexible Staffing Arrangements: A Report on Temporary Help, On-Call, Direct-Hire, Temporary, Leased, Contract Company, and Independent Contractor Employment in United States," a report for the Office of the Assistant Secretary for Policy, U.S. Department of Labor, August 1999 (www.dol.gov/dol/asp/public/futurework/conference/staffing/staffing_toc.htm).

[137]"Area Neighborhoods Buzz with Home Businesses," *Washington Post*, October 3, 1999, pp. A1, A16.

[138]"Leesburg Housewife Makes a Click Profit," *The Washington Post*, Aug. 29, 1999, pp. A1, A23.

[139]Barry Libert and William Ribaudo, "The New Space Race: Virtual Space Draws the Skylines of the Future," Arthur Andersen, 1996, www.realty4.com/art_andr.html.

[140]*CBECS*, p. 1.

[141]This is above and beyond the pre-Internet growth rate for home offices (since we are trying to estimate the incremental impact of the Internet on energy consumption). It could also represent people who already

had a home office, but were now spending much more time at home: for instance, a traditional telecommuter who became an Internet telecommuter or someone who had been moonlighting with a second job at home but who decided to give up their office job and work full-time as an Internet entrepreneur.
[142]EIA, *Annual Energy Outlook 1999*, December 1998, p. 124, www.eia.doe.gov [Hereafter, *AEO99*].
[143]*CBECS*, pp. 238, 274. As noted earlier, a few percent of the electricity savings might be offset by increased home electricity consumption. On the other hand, we have used the average electricity per square foot figure for retail buildings here, but retail stores built in the 1990s are more electricity intensive (*CBECS*, p. 251). So if a large fraction of the avoided retail space is either space built in the 1990s or, more likely, new construction, that would be tend to increase this number a few percent. So these two factors may well offset each other.
[144]The savings are small for two reasons. First, the average warehouse doesn't consume much energy: 6.4 kWh per square foot and 22,000 BTUs per square foot (CBECS, pp. 239, 274). Also, although we expect there will probably be far fewer newly constructed warehouses by e-tailers than there are old warehouses rendered unnecessary, new warehouses tend to be much more energy intensive than the average warehouse (*CBECS*, p. 251).
[145]*AEO99*, p. 124.
[146]The calculations in this table include the extra energy consumption from increased use of computers at home by Internet telecommuters and home-based workers, but do not include 1) the incremental home energy consumption from Internet retail shopping, banking, and the like or 2) the incremental commercial building energy consumption needed by businesses to make the Internet run. We suspect the former will be ultimately be fairly small since the home PC market is likely to saturate in the time frame considered (1997 to 2007); since each new generation of PC system is less energy-intensive (as discussed in Section 2), and since home PC use may displace other home energy-consuming activities, such as watching the TV. The latter is a very complicated calculation, as noted in Section 2, but suggestions that Internet electricity consumption will have a dominant impact on energy consumption have turned out to be based on very flawed analysis. See Koomey et al, "Initial comments on *The Internet Begins with Coal*," December 1999. This is an important area for further study.
[147]For good discussions of this issue, see Traci Watson, "Paperless office still a pipe ream," *USA Today*, March 8, 1999, p. 12B; Kevin J. Delaney, "Where's That Paperless Office? Reams Pile Up Despite Computers, *The Wall Street Journal*, May 28, 1999; and "Remarks prepared for Rick Thoman President and Chief Executive Officer Xerox Corporation," May 18, 1999, Palo Alto, CA, www.xerox.com/go/xrx/about_xerox/T_release1.jsp?oid=14325&view=news_archive&equip=none.
[148]Boston Consulting Group, *Paper and the Electronic Media*, September 1999. Available by emailing BCG at imc-info@bcg.com. Unless otherwise specified, all figures and quotes from this section come from this study.
[149]See, for instance, U.S. EPA, *Greenhouse Gas Emissions From Management of Selected Materials in Municipal Solid Waste*, EPA530-R-98-013, September 1998, pp. 15-34 (www.epa.gov/epaoswer/non-hw/muncpl/ghg/greengas.pdf). This is also comparable to a survey of studies and independent analysis by Bruce Nordman, Lawrence Berkeley Laboratory in 1997 (personal communications, September 1999). This life-cycle number includes not only a calculation for the production of the paper, which is the biggest contributor, but also other factors such as transportation. The estimate is meant as an average. A more precise analysis would take into account that this life-cycle calculation varies by type of paper and whether the paper is virgin (which consumes perhaps 10% to 20% more than the estimate) or recycled (which consumes 10% to 20% less). We use this average figure because the energy calculation is meant to be a rough estimate, and the BCG study numbers are themselves projections into an uncertain future.
[150]Ibid., p. ES-12.
[151]The reason the greenhouse gas savings are larger than the energy savings is that avoiding paper saves more than just the GHG emissions from the avoided energy consumption. It also avoids the loss of trees that sequester carbon and avoids the emissions associated with the waste management of the paper (such as the release of methane from paper put in landfills that do not recapture methane). The EPA study makes estimates of the proportion of paper that is virgin and recycled, as well as estimates of the proportion that is burned for energy, what proportion is landfilled (and of that which is in landfills that capture methane and which isn't), and so on.

[152]The study used relatively conservative assumptions, for instance assuming that Internet users would comprise only 44% of the U.S. population in 2003, whereas Forrester projects the number will be 56%. See www.forrester.com/ER/Press/Talking/0,1773,0,FF.html.
[153]"Online Advertising To Reach $33 Billion Worldwide By 2004," Forrester Research press release, Cambridge, Mass., August 12, 1999, www.forrester.com/ER/Press/Release/0,1769,159,FF.html.
[154]*Commerce 1998*, A4, p. 18.
[155]The BCG study notes that the vast majority of online newspapers are currently losing money, but believes, "the future probably will look different, as online version to grow increasingly customized and user-friendly and begin to show a profit.... We believe users will be willing to pay for online services after they cancel their newspaper subscriptions. And when the economics turn the corner, the data suggest online newspapers will be formidable force."
[156]Negroponte, *Being Digital*, p. 153.
[157]*OECD 1999*, p. 47.
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[196]The ultimate amount of new Internet-driven warehouse construction is difficult to estimate at this point. While some e-tailers, like Amazon.com and Webvan, are building warehouses, others are using the capabilities of existing warehouses. For instance, eToys, Levis.com, and Pier1.com have all used some of the 4.5 million square feet of warehouses owned by Fingerhut, a 51-year-old Minnesota company. "10 Companies That Get It," *Fortune*, November 8, 1999, p. 117. Drugstore.com uses a "warehouse that handles fulfillment for all kinds of pharmacies, not just the online kind." Angela Gunn, "Stuffy Nose? Achy Head? Try E-Mail," *The Industry Standard*, October 4, 1999 http://thestandard.net/articles/display/0,1449,6546,00.html (the online version is dated September 23, 1999).
[197]The manufacturing sector had 12.3 billion square feet of enclosed floor space in 1994 (EIA, *Manufacturing Consumption of Energy 1994*, December 1997, p. 88). If the Internet economy were to increase capacity utilization 0.5% a year from 1997 to 2007, that might avoid the need for some 600 million square feet of new plants.
[198]*AEO99*, p. 120.
[199]Michiya Suzuki and Tatsuo Oka, "Estimation of life-cycle energy consumption and CO2 emission of office buildings in Japan," *Energy and Buildings* 28 (1998), pp. 33-41. This includes the embodied energy in the raw materials and finished goods (i.e. office equipment) that go into the building. The figure for Japanese buildings was closer to 0.8 MBTU per square foot. We have used 1.0 because it is a simpler approximation and the U.S. manufacturing sector is more energy intensive than the Japanese manufacturing sector. Retail building construction is probably less energy intensive than office building construction, while manufacturing plant construction is probably far more energy intensive. The study found that the total energy used to construct a building in Japan represents about 7.5 years of the annual energy used by a typical office building for heating, cooling, lighting, and other equipment.
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[214]For good recent surveys see Patricia Mokhtarian, "A Synthetic Approach to Estimating the Impact of Telecommuting on Travel," *Urban Studies* Vol. 35. No. 2, 1998, pp. 215-141; and Arnfalk, *Information Technology in Pollution Prevention*.
[215]For a discussion, see Mokhtarian, Handy, and Salomon, "Methodological Issues," pp. 289-292.
[216]U.S. Department of Energy, *Energy, Emissions and Social Consequences of Telecommuting*, Washington, May 1994, DOE/PO-0021, available from NTIS (703-487-4650). [Hereafter, *DOE 1994*.]
[217]Mokhtarian, "Synthetic Approach," p. 215.
[218]Ibid., pp. 235-236. To the extent that IT and the Internet Economy are spurring economic growth that would, all things being equal, spur transportation usage. On the other hand, it would not significantly impact energy intensity, since energy use would be rising because GDP was rising.
[219]For a discussion of this, see Patricia Mokhtarian and Ravikumar Meenakshisundaram, "Beyond Tele-Substitution: Disaggregated Longitudinal Structural Equations Modeling of Communications Impacts," *Transportation Research C*, forthcoming.
[220]Personal communications with Peter Arnfalk.
[221]"By 2002, Home Offices Will Spend $10.5 Billion on Internet Access," IDC, March 22, 1999, and "IDC Reveals Home Office Internet Use Reaches Record High," IDC, September 15, 1998, Framingham, MA, www.idcresearch.com/Press/default.htm.
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[225]"Area Neighborhoods Buzz with Home Businesses," *Washington Post*, October 3, 1999, pp. A1, A16.
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[227]This is comparable to the assumption in Section 3 (an increase of a half million Internet telecommuters and a half million Internet entrepreneurs each year) if the Internet telecommuters are more like HBBs than traditional HBTs. If not, the energy savings might be reduced 20%.
[228]Each HBB has almost 100 hours less car travel a year, or some 140 gallons saved per HBB assuming an average speed of 30 miles per hour and an average efficiency for the light duty fleet of 20 miles per gallon (*AEO99*, p. 123). Each one million new HBBs would thus avoid roughly 18 million MBTUs in gasoline use, or 0.018 quads. By 2010, over 0.23 quads would be avoided compared to 2010, about 1.2% of total motor gasoline consumption in 2010 or 0.7% of total transportation energy use (AEO99, p. 114).
[229]For instance, the Caltrans data analyzed by Mokhtarian and Henderson is from 1991. For other weaknesses in the data, see Mokhtarian and Henderson, "Analyzing the Travel Behavior of Home-based Workers."
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