The Impact of the Internet Economy on Energy Intensity

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ABSTRACT

From 1996 through 1999, the U.S. experienced an unprecedented 3.4% annual reduction in energy intensity. This is about 4 times the rate of the previous 10 years and more than 3 times higher than the rate forecasted by the Energy Information Administration (EIA) for the next 10 years. This paper explores whether 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 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, a time when the Internet Economy is expected to grow rapidly.

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 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 (Brown et al. 1998).

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 freeze in energy use during this period was due to structural changes, such as declines in energy-intensive industry and increases in the service sector; two thirds was due to increases in energy efficiency (Laitner, 1999). During this period, 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 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.

Recent Drops in Energy Intensity

The nation's energy intensity dropped 4% in 1997 and 4% 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 has had two years of economic growth totaling 9%, 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, data suggest that energy intensity dropped by over 2.2% in 1999 and that GHG emissions will continue to grow at a rate much slower than EIA projected.[1] 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.

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. 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 4.0% drop in energy intensity in 1997 and 1998 (Laitner, 1999).

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. Slowdown in the Asian economies also reduced exports. 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. 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.

The Internet's Impact on Energy Intensity

The most obvious impact of IT on energy intensity is that the IT-producing sector, which includes computer manufacturing and software, is not particularly energy intensive (as opposed to more energy-intensive sectors, including chemical manufacture, the pulp and

[1] EIA projected in December 1999 that CO_2 emissions would rise 2.3% in 1999 (EIA 1999a).

paper industry, and construction). The Commerce Department said in July 1999 that those IT-producing industries accounted for 28% to 29% of real GDP growth during 1997 and 1998 (Henry et al. 1999).

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 (Laitner 1999). 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. The EPA analysis does not attempt to account for the possibility that the Internet Economy itself may generate both structural gains and efficiency gains, which is the primary focus of this paper.

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 view this analysis as less a prediction than a scenario of how the Internet may affect energy intensity if it achieves the widespread impact that many believe it will. In many cases there are inadequate data to perform an economy-wide analysis of the impact of the Internet, but we feel the impact is so potentially large that it deserves mention so as to inspire further research.

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 decreases 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 this paper we will only highlight the major issues. A longer discussion of each area can be found at www.cool-companies.org.

Buildings

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 (Sawhney & Contreras 1999):

Table 1. Comparison of Operating Models of Land-based Versus Online Bookstore

	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	2-3X	40-60X
Sales per square foot	$250	$2,000
Rent per sq. ft.	$20	$8
Energy costs per sq. ft.[2]	$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. While this 16-to-1 ratio is a remarkable ratio, it is comparable to other estimates by e-tailers (Romm 1999). 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" (Borsuk 2000).

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 (Wyckoff & Colecchia 1999).

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, 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

[2] The energy costs are for retail stores and warehouses, respectively (EIA 1998).

(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.*[3]

The Internet is widely viewed as likely to have a large impact on inventories. 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 (Romm 1999).

Companies are increasingly using the internet to work together for better forecasting and restocking, using a process 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 (Wyckoff & Colecchia 1999). Even accounting for the increase in warehouses by "e-tailers" (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 (EIA 1998).

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 (Apgar 1998). 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, virtually all of IBM's sales force can operate independent of a traditional workplace (nearly 17% of their total workforce worldwide) which helped 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 (Romm 1999). 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). Dun & Bradstreet's annual small-business survey found that 50% of small-business owners in 1999 were based at home, compared with 38% just two years earlier (Rainie 2000).

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 building energy consumption. A worker in a traditional small office building (with 300 square feet of space) would probably be consuming upwards of 6000 kWh a year. Her incremental home-based

[3] 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 (EIA 1998).

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 given in Table 2.

Table 2. Potential Net Impact of Internet on Buildings (1997 to 2007+)

Building Type	Sq. Ft. Saved	Electricity Saved (kWh)	Natural Gas Saved (MBTU)	CO2 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

Manufacturing

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*" (Greenspan 1999).

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. Much of the potential inventory savings of $250 to $350 billion a year represents savings in manufacturing, shipping, and building O&M costs. Not making products that wouldn't have been sold or not building manufacturing plants that aren't needed saves considerable energy.

Between 1990 and 1998, as Dell computer grew and simultaneously moved 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 (Fallows 2000). 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 (Margherio et al. 1998). Many, many companies from General Electric to Cisco Systems, are achieving similar efficiencies.

The Internet economy also generates unique structural gains in the economy. 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*.

In Table 2, we estimated the possibility of reduced demand for commercial buildings of at least 3 billion square feet from 1997 to 2007. 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 (EIA 1999). The total energy consumed in constructing office buildings is about one million BTUs per square foot (Suzuki & Oka 1998). 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 significant amount of energy, especially since this energy is saved every year for ten years (or longer, if the trends continue). This represents some 40 million metric tons of CO2 avoided each year.[4]

The pulp and paper industry is perhaps the most energy intensive industry facing significant e-materialization. The most comprehensive recent study done on the likely near-term impact of the Internet on paper consumption was done by the Boston Consulting Group (BCG 1999). 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. Reductions primarily come in the area of newspapers, catalogs, and directories.

The energy saved by avoiding the use of one ton of paper is about 30 million BTUs (EPA 1998). 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*. The BCG ran their model out to 2008 at our request. Those results 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 CO2 savings to over 20 million metric tons.

Finally, online exchanges are promoting material reuse. In 1999, $2.7 billion in goods were resold on Ebay. FastParts auctions off excess electronic components. Another site, iMark.com, auctions used capital equipment. 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. Paperexchange.com makes possible auctioning of paper, and can avoid the extended warehousing of unsold paper that is sometimes just turned back into pulp and produced again. There is even a solidwaste.com, which auctions off items like a 40-foot long once-used cargo container.

[4] This scenario is very speculative and omits many complicating factors, such as the how much of the 3 billion square feet represents avoided new construction, and how much represents current buildings made unnecessary. Some of the latter will be partially or wholly rebuilt, reducing energy savings. Also, given the rapid growth in GDP since 1997, it may take a considerable amount of time to disentangle any effect the Internet might be having on construction from other trends in the U.S. economy.

Transportation

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 (Davis & Strang 1993). 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.

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, the growth in VMT has slowed in recent years. In November 1999, EIA wrote of the "continued weakening of the relationship between income and travel growth" (EIA 1999b). Preliminary reports from the State Highway Agencies reveal that Total VMT rose only 2% in 1999, the slowest growth since 1991, a recession year (DOT 2000).

Second, 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" (Mokhtarian & Henderson 1998). HBB spent 1.23 hours a day traveling in cars, whereas

HBT spent 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.

Third, 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" (Lee Schipper et al. 1989). 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. Recent studies (see below) suggest that heavy Internet users (greater than five hours a week) spend less time driving than average. 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?

Fourth, 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.

For these reasons, we suspect that the Internet will have no worse than a neutral impact on transportation energy intensity, and could well significantly reduce it. 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 will be to reduce 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 (Huber & Mills 1999). Scientists at Lawrence Berkeley National Laboratory (LBNL) recently examined in detail the numbers underlying the *Forbes* analysis (Koomey et al. 1999). *LBNL found that the estimates of the electricity used by the Internet were high by a factor of eight.*

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? Recent studies suggest that they are watching television less, reading newspapers less, driving less, and spending less time in service stores (Nie and Erbring 2000) 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 as commercial and residential buildings have their energy managed over the Internet.

As then EIA head Jay Hakes testified in February 2000, U.S. electricity consumption has actually slowed since the 1995, when the Internet took off (EIA, 2000). And that is in spite of a higher annual GDP growth rate since 1995.

Conclusion

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 reductions that the previous 10 years saw, which were under 1% per year. *We expect annual reductions 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 reductions in energy intensity. If the actual number is closer 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, data suggest that energy intensity in 1999 dropped by more than 2.2%.

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.

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