

The Internet and the New Energy Economy

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From 1996 through 1999, the U.S. experienced an unprecedented 3.2% annual reduction in energy intensity. This is four times the rate of the previous 10 years and more than 3 times higher than the rate projected by traditional energy forecasters. There is increasing data and analysis to support the view that there is a connection between the recent reductions in energy intensity and the astonishing growth in Information Technology (IT) and the Internet Economy.

Growth in the Internet Economy can cut energy intensity in two ways. First, the IT sector is less energy-intensive than traditional manufacturing, so growth in this sector engenders less incremental energy consumption. Second, the Internet Economy appears to be increasing efficiency in every sector of the economy, which is the primary focus of this paper. The impact of the Internet economy on manufacturing, buildings, and transportation are all explored. The paper also considers the implications for growth in energy consumption and greenhouse gas emissions during the next ten years. This is a time when the Internet Economy is expected to grow rapidly and when the Internet is expected to be used to directly save energy through remote energy management of commercial and residential buildings.

Finally, there has been an argument put forward by two analysts, Mark Mills and Peter Huber, that the Internet is using a large and rapidly growing share of the nation's electricity, which in turn is supposedly driving an acceleration of overall U.S. electricity demand. Their numbers have very been widely quoted by financial analysts, major corporations, and the media. However, it is based on seriously faulty analysis and is inconsistent with recent national data, so all projections based on that analysis should be viewed with extreme caution.

¹Note that the contents present the views of their authors, not necessarily those of the Department of Energy, RAND, or any other organization with which the authors may be affiliated.

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. As a result, energy demand and gross domestic product (GDP) in United States historically grew in lockstep: a 3% increase in GDP meant nearly a 3% increase in energy demand. 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.²

The inextricable connection between energy and economic growth came to an 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). One third of the dramatic shift in energy intensity during this period was due to structural changes, such as declining share of economic activity in energy-intensive industries and increasing shares in the less energy-intensive service sector. Two thirds was due to increases in energy efficiency throughout the economy as a whole.³

Following the crisis, Americans bought more fuel-efficient cars and appliances, insulated 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. These investments in more efficient technologies were facilitated by higher energy prices, by government policies and programs, and behavioral changes resulting from concerns about availability of energy and dependence on Persian Gulf oil.

The nation's energy intensity routinely declined by 2% per year during the years from 1973 to 1986, and some years intensity 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

²This historical discussion is based on Brown, Levine, 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.

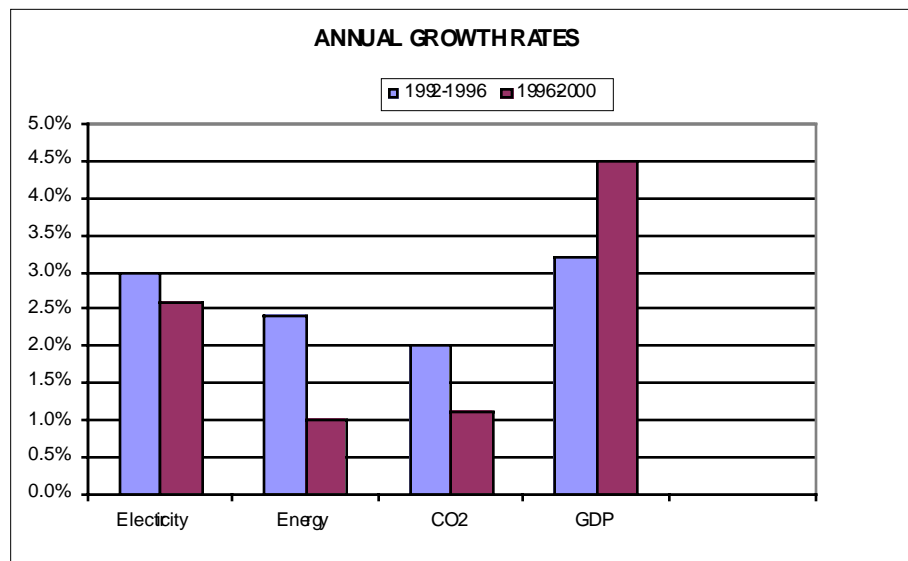
³Skip Laitner, "The Information and Communication Technology Revolution: Can it be Good for Both the Economy and the Climate?" U.S. Environmental Protection Agency. Washington, DC. December 1999.

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 less than 1% per year over the ten-year period.

Recent Drops in Energy Intensity

In the late 1990s, a startling shift appeared in the statistics. The nation's energy intensity dropped 3.7% in 1997 and 3.9% in 1998. 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 had two years of economic growth totaling 9%, yet energy use in 1998 was hardly changed from its 1996 levels, just slightly more than 94 quads. In 1999, energy intensity dropped by 2%, and current data suggest that energy intensity will drop by over 3% in 2000 and that GHG emissions will continue to grow at a rate much slower than Energy Information Administration (EIA) projected.⁴

Looking at the recent data another way, if we consider what might be called the immediate pre-Internet era (1992-1996), GDP growth averaged 3.2% a year, while



⁴Energy Information Administration (EIA) projected in December 1999 that CO2 emissions would rise 2.3% in 1999. EIA, *Annual Energy Outlook 2000*, U.S. Department of Energy (DOE), Washington, DC, December 1999. Their current "flash" estimate is that 1999 saw a 1% rise in CO2 emissions. EIA, "U.S. Carbon Dioxide Emissions from Energy Sources 1999 Flash Estimate," DOE, Washington, DC, June 2000.

energy demand grew 2.4% a year. In the Internet era (1996-2000), GDP growth is averaging over 4% a year, while energy demand is growing only 1% a year. This is a remarkable change—higher GDP growth and lower energy growth. From the point of view of greenhouse gases, the immediate pre-Internet era saw 2% annual rises in carbon dioxide emissions, while the Internet era has seen rises of slightly over 1%.

The recent remarkable declines in U.S. energy intensity have motivated the Center for Energy and Climate Solutions (CECS) 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 purpose here is not to explain in detail all of reasons for the sharp drop in energy intensity over the past two years. 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 weather was responsible for perhaps 0.5% out of the 3.8% average annual drop in energy intensity in 1997 and 1998.⁵

Other relevant factors include the rebound in federal investment in energy efficiency in the 1990s, though a countervailing trend has been the decline in demand-side management funding by utilities. Slowdown in the Asian economies also reduced exports (and hence U.S. manufacturing). Unfortunately, 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. Disentangling all of these factors is beyond the scope of this paper. The goal 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 examined here.

The New Energy Economy: A Fundamental Change

In a 1999 report, CECS examined the relationship between the economic growth and a new trend in energy intensity, and concluded that the Internet economy could fundamentally and permanently alter the store relationship—allowing

⁵Laitner, 1999, op. cit.

faster growth with less energy use than we have seen in the past. We labeled this a “New Energy Economy, ” and predicted “annual improvements in energy intensity of 1.5%—and perhaps 2.0% or more.” Although we were criticized by some, including EIA, for this prediction, the most recent data cited above are strongly suggestive that a fundamental change is occurring in the economy and that our scenario may well be a key part of the explanation. It now appears that even EIA is going to substantially increase its projection for annual energy intensity gains this decade.⁶

Our report “The Internet Economy and Global Warming: A Scenario of the Impact of E-commerce on Energy and the Environment,” remains the most comprehensive analyses to date on the nature and scope of the Internet’s effect on energy consumption and greenhouse gas emissions. It is available online at www.cool-companies.org.

Analysis by EPA and the Argonne National Laboratory suggests that one third to one half of the recent improvements in energy intensity are “structural.”⁷ Structural gains occur when economic growth shifts to sectors of the economy that are not particularly energy intensive—such as the IT sector, including computer manufacturing and software—as opposed to more energy-intensive sectors, including chemicals, pulp and paper industry, and construction.

More importantly, the remaining one-half to two-thirds of the improvement in our economy’s use of energy comes from overall efficiency throughout the system as a whole, occurring when businesses change their activities in ways that reduce energy use relative to their output of goods and services. For example, a factory might use more efficient motors on its assembly line or better 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.

According to our findings, the Internet economy itself seems to be generating both structural and efficiency gains. If companies put their stores on the Internet, rather than constructing new retail buildings, which would represent an Internet structural, gain. If that same company used the Internet to more effectively manage its existing supply chain, it would be an efficiency gain. The following is a brief summary of our principal findings, with some relevant updated data and analysis. A longer discussion of each of these sectors—manufacturing, buildings, transportation—can be found in the original report.

⁶Personal Communications with Skip Laitner, EPA, September 2000.

⁷G. Boyd and S. Laitner, *Recent Trends in U.S. Energy Intensity*, U.S. EPA, Washington D.C., 2000.in

Internet Makes Manufacturing More Efficient

The Internet Economy appears to be causing a broad improvement in manufacturing efficiency. 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.*”⁸

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.

Between 1990 and 1998, Dell computer grew considerably while simultaneously moving many of its operations to the Internet. Its sales increased 36-fold, but its physical assets (i.e. buildings, factories) rose by only a factor of four.⁹ IBM has used the Internet to improve communication between factories, marketing and purchasing departments. If one factory cannot meet its production schedule or if demand suddenly rises, IBM finds out in time to increase production at another factory. This has allowed the company to better utilize its existing manufacturing capacity and thus avoid making additional investments to meet increased volume requirements. By mid-1998, the reduced investment and operating costs had saved the company \$500 billion.¹⁰ Many, many companies from General Electric to Cisco Systems, are achieving similar efficiencies.

Inventories may be the single measure of the manufacturing sector’s overall efficiency. Higher inventory turnover and lower overall inventories represent a vast savings for the economy: Less new manufacturing infrastructure is required needs to be constructed, fewer excess goods need to be manufactured and then shipped to warehouses—where they are heated and cooled—and then either shipped again for ultimate sale or, in many cases surplus. Every stage of this process consumes a vast quantity of energy, in buildings, transportation, and most especially in the manufacturing of basic materials (such as the steel in the excess manufacturing capacity) and the manufacturing of finished goods.¹¹

⁸Alan Greenspan, “High-tech industry in the U.S. economy,” Testimony Before the Joint Economic Committee, U.S. Congress, June 14, 1999.

⁹James Fallows, “The McCain Factor,” *The Industry Standard*, February 21, 2000.

¹⁰Lynn Margherio et al, “The Emerging Digital Economy,” Department of Commerce, April 1998.

¹¹The energy used to create and transport the raw materials that a company uses may vastly exceed energy they use directly. For instance, Interface Flooring Systems calculates this “embodied energy” in raw materials for its carpet tile outstrips the energy needed to manufacture it by a factor of

The Internet is widely viewed as likely to have a large impact on inventories. As the Department of Commerce put it in July 2000, “by improving communications with suppliers and customers, IT has facilitated manufacturers, efforts to limit their inventory exposure.”¹² Companies are increasingly using the internet to work together for better forecasting and restocking, using a process called Collaborative Planning Forecasting Replenishment (CPFR). Home Depot uses information technology and the Web throughout its supply chain to largely bypass the warehouse: 85% of its merchandise moves directly from the manufacturer to the storefront. The Automotive Industry Automation Group tested an internet-based supply chain management system that cut lead times 58%, a 24% improvement in inventory levels, and a 75% reduction in error rates; a similar system by Toyota is cutting in-house inventories by 28% and storage requirements in the plant by 37%, freeing space for manufacturing.

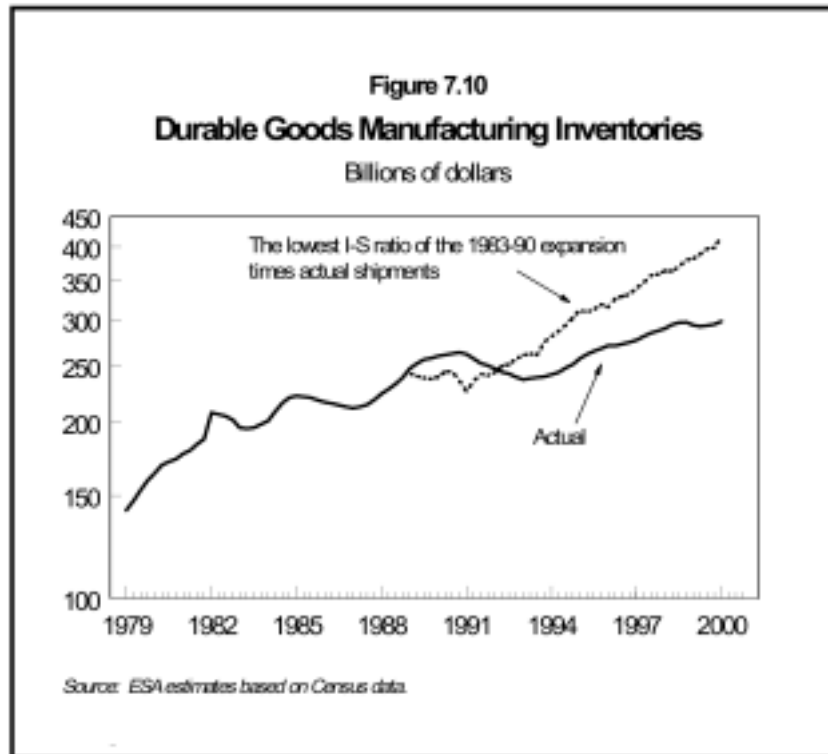
What is potential impact on the digital economy on inventories? Ernst & Young has estimated that CPFR could lead to an inventory reduction of \$250 billion to \$350 billion across the economy, roughly a 25% to 35% cut in finished goods inventory across the supply chain.¹³

What has been achieved to date in the economy? According to the Department of Commerce July report, with the aid of IT “durable goods manufacturers have reduce their inventory ratios from 16.3% of annual shipments in 1998,” which was the lowest ratio in the 1983 to 1990 expansion, “to just 12.0% in the last 12 months.” The implications are enormous: “*If U.S. manufacturers of durable goods today held inventories at the 1988 inventory to sales ratio, they would be holding an additional \$115 billion in inventory.*” This represents \$115 billion in durable goods that were not manufactured, even as output and GDP soared. It means “companies are spared the expense of storing and securing one-third more inventories than they now hold” and “they avoid the inevitable losses from holding inventories for products that lose favor in the marketplace.” This means saving the enormous energy required to make, move, and store \$115 billion worth of goods.

12. That means a 4% cut in wasted product could save the equivalent of fully half the energy used in manufacturing.

¹²Economics and Statistics Administration, *Digital Economy 2000*, Department of Commerce, Washington, DC, June 2000.

¹³Andrew Wyckoff and Alessandra Colecchia, *The Economic and Social Impact of Electronic Commerce*, Organisation for Economic Co-Operation and Development (OECD), Paris, France, 1999. [Hereafter *OECD 1999*.]



Clearly, if we continued to have significant GDP growth without significant inventory growth, that would suggest that our energy intensity gains will continue. If indeed the Ernst & Young estimate is correct, then we have not even achieved half of the inventory savings that the Internet economy will ultimately make possible.

Internet Saves Commercial Building Energy

The Internet holds the potential to increase efficiency in a variety of buildings, including retail, warehouse and storage, and office buildings. 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 to which we have added two lines of energy calculations:

Table 1
Comparison of Operating Models of Land-based Versus Online Bookstore¹⁴

	Traditional Superstore	Online Bookstore (Amazon.com)
Titles per Store	175,000	2,500,000
Revenue per Operating Employee	\$100,000	\$300,000
Annual Inventory Turnover	2-3 times	40-60 times
Sales per square foot	\$250	\$2,000
Rent per sq. ft.	\$20	\$8
Energy costs per sq. ft.	\$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. So Internet energy efficiency appears to be a very powerful tool for reducing building energy intensity. The impact of e-commerce on transportation energy consumption is discussed later.

This type of efficiency gain is likely to be seen throughout a wide swath of retail buildings, not just book stores, but electronics, software, pet stores, toy stores, banks, and the like. Mark Borsuk, Executive Director of the Real Estate Transformation Group, wrote recently that Wall Street will "demand that retailers curtail new store growth, reduce the number of locations, and shrink store size."¹⁵

What is the ultimate impact in the retail sector likely to be? A 1999 OECD report on the impact of e-commerce estimated that "economy-wide efficiency gains" from a "business-to-consumer scenario" could "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.¹⁶

These savings, plus savings in labor and capital, "leads to a reduction in aggregate distribution cost of about" 5.2% and in "total economy-wide cost by about" 0.7%. The study notes that "While small, this is still a considerable gain,

¹⁴The 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.

¹⁵Mark Borsuk, "Under the Knife." *The Industry Standard*. January 14, 2000.

¹⁶Hereafter *OECD 1999*.

since a reduction in these costs is a rough proxy for productivity gains [total factor productivity].”

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 on 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 industrial sector (i.e. construction). *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.*¹⁷

As for office space, the Internet has two key impacts. First, companies like IBM and AT&T are cutting office space for workers who spend a great deal of time with customers outside the office, such as sales and service.¹⁸ They give those “Internet telecommuters” laptops, put critical data on their corporate intranets, and then the workers spend their time working on the road and at home. If they need to come into work they can email in to reserve shared office or meeting space. Today, for example, virtually all of IBM’s sales force — nearly 17% of their total workforce worldwide — can operate independent of a traditional workplace, helping cut occupancy cost per employee by one-third. With roughly the same number of total workers in 2002 as in 1998, AT&T expects to cut total square footage from about 32 million square feet to 21 million square feet. Each Internet telecommuter saves about 175 square feet per worker times 20 kWh per square foot or 3500 kWh a year. We would not be surprised if the incremental home electricity consumption were 500 kWh based on telecommuters spending about one third of their time at home. The *net* savings would be 3000 kWh a year, worth about \$200 a year.

Second, the Internet is driving a boom in purely home-based work. International Data Corporation 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 (IDC 1999). This increase in home offices reduces the amount of incremental office space required for an increment in GDP. We believe that translates into a net savings in

¹⁷This 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. *EIA 1998*. As for warehousing, even accounting for the increase in warehouses by internet retailers, 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. Net energy savings from changes in warehousing may be modest, however, since new warehouses consume far more energy than the average warehouse.

¹⁸Mahlon Apgar IV, “The Alternative Workplace: Changing Where and How People Work,” *Harvard Business Review*, May-June 1998, pp. 121-136.

building energy consumption. A worker in a traditional small office building (with an average 300 square feet of space) would probably be consuming upwards of 6000 kWh a year. Her incremental home-based electricity consumption is perhaps 1500 kWh, yielding a *net* savings of more than 4000 kWh (Romm 1999).

Suppose that from 1997 to 2007 the Internet leads to an additional one million home offices each year. 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.

A very preliminary estimate of the potential *net* impact of the Internet on Buildings is that by 2007, business-to-consumer and business-to-business e-commerce together could avoid the need for 1.5 billion square feet of retail space—about 5 percent of the total—and up to 1 billion square feet of warehouses. Internet technology may also eliminate as much as 2 billion square feet of commercial office space, the equivalent of almost 450 Sears Towers, along with all the lighting, heating and cooling that goes with it.

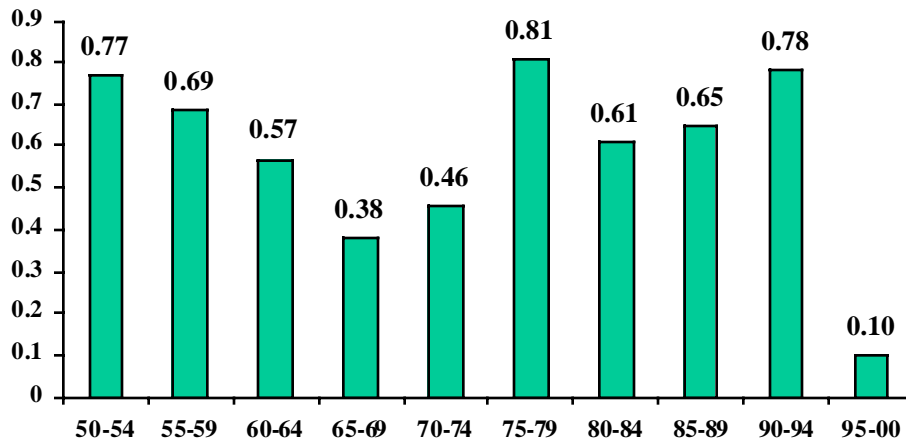
Energy savings from operations and maintenance alone for these “unbuildings” total 53 billion kilowatt hours per year, about 13 percent of total electricity growth projected under old, business-as-usual scenarios. That equals the output of 21 average power plants, plus 67 billion cubic feet of natural gas. Expressed in terms of the global warming issue, this Internet “unbuilding” scenario would prevent the release of 35 million metric tons of greenhouse gases.¹⁹

Is there any evidence that we have entered a period in which we can have GDP growth without the need for as many new buildings, particular commercial office buildings? We believe so. Consider a recent analysis by James Paulsen, Chief Information Officer, of Wells Capital Management.²⁰ According to this analysis, “during the 45 years after World War II until 1995, on average every 1 percent change in real GDP growth produced a 0.65 percent change in job growth.” But in the last five years, the job impact of GDP growth has virtually stopped: “Since 1995, for every one percent rise in real GDP growth, job growth has increased by only 0.1 percent—the weakest job impact in the postwar period!”

¹⁹Avoided construction of all those buildings saves the equivalent of 10 power plants worth of energy, and another 40 million metric tons of greenhouse pollution. By 2010, e-materialization of paper, construction, and other activities could reduce U.S. industrial energy and GHG emissions by more than 1.5%.

²⁰James Paulsen, “Economic and Market Perspective,” September 2000, Wells Capital Management.

This is strongly suggestive that we have entered a where GDP growth does not require as much commercial office buildings (and storage for inventories and retail stores) as has historically been the case. We have not yet seen data on



Percentage Change in Annual U.S. Job Growth Due to a 1-Percent Change in Real GDP Growth (by 20-quarter increments)

whether there has been an accompanying reduction or slowdown in construction, which is a very cyclical industry and subject to significant lags between supply and demand.

Internet and Transportation

The potential energy impact of the Internet Economy on the transportation sector is more of a mixed bag, with factors at play that may offset one another—potentially increasing energy intensity in some areas, but cutting it in others. If certain trends persist, however, Internet technology could lead to dramatic drops in energy intensity in this sector.

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

On the other hand, the Internet holds the prospect of *reducing* transportation energy intensity.

- 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.

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. 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.²¹ Shipping the packages by air freight, however, consumes nearly 0.6 gallons. These numbers are only very rough approximations, but they make clear that the transportation energy benefits of teleshopping are only partially offset by overnight delivery of e-commerce purchases by air freight.

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 huge swings in the price of oil will also make analysis difficult in the short term.

Nonetheless, a few key points deserve mention. First, HBB (home-based business) 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), according to the “first known U.S. study of HBB travel.”²² HBB spent 1.23 hours a day traveling in cars, whereas HBT spent

²¹Stacy Davis and Sonja Strang, *Transportation Energy Data Book: Edition 13*, Office of Transportation Technologies, U.S. Department of Energy, ORNL-6743, March 1993, p. 3.

²² 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.

1.39 and NHB spent 1.61. So to the extent the Internet is leading to an increase in HBBs, it will slow VMT growth.

Second, 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.”²³ 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 even greater than 12 to 1. Some recent studies suggest that heavy Internet users (greater than five hours a week) spend less time driving than average.²⁴

Third, the Internet is helping make the freight industry much more efficient. For instance, as many as half the freight trucks on the road are empty at any one time. A number of companies are auctioning off that empty space online, such as The National Transportation Exchange (NTE). Although this area is poorly studied, it seems clear that the capacity utilization of the trucking system has begun to increase. One trucking company, Yellow Freight, has already reported productivity gains of 20% from the application of IT.

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?

Already, in the last two and a half years, the growth rate in vehicles miles traveled (VMT) has slowed, and the VMT to GDP ratio has dropped dramatically. In November 1999, EIA wrote of the “continued weakening of the relationship between income and travel growth.”²⁵ Preliminary reports from the State Highway Agencies reveal that total VMT rose only 2% in 1999, the slowest growth since 1991, a recession year, and that VMT has risen only 1.6% for the first half of 2000.²⁶

We suspect the Internet economy will be no worse than neutral in the transportation sector, but could well have a large positive impact. We may be

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).

²³Lee Schipper et al, “Linking Life-Styles and Energy Use: A Matter of Time?” *Annual Review of Energy 1989*, 14:273-320.

²⁴N. Nie. and L. Erbring, L. “Internet and Society,” Stanford Institute for the Quantitative Study of Society, Stanford, CA: 2000.

²⁵EIA, *Short-Term Energy Outlook November*, DOE, Washington, DC, December 1999.

²⁶Federal Highway Administration, “Traffic Volume Trends, May 2000,” Department of Transportation, Washington, DC, September 2000.

seeing early signs of that, but it is certainly too early to tell. The impact in the buildings sector, and especially the manufacturing sector, seem likely to be beneficial. Therefore, we believe the overall impact of the Internet economy is to reduce the nation's energy intensity, perhaps significantly.

What About Energy Use by the Internet?

As to the important question of whether the Internet itself is consuming vast amounts of electricity, the facts simply—and irrefutably—fail to support such a conclusion. To begin with, the rate at which U.S. electricity demand is growing has *slowed* since the start of the Internet boom. As then EIA head Jay Hakes testified in February 2000:

From 1985 to 1995, retail electricity sales grew at a rate of 2.6% per year.... Since 1995, the use of the Internet has increased dramatically, yet retail electricity sales have grown by 2.1% per year.²⁷

The immediate pre-internet era (1992-1996) saw electricity demand rise 2.9% per year. Since 1996, electricity demand has risen only 2.3% per year. And this has all occurred in spite of higher GDP growth since 1995, hotter summers (1998 was the hottest summer in four decades in terms of cooling-degree days; 1999 was the second hottest summer), and less support by utilities for demand-side management, all of which would normally lead to higher growth in electricity demand. This likely has much to do with the trends already discussed here.

It is worth examining this question in more detail because the statistics and projections presented by Peter Huber and Mark Mills have been repeated widely by financial firms, energy corporations, the news media, and policy-making circles. For instance, the president of Duke Energy's Power Services is quoted in the October 2 issue of the *Industry Standard* that "electrical demand has been outpacing GDP growth. And we believe the main reason is the Internet an electronic commerce." Republican presidential candidate George W. Bush has even used in these projections as part of the reason underlying his energy policy, released in October 2000.

Mills and Huber argue the Internet has become a major energy *consumer* because it supposedly requires a great deal of electricity to run the computers and other hardware powering the Internet economy.²⁸ In fact, according to recent research,

²⁷EIA, "Statement of Jay Hakes before the Subcommittee On National Economic Growth," U.S. House of Representatives, Committee On Government Reform, Washington, DC, February 2, 2000.

²⁸Peter Huber and Mark Mills, "Dig more coal—the PCs are coming," *Forbes*, May 31, 1999, pp. 70-72.

they appear to have significantly overestimated the energy consumption of most critical pieces of equipment.

Scientists at Lawrence Berkeley National Laboratory (LBNL) examined in detail the numbers underlying the Mills and Huber analysis, and found that the estimates of the electricity used by the Internet were high by a factor of eight.²⁹ Major overestimates were found in every category, including their calculations of energy used by major dot-com companies, by the nation's web servers, by telephone central offices, by Internet routers and local networks, and by business and home PCs.

The Internet does not consume 8% of U.S. electricity as Mills claims. *The Koomey et al. analysis showed that this estimate is too large by a factor of eight.* Computers, office equipment, and the like do not consume 13% of electricity, as Mills claim; a better number is 3%.

Mills and Huber 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. Laptop computers, a key growth segment, are particularly low energy users, with some using 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).³⁰ New flat screens typically use about a quarter of the energy of traditional video display terminals with cathode ray tubes.

These basic mistakes are reflected in their conclusions. Mills and Huber claim that from 1996 to 1997, the *increase* in electricity consumed by all computers used for the Internet constituted more than 1.5% of all U.S. electricity consumed that

²⁹Jonathan 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>. The underlying analysis is Mark 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.

³⁰Typical 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, 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 our analysis, they are probably displacing far more electricity consumption by not working in an electricity-intensive office building.

year. Yet total electricity consumption for all purposes grew slightly less than 1.4% during that period, which would imply that electricity growth for everything else equaled zero—despite economic growth of 4.5%. While we believe that the Internet reduces energy intensity, we don't believe it has quite that dramatic an effect.

But mathematical and data errors are only part of the problem. Indeed, it appears Mills and Huber have the entire Internet energy story almost completely backwards. One of the reasons why energy intensity declined so slowly from 1987 through 1996 is likely 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. But Internet changed all that, unleashing a storm of new productivity in every sector of the economy. By then, of course, most office desks already had computer. The added energy needed to shift PCs from traditional uses to the Internet is modest compared to its overall benefit.

Computers and the Internet may well lead to more home electricity consumption. This is part of 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 in an office building; and, potentially, some may be not be driving to work or to malls as often 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 recent analysis, which suggests that some substitution is already occurring.³¹

Direct Energy Savings by the Internet

So far this paper has focused on the potential “indirect” energy efficiency benefits of the Internet. Yet in the very near future the Internet will itself be used to save energy directly as commercial and residential buildings have their energy managed over the Internet.

Digital energy management control systems (EMCS) can continuously gather data about what is taking place in a building and how its equipment is operating,

³¹N. Nie. and L. Erbring, L. “Internet and Society,” Stanford Institute for the Quantitative Study of Society, Stanford, CA: 2000.

feeding it into a central computer used to control building systems and optimize 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 percent with an 18-month payback in buildings that have already received on upgrade with the latest energy-saving equipment.³²

Increasingly, such technologies will operate over the Internet itself. Companies like SiliconEnergy have developed software that uses the Internet for real-time data collection and analysis and energy management. We believe energy outsourcers like Enron (discussed below) may ultimately manage hundreds if not thousands of buildings over the Internet.

The state of California is examining whether “demand-responsive” buildings may be a more cost-effective and environmentally superior strategy for dealing with peak power demand than building new generation. Currently, on hot days, California sees peak demand of 45,000 MW, of which 13,000 MW goes to air conditioning and 5,000 MW goes to commercial lighting. If a building has an energy management control system, then it could receive real-time pricing information over the Internet. On a voluntary basis and in return for a rebate from the utility, buildings could allow the indoor temperature to drift up 1 to 2 degrees Fahrenheit. This would not affect comfort much, especially since on days of predicted heat waves, the owner could precool the building. Similarly, hot days typically occur when the sun is out, so a “demand-responsive building” could also initiate some reduced lighting, both interior and exterior. This strategy could shave some 1000 MW from California’s peak demand without building several new power plants. California will be launching a pilot program soon, and, if it is successful, introduce the program statewide.³³

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. Early trials of remote controlled home energy management systems suggest the savings in energy bills could be as high as 10%.

³²Joseph Romm, *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions* (Washington DC: Island Press, 1999), pp. 28-30, 57-63, 77-99, 140-156.

³³Personal communications with Arthur Rosenfeld, California Energy Commission, September 2000.

Other Key Trends Affecting U.S. Energy Consumption

This paper has focused on the impact of the Internet on U.S. energy consumption. There are a number of other trends that are likely to have a significant impact this decade, and they deserve a brief mention.

OUTSOURCING: A new trend 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. Enron will use its own capital to improve lighting, heating, cooling and motors and to invest in cogeneration. 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 1999, Owens Corning, the fiberglass insulation manufacturer, announced a similar \$1 billion deal with Enron. Other energy service companies are taking a similar approach. 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.

The potential impact of this trend is enormous. Companies like Ocean Spray and Owens Corning 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, 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 1999. Yet, some energy outsourcers are signing up Fortune 1000 clients at a rapid pace. These deals will grow very rapidly in the next few years, and are likely to ultimately achieve savings well beyond that of utility-based demand-side management (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. Indeed, when Coors outsourced its cogeneration system to Trigen, Trigen was able to cut energy costs per barrel of beer by 20%, more than twice what Coors expected. 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.³⁴

³⁴See, for instance, Romm, *Cool Companies*, pp. 117-118 and 159-162.

It is entirely possible if not likely that *within a few years, outsourcing could lead to significantly higher levels of investment in energy efficiency than achieved in the early 1990s by utilities in their DSM programs*. 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 GHG COMMITMENTS: There is another recent business trend that will have lasting impact on energy consumption trends. Increasingly, major corporations are making company-wide commitments to reduce their greenhouse gas emissions. As the *Wall Street Journal* noted in an October 1999, article:

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.³⁵

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

This year, Johnson & Johnson and IBM each joined the Climate Savers partnership with the World Wildlife Fund (WWF) and Center for Energy and Climate Solutions, pledging to make substantial energy and greenhouse emissions cuts. Several other major companies are expected to join Climate Savers in Coming months. For its Climate Savers commitment, Johnson & Johnson has pledged to reduce greenhouse gas emissions by seven percent below 1990 levels by the year 2010, with an interim goal of four percent below 1990 levels by 2005. IBM, having already achieved an estimated 20% reduction in global CO₂ emissions through energy conservation efforts from 1990 through 1997, is now pledging to achieve average annual CO₂ emissions reductions equivalent to 4% of the emissions associated with the company's annual energy

³⁵Steve Liesman, "Dropping the Fight On Science, Companies Are Scrambling to Look a Little Greener," *Wall Street Journal*, October 19, 1999, p. B1.

use through 2004 from a baseline of 1998. Even major oil companies including BP and Shell have committed to make major emissions cuts, at least some of which will come from efficiency investments in their own facilities.

It may well be that 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.

The Future

In the September 7, 2000 issue of the *Wall Street Journal*, Huber and Mills discuss their theory that the Internet is an electricity hog, claim that “power demands are now growing at twice the rates planned for just a few years ago,” and write about “the 3%-4% annual increases in power demand that now lie ahead.”³⁶

As we have seen, there is no data to support these claims or projections. Quite the reverse. Since 1996, the country has had the fastest decline in its electricity intensity (amount of electricity needed to produce a dollar GDP) in decades.

What of the future? As noted, the growth rate of U.S. electricity consumption has been decelerating even in the face of much higher GDP growth. The Internet does not consume a large fraction of U.S. electricity today, nor do PCs, office equipment, and network equipment. The growth rate of power used by the Internet is much slower than the growth rate of the Internet. The Internet appears to save electricity indirectly (by making the whole economy more efficient) and, in the near future, will do so directly (through improved building energy management). The impact of energy outsourcing could be very significant on investment in energy efficiency. Finally, while the Internet economy certainly allows higher GDP growth, it seems unlikely that GDP growth in this decade will see an average growth rate equal to that of the past four years.

For all these reasons, *it seems unlikely that the average annual growth rate of U.S. electricity demand in this decade will significantly exceed the 2.2% growth rate we have experienced since 1996.*

³⁶Peter Huber and Mark Mills, “Got a Computer? More Power to You,” *Wall Street Journal*, September. 7, 2000, p. A 26.

Primary energy demand may be even more important than electricity demand growth, since it determines carbon dioxide emissions. If indeed the Internet is already reducing energy intensity, then it is likely to have a bigger impact in the years to come. The Internet economy in the United States is projected to grow more than ten-fold—from its current level of tens of billions of 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.

The combination of trends described above makes it likely that this decade will not see the same low-level of energy intensity gains that the 1987 to 1996 period saw, which were under 1% per year. Annual reductions of U.S. energy intensity in the Internet era could well average 2.0%. If this comes to pass, most major economic models used in the country will need to be modified. It may be that many factors widely used in economic, energy, and environmental models—such as energy per GDP and inventories per GDP—need to be changed.

Amazingly, EIA has looked at recent trends and while it has boosted its energy intensity predictions, it has apparently concluded that U.S. carbon dioxide emissions growth will actually be higher than previously projected.³⁷ We believe that many widely-used predictions of growth in energy usage and GHG emissions for this decade, particularly EIA's, are probably high.

The Environmental Protection Agency did a preliminary analysis of potential impact of structural and economic changes driven by rapid growth in the IT-producing industries. The results suggest that mainstream forecasts, such as those by EIA, may be overestimating U.S. energy use in the year 2010 by as much as 5 quadrillion BTUs, wrongly inflating carbon dioxide emissions by up to 300 million metric tons. This equals about 5% of the nation's projected energy use and GHG emissions.

Conclusion

Contrary to a very popular myth fostered by the work of Mark Mills and Peter Huber, the Internet is not driving an acceleration of electricity demand. It appears instead to be driving efficiencies throughout the economy that have resulted in the biggest dropped into electricity intensity and energy intensity the nation has seen in decades.

³⁷Personal Communications with Skip Laitner, EPA, September 2000.