KYOTO AND THE INTERNET: THE ENERGY IMPLICATIONS OF THE DIGITAL ECONOMY

HEARING

BEFORE THE

SUBCOMMITTEE ON NATIONAL ECONOMIC GROWTH, NATURAL RESOURCES, AND REGULATORY AFFAIRS

OF THE

COMMITTEE ON GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

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KYOTO AND THE INTERNET: THE ENERGY IMPLICATIONS OF THE DIGITAL ECONOMY

WEDNESDAY, FEBRUARY 2, 2000

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON NATIONAL ECONOMIC GROWTH,
NATURAL RESOURCES, AND REGULATORY AFFAIRS,
COMMITTEE ON GOVERNMENT REFORM,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:30 a.m., in room 2247, Rayburn House Office Building, Hon. David M. McIntosh (chairman of the subcommittee) presiding.

Present: Representatives McIntosh, Ryan, and Kucinich.

Staff present: Marlo Lewis, Jr., staff director; Barbara F. Kahlow, professional staff member; Bill Waller and Heather Henderson, counsels; Gabriel Neil Rubin, clerk; Elizabeth Mundinger, minority counsel; and Jean Gosa, minority staff assistant.

Mr. RYAN [presiding]. A quorum being present, the Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs will come to order. I ask unanimous consent that all Members' and witnesses' written opening statements be included in the record. Without objection, so ordered.

I ask unanimous consent that all articles, exhibits, extraneous or tabular material referred to be included in the record. Without objection, so ordered.

I also ask unanimous consent that the record be left open for 10 days for any additional statements to be included in the record. Without objection, so ordered. I understand that my colleague, Ms. Chenoweth-Hage, is attending a mark up and may not be able to join us today. However, she has asked that a prepared statement of hers be entered into the record. Without objection, so ordered.

[The prepared statement of Hon. Helen Chenoweth-Hage follows:]

Statement of Congressman Helen Chenoweth-Hage
Subcommittee on National Economic Growth,
Natural Resources and Regulatory Affairs
Committee on Government Reform
B377 Rayburn House Office Building
February 2, 2000

Thank you Chairman McIntosh, I would like to thank the Subcommittee for holding this hearing to examine the energy implications for the digital economy and how this affects the implementation of the Kyoto Protocol.

Mr. Chairman, since negotiations on the Kyoto Protocol were completed in 1997, the United States has experienced a seemingly boundless and exploding digital economy. The Internet has transformed the way America conducts its business and has put a vast amount of information at Americans' fingertips.

However, the digital economy would seem to present a possible problem in relation to the Kyoto Protocol. One would expect that some energy requirements will grow as our economy becomes more dependent on the digital economy.

The facts are clear. Use of the Internet and Information Technology is exploding both in the home and at work. The retail use of the Internet is expanding rapidly. It is estimated that online retail sales will be between forty and eighty billion dollars by 2002.

However, with this explosion in the growth of our digital economy, electronic businesses operate on a twenty-four hour basis by necessity. Many businesses require that their equipment run twenty four hours a day in an air-cooled environment With the expansion of telecommuting and liberal flex-time policies, employers now must make their energy resources available at all hours of the day. Contrary to what President Clinton or Vice President Gore may think, all of this means *increased* use for some of our energy resources.

If we can expect some growth in our use of our energy resources, how does this affect the objectives of the Kyoto Protocol?

Mr. Chairman, I have been consistent in rejecting the premises of the Kyoto Protocol from the day the United States became a signatory to it in 1998. It is an agreement that will adversely affect America's economic growth, hurt the small businessman, and impose extraordinary costs upon all Americans. With possible increased requirements for energy resources because of the digital economy, we simply cannot afford to implement the Kyoto Protocol.

Mr. Chairman, I look forward to hearing from our three distinguished witnesses who are before us today. I'm sure they will be responsive to our questions and provide much needed insight on this important topic.

Thank you, Mr. Chairman.

Mr. RYAN. Today's hearing will examine how the burgeoning digital economy, comprised of e-commerce and the information technology industries that make e-commerce possible may change energy trends in the U.S. economy and how such changes may affect the cost and feasibility of the Kyoto protocol.

In March 1999, Vice President Gore stunned some of us and amused others by claiming to have created the Internet. "During my service in the U.S. Congress, I took the initiative in creating the Internet," Mr. Gore said during an interview with CNN's Wolf Blitzer. Now, whether or not Al Gore is the father of the Internet, he is unquestionably the father of the Kyoto protocol. Mr. Gore led the United States negotiating team at the December 1997 Climate Change Conference in Kyoto, Japan. During his service in the Senate and at the White House, Al Gore took the initiative in creating a legally binding international climate treaty.

So, one might say that today's hearing will examine the relationship between the Vice President's brain children. Will the digital economy facilitate Kyoto-style energy restriction policies by decreasing the energy intensity of the U.S. economy? Or, will the digital economy sweep the Kyoto protocol into the dust bin of history by increasing United States and global demands for electric power?

The digital economy is growing at a phenomenal pace. For example, during the past 2 years alone, the number of web users worldwide increased by 55 percent, the number of web servers increased by 128 percent, and the number of new web address registrations rose by an astounding 137 percent. The U.S. Department of Commerce's recent publication, the Emerging Digital Economy II, forecasts that by 2006, almost half the U.S. work force will be employed by industries that are either major producers or intensive users of information technology products and services. The Commerce Department study also reports that information technology industries contributed over one-third of the Nation's real economic growth from 1998 to 1999.

In thinking about this key driver of U.S. economic performance, I can't help noticing that the digital economy runs solely on electricity. More than half of U.S. electricity is produced from coal. Coal is the fuel source targeted for extinction by the Kyoto protocol. So, is there not a fundamental incompatibility between the energy requirements of a digital economy and the Kyoto protocol? Can we really wire the world and, at the same time, restrict United States and global access to abundant, affordable and reliable electric power?

Our witnesses, I am aware, have different answers to those questions. We encourage this, and we are excited about hearing your testimony. Yet, there appear to be some broad areas of agreement. The experts agree that the digital economy is enormously important, enormously large, and growing exponentially. They also agree that Internet forecasting is fraught with uncertainty. As the Commerce Department has observed, this emerging digital economy regularly surprises those who study it most closely. What this suggests to me is that we should proceed with caution in considering any policy that may damage or restrict the electricity supply that powers the digital economy. Indeed, since the digital economy is still very much in its infancy, we should probably move more slowly and cautiously in considering a treaty like the Kyoto protocol than at any other time.

Before turning to my colleague, Mr. Kucinich, for his opening statement, I would like to introduce our witnesses: The Honorable Jay Hakes, Administrator of the Energy Information Administration [EIA], of the U.S. Department of Energy. Jay, I believe, will be speaking first. Mr. Hakes will present EIA's analysis of energy trends and the digital economy. EIA testified before this subcommittee last year on a related issue. Welcome back, Mr. Hakes.

Mr. HAKES. Thank you.

Mr. RYAN. Dr. Joseph Romm, executive director of the Center for Climate and Energy Solutions and a former Clinton administration Acting Assistant Secretary for Energy Efficiency and Renewable Energy, will speak next. Welcome, Dr. Romm.

Mr. ROMM. Thank you.

Mr. RYAN. Dr. Romm will present the case that the Internet economy is breaking the historic link between economic growth and energy demand growth. If I am not mistaken, Dr. Romm believes that Internet efficiencies will enable us to implement the Kyoto protocol without economic pain. Thank you for testifying, Dr. Romm.

Our final witness is Mark Mills, senior fellow at the Competitive Enterprise Institute and scientific advisor to the Greening Earth Society. Mr. Mills will present the case that the digital economy is fueling a surge in demand for cheap, abundant and reliable electric power. He views the Kyoto protocol as a threat to the digital economy. To my knowledge, Mr. Mills was the first analyst to raise the topic of today's discussion. Thank you for participating in this hearing, Mr. Mills.

Mr. MILLS. Thank you.

[The prepared statement of Hon. David M. McIntosh follows:]

Statement of Chairman David M. McIntosh
Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs
on
"Kyoto and the Internet: the Energy Implications of the Digital Economy"
February 2, 2000

Today's hearing will examine how the burgeoning digital economy, comprised of electronic commerce (E-commerce) and the information technology industries that make E-commerce possible, may change energy trends in the U.S. economy, and how such changes may affect the cost and feasibility of the Kyoto Protocol.

In March 1999, Vice President Gore stunned some of us and amused others by claiming to have created the Internet. "During my service in the United States Congress, I took the initiative in creating the Internet," Mr. Gore said during an interview with CNN's Wolf Blitzer. Now, whether or not Al Gore is the Father of the Internet, he is unquestionably the Father of the Kyoto Protocol. Mr. Gore led the U.S. negotiating team at the December 1997 climate conference in Kyoto, Japan. During his service in the Senate and the White House, Al Gore took the initiative in creating a legally binding international climate treaty.

So, one might say that today's hearing will examine the relationship between the Vice President's brainchildren. Will the digital economy facilitate Kyoto-style energy restriction policies by decreasing the energy intensity of the U.S. economy? Or will the digital economy sweep the Kyoto Protocol into the dust bin of history by increasing U.S. and global demand for electric power?

The digital economy is growing at a phenomenal pace. For example, during the past two years alone, the number of web users world-wide increased by 55 percent, the number of web servers increased by 128 percent, and the number of new web address registrations rose by 137 percent. The U.S. Commerce Department's recent publication, *The Emerging Digital Economy II*, forecasts that by 2006, almost half the U.S. workforce will be employed by industries that are either major producers or intensive users of information technology products and services. The Commerce Department study also reports that information technology industries contributed over one-third of the nation's real economic growth from 1998 to 1999.

In thinking about this key driver of U.S. economic performance, I can't help noticing that the digital economy runs solely on electricity. More than half of U.S. electricity is produced from coal. Coal is the fuel source targeted for extinction by the Kyoto Protocol. So, is there not a fundamental incompatibility between the energy requirements of digital economy and the Kyoto Protocol? Can we really "wire the world" and, at the same time, restrict U.S. and global access to abundant, affordable, and reliable electric power?

Our witnesses, I am aware, have different answers to those questions. Yet there appear to be some broad areas of agreement. The experts agree that the digital economy is enormously important, enormously large, and growing exponentially. They also agree that Internet forecasting is fraught with uncertainty. As the Commerce Department has observed, "This emerging digital economy regularly surprises those who study it most closely." What this suggests to me, is that we should proceed with caution in considering any policy that may damage or restrict the electricity supply that powers the digital economy. Indeed, since the digital economy is still very much in its infancy, we should probably move more slowly and cautiously in considering a treaty like the Kyoto Protocol than at any other time.

Before turning to Mr. Kucinich for his opening statement, I would like to introduce our witnesses. The Honorable Jay Hakes, Administrator of the Energy Information Administration (EIA) of the U.S. Department of Energy, will speak first. Mr. Hakes will present EIA's analysis of energy trends and the digital economy. EIA testified before this Subcommittee last year on a related issue. Welcome back, Mr. Hakes.

Dr. Joseph Romm, Executive Director of the Center for Climate and Energy Solutions, and former Clinton Administration Acting Assistant Secretary for Energy Efficiency and Renewable Energy, will speak next. Dr. Romm will present the case that the Internet economy is breaking the historic link between economic growth and energy demand growth. If I am not mistaken, Dr. Romm believes that Internet efficiencies will enable us to implement the Kyoto Protocol without economic pain. Thank you for testifying, Dr. Romm.

Our final witness is Mark Mills, Senior Fellow at the Competitive Enterprise Institute and Scientific Adviser to the Greening Earth Society. Mr. Mills will present the case that the digital economy is fueling a surge in demand for cheap, abundant, and reliable electric power. He views the Kyoto Protocol as a threat to the digital economy. To my knowledge, Mr. Mills was the first analyst to raise the topic of today's discussion. Thank you for participating in this hearing, Mr. Mills.

Mr. RYAN. Mr. Kucinich.

Mr. KUCINICH. Good morning, Mr. Chairman.

Mr. RYAN. Good morning.

Mr. KUCINICH. Nice to see you. I appreciate the chance to participate with this panel, with you in the chair.

As you know, my approach in this Congress has been bipartisan, and I think that is a good way to proceed in trying to get to the truth of all of the matters into which we inquire, and I think that one of the things that we may be able to do in future Congresses, anticipating that we are both going to be here, is to find a way to diminish the partisan rancor and find ways where we can work together.

Now, we may have differences of opinion on this particular hearing. I would like to say that I consider Vice President Gore one of the most visionary leaders we have ever had in American government. He has corrected his misstatement about whether he was the—about being the creator of the Internet, but I think that everyone understands that his involvement in the development of new technologies cannot be disputed. I also know that as someone who is the author of a book called Earth in the Balance, it was one of the most visionary statements on the concern for the global and the U.S. environment.

So I just want that said, because to let this hearing begin on a note where the Vice President is challenged I think requires a response, not simply in order to defend his record, which speaks for itself, it can stand without my humble efforts, but because I think that the nature of what we are discussing today is so significant that it shouldn't be minimized by setting a tone, which I think we are all capable of going beyond.

I really appreciate having this hearing on the impact of the Internet on energy demand and our production of greenhouse gases.

The Internet economy is growing at an explosive rate. Studies estimate that it may grow more than tenfold, from the tens of billions of dollars to perhaps trillions of dollars. Our economy is already reaping the benefits. The question remains, what does this mean for the environment?

Historical patterns indicate that economic growth comes at the expense of the environment. Economic growth and energy use rose and fell in tandem. However, the rules seem to be changing. In 1997 and 1998, our economy soared, yet energy use and our emission of greenhouse gases rose at a much slower rate than was indicated by historical pattern. Apparently, our economy is becoming more energy efficient.

I think President Clinton made that point in his State of the Union when he spoke about how perhaps in this next century we can finally put to rest this mythology that you cannot have economic growth and a cleaner environment at the same time. So we are challenged in this Congress to keep unfolding this new thinking, which I think we are capable of doing.

I think there is good reason to believe the Internet will help us become even more energy efficient. E-businesses require less retail space, relying instead on warehouses. This saves energy otherwise spent on construction. Businesses and individuals do not need to store as much information on paper, which saves energy otherwise spent producing paper and building storage space. Businesses will likely obtain more accurate consumer information, which saves energy otherwise spent building storage space for unused inventory. Consumers save the energy used to drive to and from the mall when they order products on line, and telecommuting saves energy otherwise expended on driving to work and constructing office space.

These benefits apparently come at little cost because the Internet is not energy intensive. According to the Energy Information Administration, personal computers in residences and business accounted for less than 2 percent of our electricity use in 1999. Much of this energy was used to power other aspects of computer use, not just the Internet. And we did not see a substantial increase in energy use in 1997 and 1998 when Internet use rose dramatically. In fact, energy use increased at a much slower rate than expected. In his written testimony, Mr. Hakes testifies that "it is clear that the size of Internet electricity use today is small compared to that of all other uses of electricity."

If the Internet does provide great energy benefits at little cost, we may need to rethink some of our earlier analyses of the cost of complying with the Kyoto protocol. A working paper prepared at the Environmental Protection Agency found that information and communication technology "may prompt large structural changes that can reduce overall energy consumption." These changes could potentially significantly reduce mainstream estimates of energy use and carbon emissions, such as the Energy Information Administration's analysis of the cost of the Kyoto protocol. In other words, we may have greatly overestimated the cost of complying with the Kyoto protocol.

I think that one of the things that we should also consider is that as we move toward this tremendous explosion of new thought in this new century, that we will most likely be ushering in alternative energy strategies. It is inevitable. We could not foresee at the beginning of the 19th century the great developments in transportation and energy and science. I think that we have an understanding of how this impulse to create is so powerful in our society, and I think we can anticipate that there will be dramatic developments in information technologies, which in some ways will make this debate itself hopefully obsolete. But it is not obsolete at the moment, I respect that, and I appreciate the opportunity to proceed. I think it is an important issue.

I look forward to hearing from the witnesses today, and I would ask the Chair unanimous consent to hold the record open for relevant materials.

Mr. RYAN. Without objection.

[The prepared statement of Hon. Dennis J. Kucinich follows:]

Statement of Mr. Kucinich
February 2, 2000
NEG Subcommittee hearing on Global Warming and the Internet

Mr. Chairman, thank you for holding this important hearing on the impact of the Internet on energy demand and our production of greenhouse gases.

The Internet economy is growing at an explosive rate. Studies estimate that it may grow more than ten-fold -- from the tens of billions of dollars to one trillion dollars -- in just a few years. Our economy is already reaping the benefits. But the question remains, what does this mean for the environment?

Historical patterns indicate that economic growth comes at the expense of the environment. Economic growth and energy use rose and fell in tandem. However, the rules seem to be changing. In 1997 and 1998 our economy soared, yet energy use – and our emission of greenhouse gases – rose at a much slower rate than was indicated by historical patterns. Apparently, our economy is becoming more energy efficient.

Mr. Chairman, there is good reason to believe the Internet will help us become even more energy efficient:

- **E-businesses require less retail space, relying, instead, on warehouses. This saves energy otherwise spent on construction.**
- **Businesses and individuals do not need to store as much information on paper which saves energy otherwise spent producing paper and building storage space.**
- **Businesses will likely obtain more accurate consumer information which saves energy otherwise spent building storage space for unused inventory.**
- **Consumers save the energy used to drive to and from the mall when they order products on line.**
- **And telecommuting saves energy otherwise expended on driving to work and constructing office space.**

These benefits apparently come at little cost because the Internet is not energy intensive. According to the Energy Information Administration, personal computers -- in residences and business -- accounted for less than 2% of our electricity use in 1999. Much of this energy was used to power other aspects of computer use -- not just the Internet. And we did not see a substantial increase in energy use in 1997 and 1998 when Internet

use rose precipitously. In fact, energy use increased at a much slower rate than expected. In his written testimony, Mr Hakes testified that, quote, "it is clear that the size of Internet electricity use today is small compared to that of all of the other uses of electricity."

If the Internet does provide great energy benefits at little cost, we may need to rethink some of our earlier analyses of the cost of complying with the Kyoto Protocol. A working paper prepared at the Environmental Protection Agency found that information and communication technology, quote, "may prompt large structural changes that can reduce overall energy consumption." These changes could potentially significantly reduce mainstream estimates of energy use and carbon emissions -- such as the Energy Information Administration's analysis of the cost of the Kyoto Protocol . In other words, we may have greatly overestimated the cost of complying with the Kyoto Protocol.

Mr. Chairman, this is an important issue and I look forward to hearing from the witnesses today.

[Witnesses sworn.]

Mr. RYAN. I will start with Mr. Hakes. Mr. Hakes, thank you.

STATEMENTS OF JAY HAKES, ADMINISTRATOR, ENERGY INFORMATION ADMINISTRATION, DEPARTMENT OF ENERGY; JOSEPH ROMM, EXECUTIVE DIRECTOR, CENTER FOR ENERGY AND CLIMATE SOLUTIONS, AND FORMER ACTING ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY; AND MARK MILLS, SENIOR FELLOW, COMPETITIVE ENTERPRISE INSTITUTE, AND SCIENTIFIC ADVISOR, GREENING EARTH SOCIETY

Mr. HAKES. Thank you, Mr. Chairman. It is a pleasure to be before the Congress talking about something other than high oil prices this week.

The Energy Information Administration estimates that if current Federal policies remain in place, electricity use in the United States over the next two decades is likely to grow by about 1.5 percent a year. While no one can estimate growth in electricity with exactitude, this number does provide a useful benchmark for people who study energy issues.

A lively debate has emerged over whether consumption of electricity is likely to rise more slowly or more rapidly than the EIA projects. One camp represented today argues the former and another the latter, and they can testify why they have reached these conclusions.

The points raised by these analysts certainly have some merit. Most of them, however, are already incorporated in the EIA analysis, although not at a scale that would satisfy either of the camps. Several of our assumptions would seem to reflect the trends they are talking about; for example, a steady shift to less energy intensive industries, new equipment in the industrial sector that is much more efficient than the stock it replaces, penetration of more efficient equipment in the residential and commercial sectors, and a growth of 3.2 percent a year in a category called "other uses of electricity," which would allow for considerable growth in electric load brought about by computers and the Internet.

While it is certainly not possible to rule out the slower electronic growth or the faster electric growth arguments, we don't find either convincing enough to suggest that the EIA should be altered in either direction. In the first place, as seen from the list above, the arguments haven't been ignored in the EIA analysis and, in addition, to some extent, they offset each other.

The slow energy growth camp must deal with expectations that lower prices for electricity and rapid growth in personal disposable income will create a climate in which demand for new energy services is likely to grow and the priority given to reducing fuel costs is not likely to be high. The rate of stock turnover limits the speed with which many more efficient pieces of equipment can enter the market and many of the changes suggest that they are less dramatic than they might appear.

For instance, as web-based shopping grows, much of the displacement will be of catalogs and 800 telephone numbers. There will still be some reduction in energy use, but trucks will still be needed for their frequently long journey from the warehouse to the home. The warehouses the products come from are likely to be smaller, but the homes they go to are likely to be larger.

The high energy growth camp has to deal with the fact that computer equipment of whatever type tends to have very low electric load compared to space heating and cooling and other more traditional equipment. This can be seen in the graph which is figure 1 of my prepared testimony. Those of you who have the testimony can find this as figure 1, but on the graph here, you can see that PCs are estimated to be 2 percent of the electric load in residential buildings. Now, as other witnesses will point out, there is some fuzziness to the data, and maybe that is not perhaps an exact number. But we do know a lot about these other uses and we know the total electric consumption. Say we are off by some magnitude here, we are still not talking about something that is a heavy load in the home. At home I now listen to more CDs, music on my computer, but that means I am using my stereo system less, which actually uses more watts.

PCs and other electronics are growing rapidly, but still a small part of overall consumption, and this is shown in a later graph. This is all buildings, commercial and residential. Some of what Mr. Mills is talking about is in the PC category and some of it is in commercial office equipment. You can see that the rates of growth are very, very high there, much above average, but the BTUs growth is relatively small, because it is just a small part of the electrical load.

I would also say that we do question some of the calculations in the high-growth camp on the load of these pieces of electrical equipment.

Future trends in energy efficiency and expanded demand for energy services are particularly difficult to anticipate. It is hard often to get good data. But in summary, we continue to believe that our estimates on the growth of electricity are good base case projections under current policies for at least a couple of reasons. One, we are not seeing either of the alternate growth paths reflected in the current data. Second, the advances in technology that accelerate efficiency are often the same as those that accelerate demand for energy services. Just look at the automobile as an example of that.

For instance, if technology progresses more rapidly than projected, it will likely spur both greater efficiency and greater demand for new energy services, so the two results tend, to some extent, to offset each other.

I would also hope in the question period I will have an ample opportunity to discuss the testimony of my former colleague, Mr. Romm. His characterizations of EIA's previous work on Kyoto and other subjects I believe are highly misleading. These mistakes have been pointed out rather fully in the public record, and I am somewhat puzzled why they continue to appear in the public record. So I hope that in the question and answer period we will have a chance to fully discuss some of the points he raises in his testimony.

[The prepared statement of Mr. Hakes follows:]

STATEMENT OF

JAY E. HAKES

ADMINISTRATOR, ENERGY INFORMATION ADMINISTRATION

DEPARTMENT OF ENERGY

before the

SUBCOMMITTEE ON NATIONAL ECONOMIC GROWTH,

NATURAL RESOURCES, AND REGULATORY AFFAIRS

COMMITTEE ON GOVERNMENT REFORM

UNITED STATES HOUSE OF REPRESENTATIVES

February 2, 2000

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss the potential impacts of the growing use of computers and the Internet on electricity consumption.

The Energy Information Administration (EIA) is a statistical and analytical agency within the Department of Energy. We are charged with providing objective, timely, and relevant data, analysis, and projections for the use of the Energy Department, other agencies, the Congress, and the public. We do not take positions on policy issues, but we do produce data and analysis reports that are meant to help policy makers decide energy policy. Because we have an element of statutory independence with respect to the analyses we publish, our views are strictly those of EIA. We do not speak for the Department, nor for any particular point of view with respect to energy policy, and our views should not be construed as representing those of the Department or the Administration. EIA's baseline projections on energy trends, however, are widely used by government agencies, the private sector, and academia for their own energy analyses. Each year EIA publishes the *Annual Energy Outlook*, which provides projections and analysis of domestic energy consumption, supply, prices, and carbon emissions. These projections are not meant to be exact predictions of the future but represent a likely future, assuming known trends in demographics and technology improvements and also assuming no change in current law, regulation, and policy.

Background

We are all well aware of the explosive growth of personal computers (PCs) and the Internet in our homes and in all aspects of our daily lives—schools, businesses, and industries. A recent report from the Department of Commerce, *The Emerging Digital Economy II*, is one of many recent studies undertaken to analyze the growing public access and availability to the Internet and the growth of electronic commerce (E-commerce).[1] These studies have indicated that E-commerce,

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[1]Economics and Statistics Administration, U.S. Department of Commerce, *The Emerging Digital Economy II*, (Washington, DC, June 1999), www.ecommerce.gov/ede.

in the form of business-to-consumer and business-to-business sales over the Internet, may transform the way business is currently carried out, while increasing productivity and reducing waste. Some argue that the increase in the use of electronic equipment will increase energy use while others contend that the Internet will temper future growth in energy use by reducing the need for energy-intensive manufacturing, retail space, and transportation requirements.

Electricity Use – Past and Future

From 1985 to 1995, retail electricity sales grew at a rate of 2.6 percent per year, faster than any other delivered energy source over the same ten year period.[2] Since 1995, the use of the Internet has increased dramatically, yet retail electricity sales have grown by 2.1 percent per year, 0.5 percentage points less than the previous 10 years.[3] Economic activity, weather, and other factors can, of course, affect these growth rates. However, some might conclude that the Internet, in and of itself, has not yet caused a significant impact on the amount of electricity used by households, commercial establishments, and large industrial users combined, due to the substitution away from other uses of electricity, such as color televisions and stereo systems. From 2000 to 2010, the *Annual Energy Outlook 2000* (*AEO2000*) projects electricity sales to grow at about 1.5 percent per year, as trends in energy efficiency, appliance saturation, population, and economic growth act to slow the growth realized in the 1980s and 1990s.[4] An in depth look at how electricity is used in each sector will help in understanding the projected growth rates for electricity in the *AEO2000*.

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[2]Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(99/12),(Washington, DC, November 1999).

[3]Energy Information Administration, *Short Term Energy Outlook*, DOE/EIA-0202(2000/01), (Washington, DC, December 1999), www.eia.doe.gov/cmeu/steo/pub/10tab.html.

[4]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000), (Washington, DC, December 1999).

Residential Buildings

Households currently consume more electricity, 35 percent, than any other end-use sector in the United States (Figure 1). The uses for electricity in the house are numerous, with no single service responsible for more than 13 percent of the total electricity sold to the residential sector on an annual basis. Over the past decade, many new electronic devices have made their way into the home, including PCs and peripheral equipment. Although PCs have been on the market for more than 15 years, sales have recently skyrocketed as a result of the development of various software applications and the popularity of the Internet. Trade publications estimate that about half of the households in the United States have at least one PC, up from 35 percent in 1997.[5]

Even with the increasing use of PCs in the residential sector, it is estimated that in 1999, PCs accounted for only 2 percent of the electricity delivered to the home (Figure 1).[6] The four largest uses for electricity—space heating, space cooling, refrigeration, and water heating—account for almost half of all electricity used on an annual basis. In fact, an average household using electricity as its main space heating fuel would use nearly 12 times more electricity for space heating than for PCs.[7] PCs, however, are one of the fastest growing uses for electricity, as more householders purchase them and those that have them use them for more than simply balancing their checkbook. Even with the explosion in the use of a variety of home electronics, residential electricity sales in the 1990s grew at an average rate of only 2.4 percent per year (compared to 2.6 percent per year in the 1980s), about twice the rate of household formation (1.2 percent per year). Within this decade, residential electricity consumption declined from its previous year total twice (1992 and 1997), as cooler summer temperatures, particularly in 1992, significantly reduced

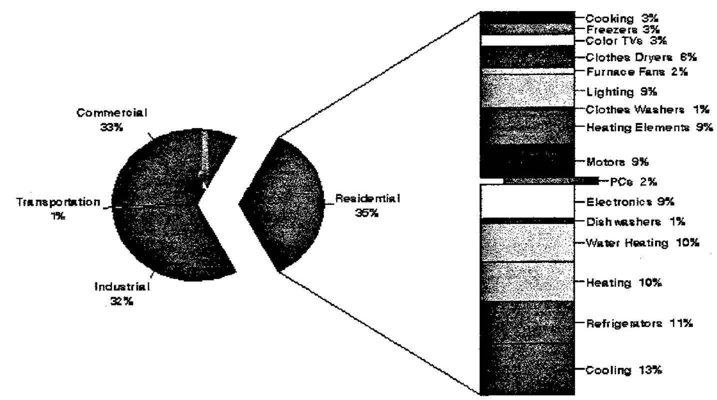
[5]Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, DOE/EIA-0632(97), (Washington, DC, November 1999).

[6]Residential PC use is defined as the electricity required for the central processing unit (CPU) and monitor.

[7]Energy Information Administration, *A Look at Residential Energy Consumption in 1997*, DOE/EIA-0632(97), (Washington, DC, November 1999).

the amount of electricity needed for air conditioning. The *AEO2000* projects residential electricity sales to grow at an annual rate of 1.5 percent per year through 2010, as household formation growth slows and energy efficiency increases, dampening the growth in miscellaneous electric devices. In *AEO2000*, electricity use by miscellaneous electric appliances, including PCs, color televisions, and the like, are projected to grow at 3.2 percent per year through 2010, more than twice the rate of the average electricity growth rate, and more than three times the rate of household formation. These growth rates are based on saturation rates and recent data detailing the use of these appliances in the home.

Figure 1. Residential Sector Site Electricity Consumption by End-Use, 1999



Source: Annual Energy Outlook 2000.
Note: PCs are defined as central processing unit and monitor.

The commercial sector currently uses about one-third of all of the electricity consumed in the United States (Figure 2). PCs[8] and other office equipment were estimated in 1999 to account for 2.4 and 7.5 percent of total commercial electricity use, respectively, for a total of about 10 percent. In contrast, lighting in commercial buildings is estimated to require more than three times the electricity needed to power PCs and other office equipment. Space conditioning—heating, cooling, and ventilation—also commands a significant share of commercial electricity use, about twice that used for PCs and office equipment.[9] Refrigeration, water heating, cooking, and various other services account for the remaining commercial energy use.

EIA's recent report on PC use in commercial buildings[10] estimated that the number of PCs and computer terminals used in commercial buildings increased by 45 percent from 1992 to 1995. For all commercial buildings, there were three PCs or computer terminals for every five employees in 1995, and in office buildings, which comprised nearly half of all computers used in the commercial sector in 1995, there were four PCs or computer terminals for every five employees. However, the dramatic growth in commercial PCs has not translated to similar growth in electricity use, which has averaged 3.0 percent per year in the 1990s (compared to 4.5 percent per year in the 1980s) because PC use still comprises a relatively small share of commercial electricity consumption. Electricity used for all office equipment, PCs, and miscellaneous applications, including Internet-related uses, is projected to grow at 3.0 percent per year through 2010, more than 2.5 times the rate of commercial floor space, and nearly twice the rate of total commercial sector electricity use (Figure 3). The growth rates assumed for these miscellaneous uses are based on recent data on appliance saturation and usage rates.

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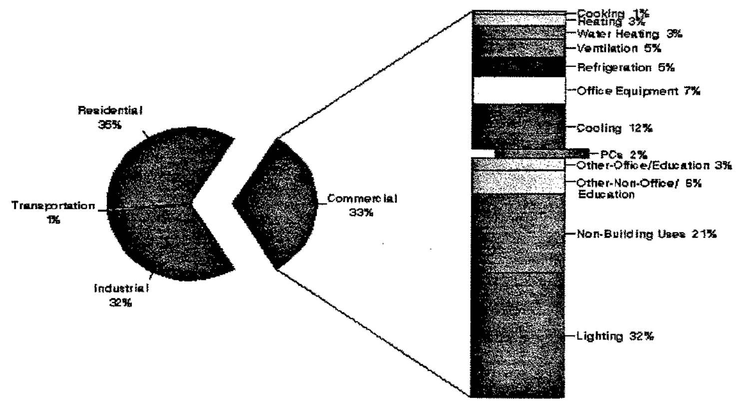
[8]Commercial sector PC use is defined as the electricity required for the central processing unit, monitor, and laser printer.

[9]Office equipment includes FAX machines, copiers, and point of sale equipment (cash registers). Telecommunication equipment and routers for Internet connection are included in "Other - Office/Education" in Figure 2.

[10]Energy Information Administration, *Personal Computers and Computer Terminals in Commercial Buildings*, (Washington, DC, April 1999), www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pcsterminals.html.

Figure 2. Commercial Sector Site Electricity Consumption by End-Use, 1999



Source: Annual Energy Outlook 2000.
Note: PCs are defined as the central processing unit, monitor,and laser printer.

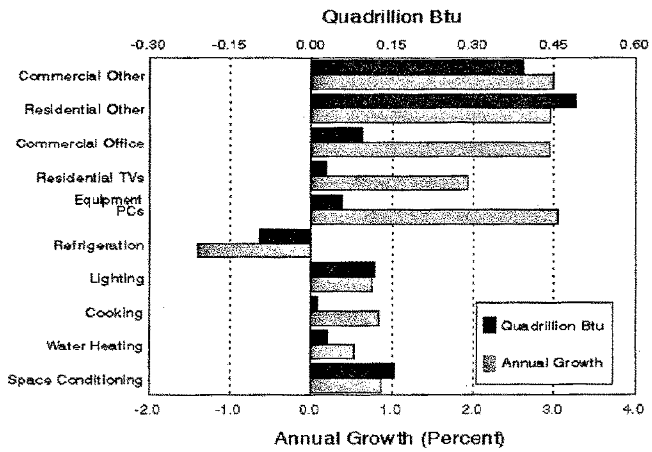
Industrial Manufacturing and Facilities and Economic Growth

The EIA report *Manufacturing Consumption of Energy 1994* [11] estimates that less than 2 percent of all electricity used in manufacturing facilities in 1994 was consumed for facility support. Facility support, in this case, includes the functions normally associated with office or building operations other than facility lighting, heating, ventilation, and air conditioning. Operation of office equipment such as PCs and copying machines are part of facility support. However, cooking and refrigeration in cafeterias, elevator operation, and the energy used by vending

[11]Energy Information Administration, *Manufacturing Consumption of Energy 1994*, DOE/EIA-0512(94), (Washington, DC, December 1997) and ftp://ftp.eia.doe.gov/pub/pdf/consumption/051294.pdf.

machines are a few examples of other functions included in facility support, highlighting the fact that office equipment use comprises just a small fraction of the electricity used in manufacturing facilities.

Figure 3. Buildings Sector Site Electricity Growth by End-Use, 2000-2010



Source: Annual Energy Outlook 2000.

There are limited data detailing the energy use associated with the manufacturing of computer-related products. The Annual Survey of Manufactures (ASM)[12], however, reports the amount of electricity purchased by Standard Industrial Classification (SIC) 357 (computer manufacturing) and SIC 367 (semiconductor manufacturing). In 1994, computer manufacturers purchased 4.9 billion kilowatthours of electricity while semiconductor manufacturers purchased 15.7 billion

[12]Bureau of the Census, U.S. Department of Commerce, *1994 Annual Survey of Manufactures*, M94(AS)-1, (Washington, DC, March 1996).

kilowatthours of electricity, which together account for 2.6 percent of the 802 billion kilowatthours of total manufacturing sector purchased electricity. These two sub-sectors accounted for 5.2 percent of the total value of manufacturing shipments in 1994. In 1996, the ASM reported that these same SIC groups accounted for the same percentage of total manufacturing purchased electricity, while its value of manufacturing shipments increase to 6.2 percent.[13] From 2000 to 2010, *AEO2000* projects the value of output for SIC 367 to grow at 7.3 percent per year, one of the fastest growing manufacturing sectors in the U.S. economy, which contributes to a projected overall Gross Domestic Product (GDP) growth rate of 2.3 percent per year through 2010. Total gross output of the U.S. economy is projected to grow at 2.3 percent per year through 2010, the same rate as GDP. As a percentage of total gross output, SIC 367 is projected to grow to 2.8 percent by 2010, up from 1.7 percent in 2000. The high rate of growth in SIC 367 contributes to an electricity sales growth rate of 3.2 percent per year for metal based durables manufacturing, more than twice the rate of overall industrial sector electricity sales through 2010.

The Digital Age and Energy Consumption

The Digital Age has brought about many new electronic devices over the recent years, many of which are associated with the use of PCs. For household PC use, current electricity use estimates range from 130[14] to 262[15] kilowatthours per year, based on many factors, including hours of use, efficiency features (e.g., sleep mode), and monitor size. While it appears obvious that the Internet has increased the number of hours a home PC might operate, it is not clear that the energy use associated with the extra operating hours necessarily adds extra kilowatthours to the average

[13]Bureau of the Census, U.S. Department of Commerce, *1996 Annual Survey of Manufactures*, M96(AS)-1, (Washington, DC, February 1998).

[14]Ernest Orlando Lawrence Berkeley National Laboratory, *Energy Data Sourcebook for the U.S. Residential Sector*, (Berkeley, CA, September 1997).

[15]Arthur D. Little, *Electricity Consumption by Small End Uses in Residential Buildings*, (Cambridge, MA, August 1998).

monthly electricity bill. In some cases, the time spent on the Internet could supplant watching television or playing video games, both of which consume electricity. In fact, a home theater equipped with a cable box and VCR could, depending on the features of the equipment, use more electricity than surfing the Internet for a comparable amount of time. Newer PCs are equipped with efficiency features that allow the unit to "power down" when left inactive for a certain amount of time. This feature, however, can be disabled in a manner similar to flow restriction devices in showerheads, limiting the overall effectiveness of the option. Current estimates for Internet use at home are 7 hours per week, less than half the hours (15) estimated for television use. Recent trends have shown that hours spent on the Internet have been increasing, while time spent watching television has been flat or falling.[16]

In the commercial sector, growth in the number of PCs is expected to slow in the next decade as the market becomes saturated. As noted earlier, office buildings were estimated to have four PCs for every five employees in 1995. Office workers may increase Internet use; however, this may offset use of other types of office and computer equipment, such as FAX machines and copiers or travel for reference materials. In short, it is extremely difficult to separate computer use associated with the Internet from computer use in general, given the fact that no matter the application, the desktop computer will use the same amount of electricity (i.e., ON is ON).

Uncertainties Relating to Electricity Consumption

The uncertainty related to future electricity demand due to the growth of the Internet is just a small component of all the uncertainty relating to future electricity demand. There are many factors that can either increase or decrease the use of electricity on a per household or per building basis. As a wealth of new electronic devices makes its way into homes and businesses,

[16]EEnergy Informer Newsletter, (Menlo Park, CA, January 2000).

electricity use can be expected to increase. However, many programs exist to reduce the amount of electricity needed to power most major appliances. These include Federal equipment efficiency standards, State and local building codes, research and development (R&D) programs, voluntary programs, and executive orders for Federal agencies. More efficient versions of current technology can provide a means to offset the expected growth in electricity use due to the introduction of new electronic devices. However, the timing and widespread acceptance of these technologies provide a degree of uncertainty regarding their effectiveness. The implementation of unforseen policies and advances in technologies can easily dwarf any impact that the Internet might have on electricity demand. This is especially true internationally, where regions such as China and South America are in the process of providing electricity to hundreds of millions of people. Europe is currently transitioning to a continent-wide wholesale market for electricity, which could have a major impact on future electricity demand, regardless of how fast the Internet grows.

Future energy prices and their effects on consumer behavior add further uncertainty to projections of total energy and electricity consumption. It is possible that the increasingly competitive structure of the electricity generation, transmission, and distribution industry may lead to declining electricity prices. In that case, consumers are likely be less concerned about their use of electricity-consuming services and the purchase of energy-efficient products. As the marginal price of providing a particular service falls, as a result of either declining energy prices or increasing energy efficiency, one would expect the energy intensity for that service to increase. This "rebound" effect is particularly important in space conditioning applications, where a direct response to higher or lower energy prices can be easily accomplished by modifying the thermostat setting. On the other hand, higher prices of fuels used to generate electricity, electricity industry developments, or policy initiatives to reduce U.S. energy consumption and emissions could lead to higher electricity prices.

Electricity Use and the Kyoto Protocol

In the EIA report *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*,[17] reference case electricity sales are projected to grow at 1.5 percent per year from 2000 to 2010, identical to the rate projected in *AEO2000* over the same period. Depending upon the magnitude and availability of flexibility measures to meet the Kyoto Protocol (U.S.carbon emissions 7 percent below their 1990 levels), the carbon price is projected to range from $67 to $348 ($1996) per metric ton in 2010. Average electricity price increases in these scenarios in 2010 range from 20 to 86 percent over the reference case level of 6 cents per kilowatthour. Residential electricity prices in the Kyoto study range from 19 to 82 percent over reference case levels in 2010. Even at the most extreme price increase, it is not expected that household use of the Internet would substantially change. With the near doubling of projected electricity prices by 2010 compared to recent history in the most extreme case of the Kyoto study, operating a home PC for a month would cost about 5 times less than the cost of a standard monthly subscription for Internet access.[18] In the most extreme case of the Kyoto study, residential sector electricity use by PCs was projected to decrease by 14 percent (1.7 billion kilowatthours) relative to the reference case in 2010.

Recent Studies on the Digital Age and Energy Use

Several recent articles have indicated that the increasing popularity of the Internet will dramatically increase electricity use, creating the need for new power plants, while others suggest that the Digital Age will bring about structural change leading to more efficient use of resources and energy.

The Internet Begins With Coal: A Preliminary Exploration of the Impact of the Internet on

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[17]Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03, (Washington, DC, October 1998).

[18]This calculation is based on a PC using 262 kilowatthours per year, electricity prices at 13.9 cents per kilowatthour, and Internet access costing $15 per month.

Electricity Consumption by the Greening Earth Society, and the derivative *Dig more coal – the PCs are coming* in the May 31, 1999, issue of Forbes Magazine, both contend that the Internet economy will require a substantial increase in electricity use to keep up with the pace of Internet development. In summary, these articles suggest that there are over 200 million computers in homes and businesses, and that these computers, coupled with their accessories and associated devices, use about 8 percent of the U.S. demand for electricity. In addition, these articles suggest that within 10 years, half of the electric grid will power the Internet and E-commerce activity. The Forbes article, as the title suggests, purports that coal will be the generating fuel of choice to meet the demand for electricity.

The *AEO2000* reference case projects electricity sales to grow at 1.5 percent per year through 2010, half the rate implied by the Forbes article. This projection includes recent trends in the growth of consumer electronics, recently enacted Federal appliance efficiency standards, the effects of structural changes in the economy, and electricity deregulation. These factors have different effects on the electricity growth rates and consumption of various building sector end uses (Figure 3). However, at the average rate of growth of 1.5 percent per year, electricity generated by coal increases by only 13 percent (242 billion kilowatthours), while electricity generated by natural gas increases by 96 percent (309 billion kilowatthours). By 2010, only 2 percent of cumulative electric generator additions are projected to be coal-fired, while 94 percent are projected to be natural gas-fired.

If the demand for electricity were to grow at 3 percent per year through 2010, as suggested in the Forbes article, generation from coal would account for 32 percent of the increase, while natural gas would account for 60 percent.[19] In this "high electricity growth case," coal would account for less than 50 percent of electricity generation, while generation from natural gas would nearly

[19]Energy Information Administration, National Energy Modeling System run HIEL3.D122999A.

triple, increasing to 25 percent by 2010. Given the increased reliance on natural gas in the electric generation sector, the 16 percent increase in electricity sales in this "high electricity growth case" would increase carbon dioxide emissions by 6.6 percent in 2010 (117 million metric tons of carbon equivalent), relative to the *AEO2000* reference case forecast.

While it is indisputable that the Internet and E-commerce are growing rapidly, estimates regarding the electricity associated with its direct use cited in the Forbes article have been subject to some debate. Lawrence Berkeley National Laboratory, for example, asserts that electricity use associated with the Internet has been overestimated by a factor of 8 in the Forbes article.[20] The Forbes article appears to have severely over estimated the number of PCs in use today. While it is true that sales of PCs have been brisk of late, not all of these purchases are additive to the stock. In fact, because of fast stock turn over (roughly 2 to 3 years), many computer purchases replace older units, especially since the technology has been evolving so rapidly over the past several years. Also, for many of the devices associated with Internet use and dot-com companies, such as routers and mainframe computers, the electricity use was estimated using the rated power, which is typically twice the actual power draw.[21] Correcting for this error reduces the amount of electricity attributable to routers in the Forbes analysis by a factor of three. With all of these corrections taken into account, it is unlikely that the Internet will require 30 to 50 percent of the electric grid in the coming years, as suggested in the Forbes article.

While the *AEO2000* forecast does include Internet use in the projections, it does not include it as a separate category due to the difficulties in quantifying its exact use. Figures 1 and 2 detail electricity use in the residential and commercial sectors for 1999. Electricity use attributed to PCs accounted for about 2 percent (19 and 27 billion kilowatthours in the residential and commercial

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[20]Lawrence Berkeley National Laboratory, Memorandum LBNL-44698, (Berkeley, CA, December 1999).

[21]Lawrence Berkeley National Laboratory, Memorandum LBNL-44698, (Berkeley, CA, December 1999).

sectors, respectively) of the electricity used in each sector, with peripheral equipment related to the Internet in businesses and home PCs accounting for 1.5 and 0.3 percent (16 and 3 billion kilowatthours) of commercial and residential sector electricity use, respectively. With the addition of the electricity used to manufacture computer-related equipment, electricity used by all computers and Internet-related uses accounted for less than 3 percent (98 billion kilowatthours) of all domestic electricity sales in 1999, well below the 8 percent (263 billion kilowatthours) reported in the Forbes article. Included in the *AEO2000* forecast are the recent historical growth trends in miscellaneous uses of electricity, of which the Internet is one, in order to quantify future electricity use. Even with the inclusion of these recent growth rates, the amount of electricity used by PCs and peripherals in the home and PCs and office equipment in commercial establishments is well below the amount claimed in the Forbes article.

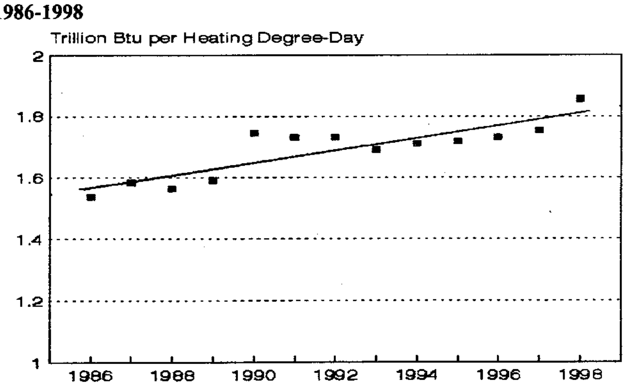
A recent article by The Global Environment and Technology Foundation (GETF) entitled *The Internet Economy and Global Warming* takes the position that the growth in the Internet will help companies become more energy and resource efficient, contributing to higher economic growth and less negative impact on the environment. These claims are based largely on economic and energy data for two years, 1997 and 1998, which exhibited fairly substantial increases in economic growth while energy consumption "hardly grew at all."[22] The paper suggests that the precipitous drop in energy intensity over this time period can be attributed to structural changes in the economy and gains in energy efficiency. While it is true that total delivered energy (excluding fuel used to generate electricity) decreased from 1996 to 1998, it should be noted that the decline is almost entirely due to a decrease in the use of natural gas in the buildings and industrial sectors.[23] Natural gas use in these sectors decreased by 6 percent over this period, however, three-fourths of the decrease was in the buildings sector, where gas-weighted heating degree-days

[22]The Center for Energy and Climate Solutions, *The Internet Economy and Global Warming*, December, 1999.

[23]Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(99/12),(Washington, DC, November 1999).

were 16 percent lower in 1998 than were observed in 1996. In fact, through the first nine months of 1999, natural gas consumption in the buildings sector was 4.1 percent higher than the first nine months of 1998, as winter temperatures became more "normal" in early 1999. In fact, buildings sector natural gas consumption, when normalized for weather fluctuations, increased in 1998, relative to all other years since 1986 (Figure 4). Although customer growth is not reflected in Figure 4, the trend line shows that growth in natural gas use, in terms of customers and/or intensity, has more than offset increases in efficiency. If energy efficiency was responsible for the decline in natural gas consumption over this period, one would not expect such a marked increase in this index in 1998, relative to 1996. Overall, one would expect the change in energy consumption and intensity to have occurred over a widerrange of fuels and sectors if energy efficiency and structural changes were responsible for the lower energy use over this two year period, which was not the case.

Figure 4. Buildings Sector Natural Gas Consumption per Heating Degree-Day, 1986-1998



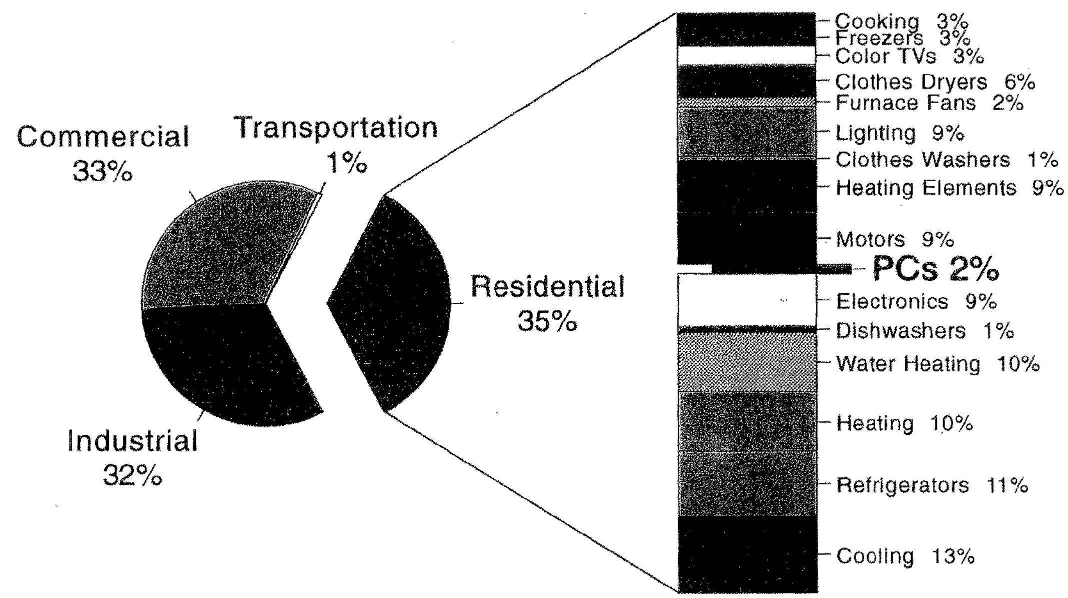
Sources: Monthly Energy Review, December 1999 and Short Term Energy Outlook, January 2000.

The GETF paper discusses various energy saving consequences brought on by widespread adoption of the Internet, particularly those related to E-commerce. The merits of E-commerce are numerous. The Internet has been successful in bringing together buyers and sellers of goods, on a virtually international level, reducing transactions costs in the process. Ford and General Motors, for example, have plans to integrate their respective supply chains via the Internet, allowing for a more precise inventory scheme and allowing vendors to compete in an auction-type setting for the right to supply parts. These new concepts may radically change the way companies compete for business, but the effect on energy consumption is vague at best. To the extent that this new business model lessens the need for energy-using services such as business travel, retail outlets, or the production of excessive inventories, overall energy use may decline. On the other hand, as electricity markets are deregulated and electricity is auctioned via the Internet, electricity prices might decline, effectively making some investment decisions regarding energy efficiency less attractive. However, real-time pricing in wholesale electricity markets has been subject to large price spikes over the past several years. A more coordinated market structure via the Internet may help alleviate some of these spikes in the future, as buyers and sellers of electricity are brought together more efficiently in the marketplace. Other energy-saving applications of the Internet could include more efficient monitoring of heating and cooling equipment in buildings and increased telecommuting, which could reduce transportation energy use.

Summary and Conclusions

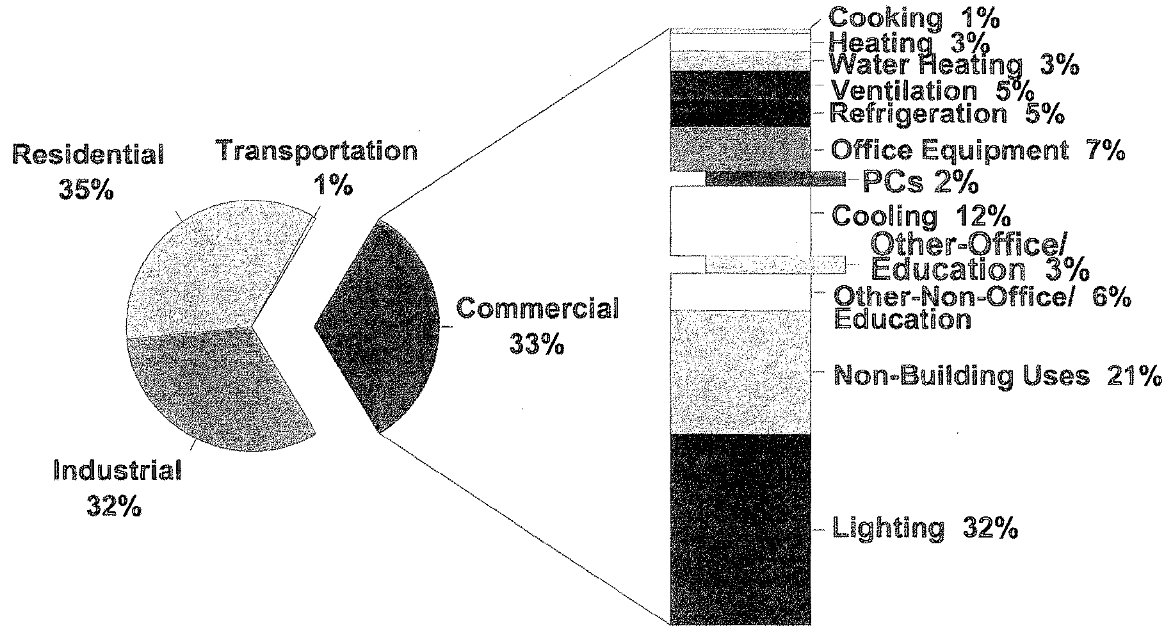
At this point in time, it is too soon to come to any conclusions as to the precise energy path of electricity use resulting from Internet and Internet-based commerce. Attempts have been made to show that the growth of the Internet will substantially increase electricity use, while others have stated that the growth in the Internet and the information technology sector will decrease energy use. There are many problems associated with trying to estimate the direct impact that the Internet will have on energy consumption. As mentioned earlier, Internet use is not purely additive as implied in the Forbes article. Other uses for electricity, such as television and stereo equipment, will most likely see less use in the home as Internet use rises. The energy implications, therefore, are vague at best, especially given the lack of time series data available to assess the likely impacts. The *AEO2000* reference case includes the major policies and market phenomena that have and are projected to continue to influence the amount and type of energy used throughout the U.S. economy. Recent trends in the growth of electronic equipment, stock turnover, appliance efficiency standards, structural changes in industry, electricity restructuring, and macroeconomic activity all factor into the development of the *AEO2000* reference case forecast. While there is uncertainty in all of these elements, it is clear that the size of Internet electricity use today is small compared to that of all of the other uses of electricity. The uncertainties relative to all those uses, including the Internet, could result in higher or lower electricity forecasts than those of *AEO2000*.

Residential Sector Site Electricity Consumption by End-Use, 1999



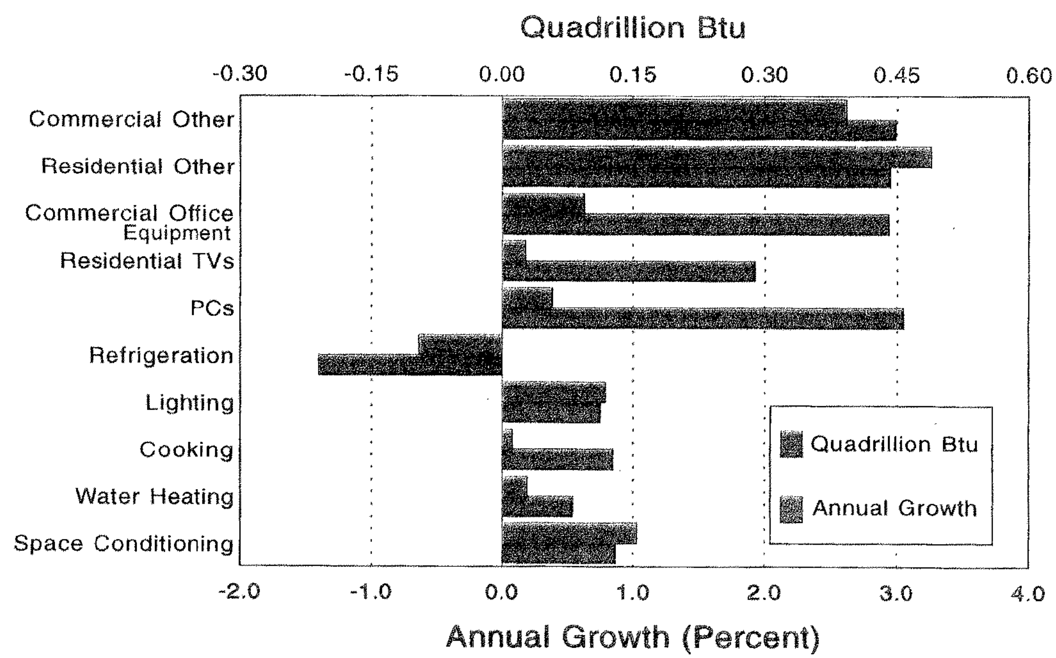
Note: PCs are defined as central processing unit and monitor.

Commercial Sector Site Electricity Consumption by End-Use, 1999

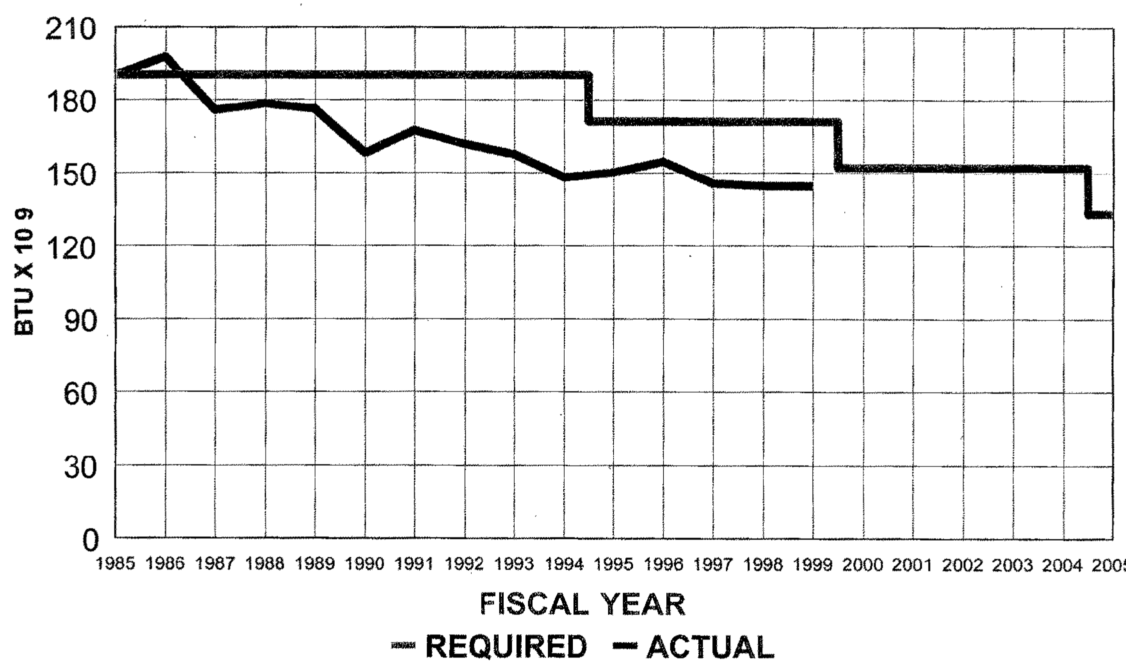


Note: PCs are defined as the central processing unit, monitor,and laser printer.

Buildings Sector Site Electricity Growth by End-use, 2000-2010



FORRESTAL TOTAL ENERGY CONSUMPTION BY FISCAL YEAR



TOTAL $ SAVINGS FY85 - FY99 = $6.0 Million

Annual Growth Rate of GDP and the Energy to GDP Ratio

	GDP	E/GDP	
1960	2.4%	1.3%	
1961	2.3%	-0.8%	
1962	6.1%	-1.4%	
1963	4.3%	-0.4%	
1964	5.8%	-1.3%	
1965	6.4%	-2.0%	
1966	6.5%	-0.9%	
1967	2.5%	0.7%	
1968	4.7%	1.2%	
1969	3.0%	2.1%	
1970	0.1%	3.3%	
1971	3.3%	-1.1%	
1972	5.5%	-0.5%	
1973	5.8%	-1.5%	
1974	-0.6%	-1.6%	
1975	-0.4%	-2.3%	
1976	5.4%	0.2%	
1977	4.7%	-1.9%	
1978	5.4%	-2.7%	
1979	2.8%	-1.6%	
1980	-0.3%	-2.9%	
1981	2.3%	**-4.6%**	**Largest annual energy intensity decline**
1982	-2.1%	-2.0%	
1983	**4.0%**	**-4.0%**	**High GDP growth & fast energy intensity decline**
1984	7.0%	-1.9%	
1985	**3.6%**	**-3.7%**	**High GDP growth & fast energy intensity decline**
1986	3.1%	-2.6%	
1987	2.9%	0.4%	
1988	3.8%	0.5%	
1989	3.4%	-1.5%	
1990	1.2%	-1.7%	
1991	-0.9%	0.8%	
1992	2.7%	-0.9%	
1993	2.3%	-0.2%	
1994	3.5%	-1.2%	
1995	2.3%	-0.3%	
1996	3.4%	-0.2%	
1997	**3.9%**	**-3.4%**	**High GDP growth & fast energy intensity decline**
1998	**3.9%**	**-3.9%**	**High GDP growth & fast energy intensity decline**
	GDP	**E/GDP**	

Mr. MCINTOSH [presiding]. Thank you, Mr. Hakes. We will certainly afford you that opportunity during that period.

Our next witness is Mr. Romm. If you could summarize your written testimony for us, that would be great.

Mr. ROMM. Mr. Chairman and members of the subcommittee, I am delighted to appear before you today. Let me start with three things that we know for sure. Mr. Mills is wrong; EIA's key forecasts are often wrong; and something very unusual is happening with the way the United States uses energy. Let's start with Mr. Mills.

It is rare that we know so conclusively that someone is as wrong as Mr. Mills. Let me present the results of a detailed study by five scientists at Lawrence Berkeley National Laboratory. On the left is current electricity used by the Internet according to Mr. Mills, the revision by Lawrence Berkeley National Laboratory on the right. Mills now repeatedly overestimates the electricity consumed by different components of the Internet. Mills is wrong by at least a factor of 8. He makes a variety of methodological and analytical errors that I would be happy to go into during the question and answer. He keeps ascribing all of the electricity used by a computer for all purposes, even if it only spends a few hours on the Internet. But the main reason we know Mr. Mills is wrong is, as Dr. Hakes said, electricity consumption hasn't exploded in the last few years, and I will return to this point later.

On EIA, EIA is quite good at collecting and analyzing data. It is very bad at forecasting. In a 1996 Science Committee hearing, Dr. Hakes and I were witnesses. Chairman Dana Rohrabacher asked him, "Dr. Hakes, you admit in your testimony that your forecasts have been off, and I would say they have been off not just a small amount, but they have been off the chart. How come your predictions have been so far off?" Dr. Hakes replied, "It is the price side where there has been the greatest error in areas like predicted demand and consumption. I think basically a lack of understanding of the impact of decontrol of the market. Second, I think a lot of people, including us, underestimated the impact of technologies."

Dr. Hakes testified that such errors were in the past, but that is not the case. Fourteen months ago, EIA projected that the world price of oil in the year 2000 would be $13.97 a barrel. That looks to be wrong by a factor of 2. EIA also predicted that total U.S. carbon emissions would rise by 105 million tons from 1997 to 2000. That also looks to be wrong by more than a factor of 2. EIA's analysis of the Clean Air Act overestimated the cost of sulfur permits by a factor of 4. Why? They underestimated technology improvements, fuel switching and the benefits of railroad competition.

I believe their estimates of the costs of Kyoto are also wrong by a factor of 4 since they make the exact same mistakes. EIA's model shuts out almost all industrial fuel-switching; EIA freezes electric utility restructuring and, as but one technology example, EIA projects that fuel cells will provide no electricity, not even 100 megawatts, through 2020, even under the most extreme scenario, coal prices up 600 percent, electricity prices doubled. These kind of obviously wrong assumptions have hurt their credibility.

The last thing we know for sure and the most interesting is that something unusual has happened to the way the United States uses energy. I think this is the central chart. It compares 4 years of data, 1992 to 1996, which are the left-hand bars in each case, with the 3 years of 1996 through 1999. The left-hand bars could be called right before the Internet economy took off, and the right-hand bars, the Internet economy. What is fascinating is that as you can see, GDP before the Internet had about 3.2 percent growth per year. GDP growth since the Internet was accelerated by 1 full percentage point. But what is fascinating is at the same time that the GDP has taken off, electricity consumption is down, which is the main reason we know that Mr. Mills is wrong. We are actually using less electricity, energy use is way down, and carbon dioxide emissions are also way down. This is stunning.

Mr. MCINTOSH. Mr. Romm, just to interject quickly, your chart doesn't really say energy use is down—just the growth in energy use——

Mr. ROMM. Yes, you are right. What we have here is the historical rate relationship between GDP and energy use. As you can see, if you compare these 2 numbers, energy use grew just slightly less than GDP from 1992 to 1996, but from 1997 through 1999, 3 years of data, what we see is bigger GDP growth, and I appreciate the correction, and slower energy growth and slower electricity growth and slower CO_2 growth. Obviously, the key question is whether this is an anomaly or a trend. I believe that this is, in fact, a trend, and I think that is the central point.

Let me, if I may, just briefly explain why I do think this is a trend, because after all, if this were to continue, it would be the biggest trend to hit the U.S. energy economy in 50 years.

First, technology. The information technology sector, as Dr. Hakes has said, which includes computer manufacturing and software, is just not very energy-intensive. A new EPA study that Mr. Kucinich cited projected that if this sector continues to generate a large fraction of our economic growth, this alone will reduce energy consumption in 2010 by 5 percent, compared to current EIA forecasts.

Second, the Internet economy also makes the economy more efficient. I won't go into this at length. I wrote an 80-page report on this and we can get into this in the question and answer. Let me say what I think is the most important aspect of the Internet economy. As more companies put their supply chain on the Internet and reduce inventories, overproduction, unnecessary capital purchases and mistaken orders, they achieve greater output with less energy consumption. Federal Reserve Board Chairman Alan Greenspan testified in front of 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 2 ago."

What I am basically positing is that if you believe that the Internet is increasing labor productivity and reducing inflation, that it is also improving total factor productivity, including the Nation's energy productivity.

I think there is another reason why emissions may be slowing, and that is that a lot of companies are voluntarily cutting their emissions. The Wall Street Journal article noted in October 1999, "in major corners of corporate America, it is suddenly becoming cool to fight global warming." Mr. Hakes collects data on this subject and their latest report, which came out just last week, said that since 1994, the quantity of emissions reductions reported each year has roughly tripled. Total reported savings in 1998 alone exceeded 3 percent of U.S. emissions, no small amount. I also believe that electricity competition will slow emissions. We can get to that in the question and answer.

Let me just sum up. In conclusion, we know Mr. Mills is completely wrong. Indeed, his argument is the reverse of the truth. The Internet almost certainly saves energy. I personally believe that the Internet may be one of the greatest systems ever devised for minimizing energy use and greenhouse gas emissions.

The final point. Again, something big is happening to the U.S. economy. Faster economic growth and slower energy and greenhouse gas growth. I believe this is a major trend, a new energy economy, and that current EIA forecasts of high growth in greenhouse gas emissions for the next decade are, like many of their forecasts, wrong, perhaps by a factor of 2.

Thank you very much.

[The prepared statement of Mr. Romm follows:]

STATEMENT OF

JOSEPH ROMM

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CENTER FOR ENERGY AND CLIMATE SOLUTIONS

before the

SUBCOMMITTEE on
NATIONAL ECONOMIC GROWTH,
NATURAL RESOURCES, AND REGULATORY AFFAIRS

of the

COMMITTEE on GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

February 2, 2000

Mr. Chairman, members of the Subcommittee, I am delighted to appear before you today to discuss the Energy Implications of the Digital Economy. My non-profit Center for Energy and Climate Solutions recently completed one of the most comprehensive analyses done to date on this exact subject—the possible impact of the Internet on energy consumption and greenhouse gas emissions. That report "The Internet Economy and Global Warming: A Scenario of the Impact of E-commerce on Energy and the Environment," is available online at www.cool-companies.org. Let me review the principal findings and conclusions of that analysis:

- The nation experienced remarkable economic growth in 1997 and 1998, over 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 (GDP) declined (i.e., improved) by under 1% per year. In both 1997 and 1998, it improved by 4%—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 one third to one half 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 one half to 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, such as those by the Energy Information Administration (EIA) may be significantly underestimating overall U.S. economic growth while overestimating U.S. energy and carbon dioxide emissions in the year 2010 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.

- 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, 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?

- 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.

- 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, EIA uses a figure of 1.0% 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 make clear that energy intensity in 1999 will 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.

I would like to expand on some of the key trends affecting how the nation uses energy today and in the future.

KEY TRENDS IN ENERGY EFFICIENCY

Energy technologies have improved dramatically over the past decade. 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. 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. Even boilers and hot water heaters can cut energy consumption 25% or more through the installation of microprocessor-based controllers. 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.[3]

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. 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."[4] 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.

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.

The potential impact of this trend is enormous. Companies like Ocean Spray, Owens Corning, and Ultramar Diamond Shamrock 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. I believe that these deals will grow very rapidly in the next few years, and are likely to ultimately achieve savings well beyond that achieved by utility demand-side management (DSM) programs, which have been scaled back in recent years. This is especially 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.[5] Energy outsourcing is poised to have a major impact on improving the nation's energy intensity in this decade, particularly as the large energy service companies are increasingly using the Internet to deliver services and cut costs.

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.[6]

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. 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).

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.

COSTS TO CUT GHGS TYPICALLY OVERESTIMATED

The notion that it will be costly for the nation to reduce GHGs is certainly wrong, and reports that say so are typically very flawed. For instance, EIA's 1998 study "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity," wildly overstates the carbon price required to reach various levels of emissions reductions. As a result, EIA wildly overestimates the increase in energy prices and the short-term impact on GDP. Even though EIA's results are more pessimistic than those from the two models commissioned by the anti-Kyoto industry groups, the EIA study finds that compliance with the Kyoto Protocol can be achieved with "no appreciable change in the long-term [GDP] growth rate." A variety of flaws render the study irrelevant to the current policy debate about Kyoto.

FLAW #1: EMISSIONS REDUCTIONS DON'T START UNTIL 2005. EIA assumes the country waits until just 3 three before the Kyoto mandates to start reducing emissions. That means, the country must reduce from a much higher levels of carbon emissions than if it started earlier, such as 2000. Even worse, this assumption gives the country far less time to act, only 3 years to meet the first target, forcing the economy to try to turn on a dime, rather than 8 years if we started in 2000. No consumer or industry who uses energy takes any anticipatory actions prior to 2005. While any person or company could dramatically reduce the impact if they started just a few years early, EIA forbids them from doing so. EIA undoes all voluntary commitments by industry (such as BP and the steel industry, which have said they will reduce to 10% below 1990 levels by 2010). EIA partly fixed this flaw in a later report, but the other flaws continue to render their conclusions indefensible.

FLAW #2: EIA ASSUMES THE U.S. GOVERNMENT NEVER INSTITUTES A SINGLE POLICY TO REDUCE THE IMPACT OF KYOTO. EIA assumes that, after waiting until the last possible moment to mandate that the country meet the Kyoto targets, the government passes not a single law or tax break or utility deregulation bill to make it *easier* to reduce emissions. So this is truly an irrelevant exercise, since it models the one thing that will never happen. EIA even ignores key ongoing policies and trends that would temper their results:

- *EIA freezes all utility deregulation and restructuring efforts for the next two decades.* Competitive pricing (based on marginal costs) of electricity is allowed only in California, New York, and New England, regions which do not account for much coal use. Everywhere else, regulated pricing (based on average price) is used through 2020 even though EIA acknowledges "this may not be appropriate in the near future" and that under competitive pricing "it is easier for suppliers to meet the carbon reduction goals, and the carbon price is lower, than it would be under average cost pricing." As discussed below, deregulation is fostering energy outsourcing, which will likely slow energy and GHG growth nationwide significantly.

FLAW #3: EIA TECHNOLOGY ASSUMPTIONS YIELD "GARBAGE IN, GARBAGE OUT" RESULTS. EIA ignores or artificially limits technologies that every other major study has indicated would play a major role in reducing the impact of Kyoto. Here are just a few key errors:

- COGENERATION: This is widely seen as a major greenhouse gas reducer since it cuts carbon emissions by about half with no increase in energy costs, and, with technology now coming on the market, a decrease in electricity costs. (Britain expects to double cogen from 1990 to 2010, accounting for about 20% of its Kyoto reductions.) Yet, for EIA, even if coal prices rise 700% and electricity prices double, cogeneration rises only 3% to 4% compared to the baseline in 2010—and it remains flat from 2010 to 2020! Even more amazing, with delivered coal prices averaging about 6 times higher from 2010 to 2020, industrial use of steam coal remains flat during that time.

- FUEL CELLS: EIA projects that even under the most extreme scenario, carbon at over $300 a ton, which nearly doubles electricity prices, fuel cells will provide no electricity—not even 100 Megawatts—through 2020. EIA, in examining the potential for fuel cells to achieve 3- to 4-year paybacks in buildings concludes "the likelihood of such substantial improvements in the next two decades is small." This view is contrary to virtually every other technical projection.

- RENEWABLES: EIA artificially constrains key renewables, such as wind. As a result, even when carbon and electricity prices soar through the roof, renewables hardly budge. Utilities are the one sector that (supposedly) acts with foresight—indeed, with "perfect foresight of carbon prices for capacity planning." Yet, knowing that the price of delivered coal is about to jump 350% and electricity prices by 50%, renewable capacity is only 2% higher than the reference case in 2005 and 9% higher in 2010. In the 2010-3% case, where electricity prices nearly double, renewables in 2010 are only 18% higher.

FLAW #4: EIA uses the "highly inappropriate" DRI model for calculating economic impact. As Dale Jorgenson and William Nordhaus wrote in April 24, 1997 in their review of the Administration's climate modeling effort—an effort that EIA participated in:

> "The DRI model is probably the best known short-term forecasting model for the U.S. economy. This model is especially appropriate for projecting the impacts of monetary and fiscal policy over a time horizon of approximately two or three years. For longer term projections, however, it is highly inappropriate and has some important limitations that are well-known to the community of economic forecasters. For example, the DRI long term projections are extremely sensitive to assumptions about energy prices. This feature is totally at odds with most empirical work and with the practice of government agencies that produce such projections."

In spite of its deeply flawed modeling, the EIA study finds that if carbon tax revenue is recycled through a reduction in either income or social security taxes, compliance with the Kyoto protocol can be achieved with "no appreciable change in the long-term (GDP) growth rate".

FLAW #5: EIA's long-term projections are invariably wrong and it is making the exact same mistakes it made when EIA overestimated the cost of sulfur permits by a factor of four just a few years ago. In particular, EIA notes that just a few years ago, its first analysis of the cost of SO2 allowances under the Clean Air Act was projected at $423 a ton in 2000 (in 1996 dollars) rising to $751 a ton in 2010. "Currently, the cost of an allowance is $95 a ton, and AEO98 projects that the cost will be $121 a ton in 2000 and $189 a ton in 2010." Why was EIA wrong?

- "There has also been downward pressure on short-run allowance costs because generators have taken actions to comply with the SO2 limitations earlier than anticipated."
- "There has been more fuel switching to low-sulfur, low cost-Western coal than previously anticipated."
- "Finally, technology improvements have lowered the costs of flue-gas desulfurization technologies, or scrubbers.... The cost of SO2 compliance was overestimated to a large extent because compliance relied on scrubbing, a relatively new technology with which there was little experience."

These are exactly the reasons EIA is once again wrong by a factor of 4. They have forbidden all energy users—and the federal government—to take any anticipatory actions. They have overestimated the cost and underestimated the opportunity for fuel switching to low-carbon fuels (like gas and renewables). And they have ignored the role of key technologies, including cogeneration, fuel cells, and advanced end-use efficiency. Since this analysis has nothing to do with how the government, businesses, or consumers will act in the real world, the study is wholly irrelevant and has no bearing on "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity."

INTERNET EFFICIENCY

Let me return to the issue of trying to explain the remarkable gains in energy intensity in the last two years. Weather played a 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 0.6% out of the 4.0% improvement in energy intensity in 1998. 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."[7]

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.

The Commerce Department said 1999 that those IT-producing industries were responsible for 28% to 29% of the contribution to real growth during 1997 and 1998.[8] 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.[9] 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. 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. 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. As Federal Reserve Board Chairman Alan Greenspan told 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.[10]

So, capital deepening allows economic growth without as much increased resource use as typically occurs. As discussed in our analysis, 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.

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. However, 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.[11] 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.

Scientists at Lawrence Berkeley National Laboratory (LBNL) recently examined in detail the numbers underlying the *Forbes* analysis.[12] 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).[13] 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."[14] 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."[15] 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, I believe that the argument of the *Forbes'* authors is 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. 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."[16]

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 4.5%. 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.

Computers and the Internet may well 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 our recent analysis.

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. 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%. 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.

In conclusion, energy consumption and GHG emissions in the economy appears to be slowing even as GDP growth is accelerating. If, as we believe, part of this is due to the Digital Economy, then it is likely to continue for some time to come, and with other trends, such as energy outsourcing and corporate voluntary efforts to reduce GHG emissions (and warmer weather), is likely to slow the growth of energy and GHG emissions for the next ten years. These factors together mean that it will be easier for the nation to reduce GHG emissions.

[1]Alan Greenspan, "High-tech industry in the U.S. economy," Testimony Before the Joint Economic Committee, U.S. Congress, June 14, 1999 [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 [Hereafter *OECD 1999*]. The discussion of the Internet here 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]Joseph 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.

[4]*Fortune*, May 11, 1998, p. 132C.

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

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

[7]EIA, "Weather Assumptions Changed for EIA's Short-Term Energy Projections," September 1999.

[8]David Henry, Sandra Cooke et al, *The Emerging Digital Economy II*, Department of Commerce, June 1999. For a list of all of the IT-producing industries see Table 2.1 of the report.

[9]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.

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

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

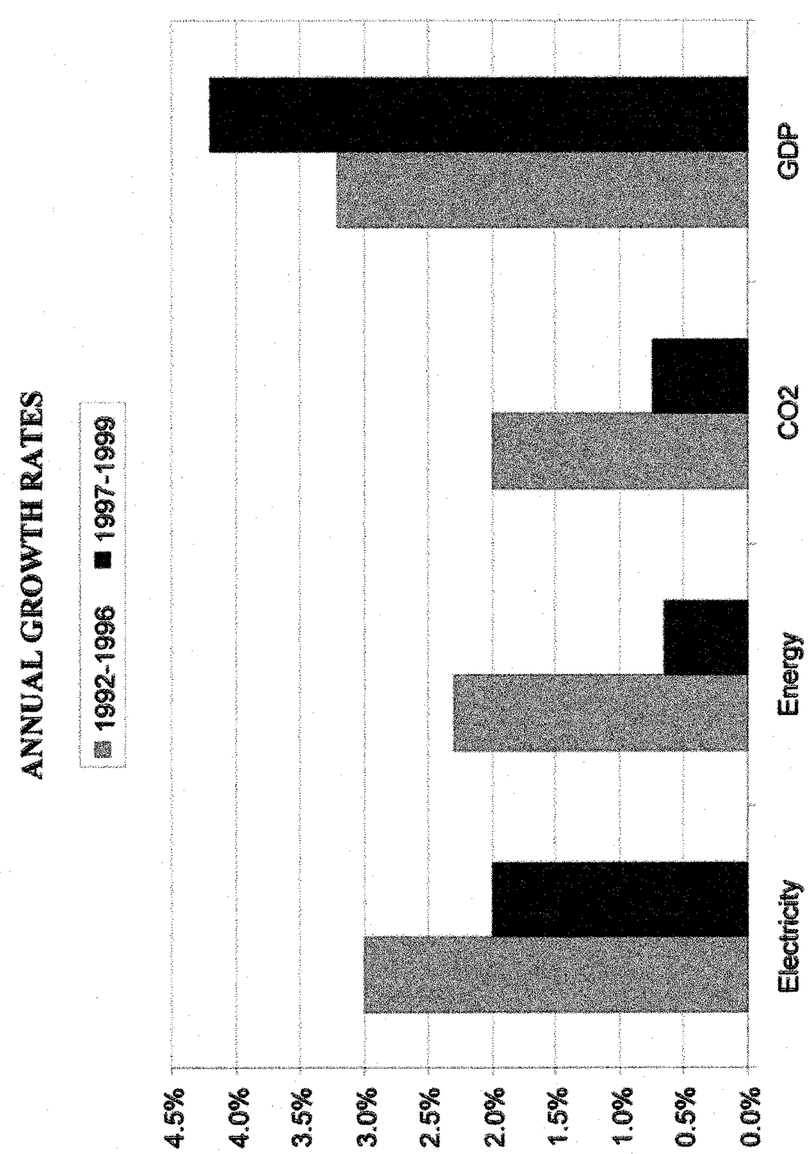
[12]Jonathan Koomey, Kaoru Kawamoto, Maryann Piette, Richard Brown, and Bruce Nordman. "Initial comments on *The Internet Begins with Coal*," memo to Skip Laitner (EPA), Lawrence Berkeley National Laboratory, Berkeley, CA, December 1999, available at http://enduse.lbl.gov/Projects/infotech.html. The 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.

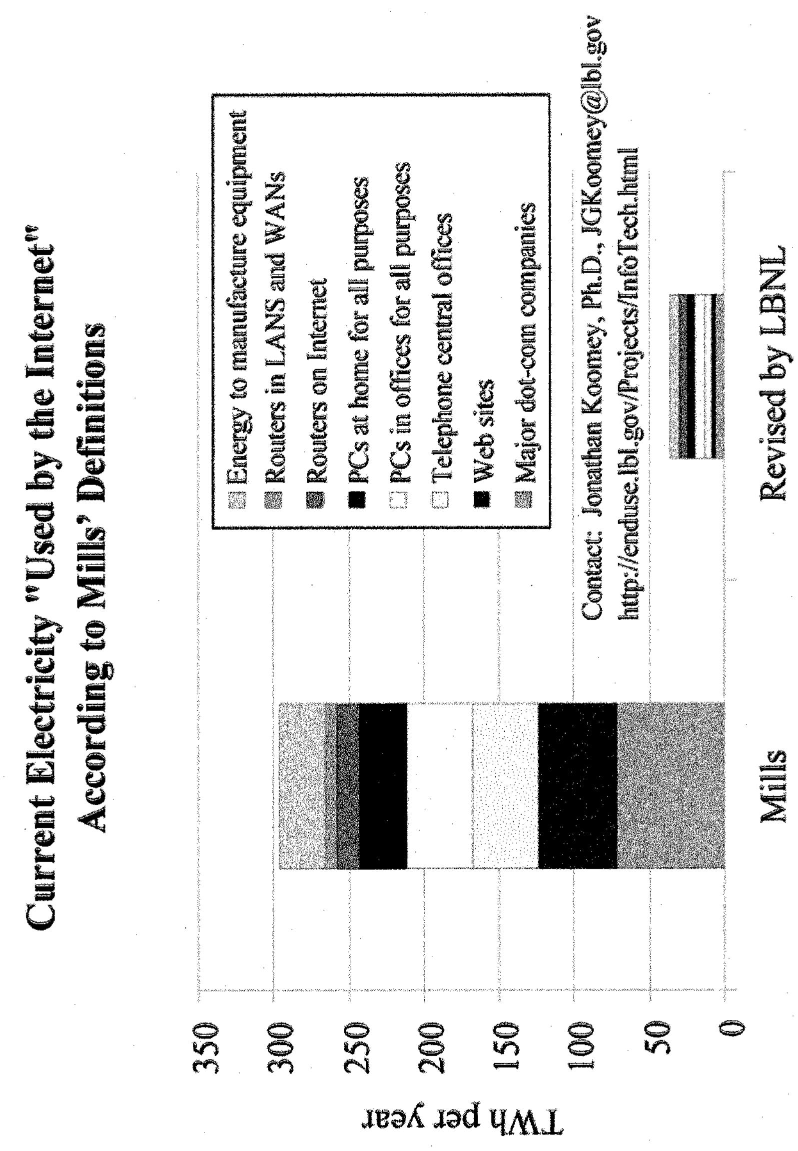
[13]Typical home Internet users are online 5 to 10 hours a week (under 500 hours a year). So they consume under 100 kWh a year on the Internet, more than a factor of 10 *less than* the estimate of the *Forbes'* authors of 1000 kWh a year. And this does not even include any of the myriad potential offsets 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 our analysis, they are probably displacing far more electricity consumption by not working in an electricity-intensive office building.

[14]John B. Horrigan, Frances H. Irwin, and Elizabeth Cook, *Taking a Byte Out Of Carbon*, World Resources Institute, Washington D.C., 1998, p. 18.

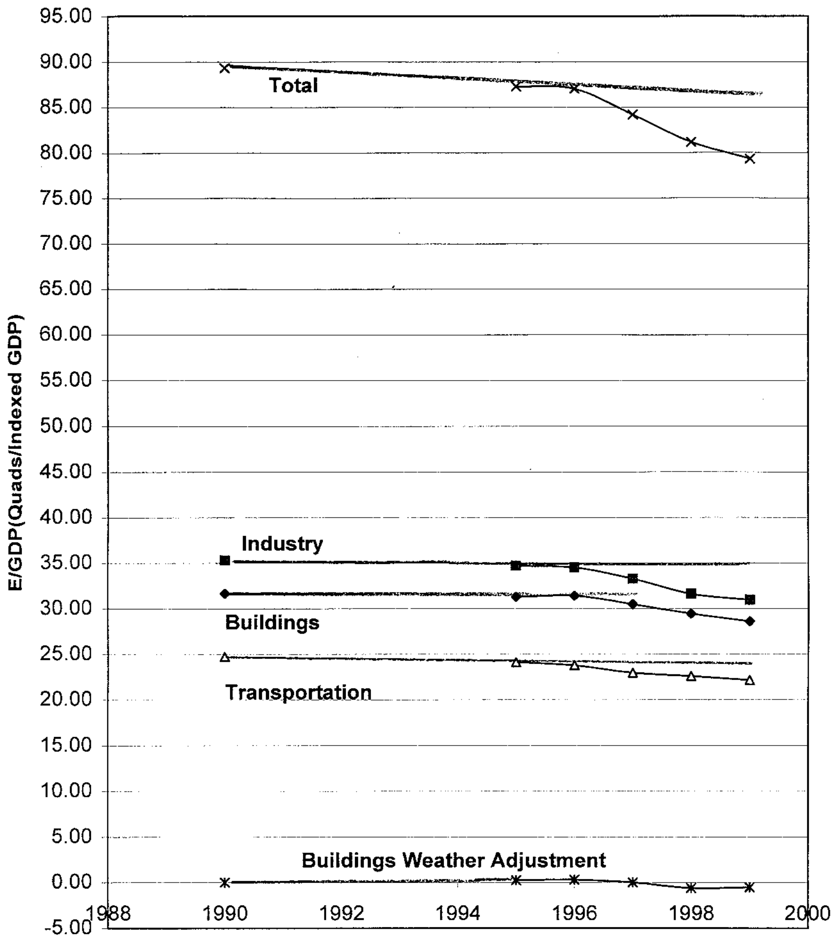
[15]"Dell Online," Harvard Business School Case Study 9-598-116, revised March 26, 1999, Harvard Business School Publishing, Boston, MA, p. 23. So if a business user seeking the latest technology for Internet access replaces an old, inefficient computer with a new laptop, for instance, that might actually 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.

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


ANNUAL GROWTH RATES
1992-1996
1997-1999
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Electricity
Energy
CO2
GDP


Current Electricity "Used by the Internet"
According to Mills' Definitions
TWh per year
350
300
250
200
150
100
50
0
Energy to manufacture equipment
Routers in LANS and WANs
Routers on Internet
PCs at home for all purposes
PCs in offices for all purposes
Telephone central offices
Web sites
Major dot-com companies
Contact: Jonathan Koomey, Ph.D., JGKoomey@lbl.gov
http://enduse.lbl.gov/Projects/InfoTech.html
Mills
Revised by LBNL

E/GDP in Primary Energy for 3 Sectors and Total U.S. GDP is indexed to 1.0 in 1995. Data from 1990-1995 are interpolated.



Except for Industry sector quads, all data are from Monthly Energy Review, Dec. '99. But Industry and Buildings fall on top of one another, and Industry in Ann. Energy Outlook is about 3 quads larger, so we took the AEO values.

Year	Buildings Energy (Quads)	Industry Energy (AEO) (Quads)	Transportation Energy (Quads)	US Energy (Quads)	Buildings Weather Adjustment (Quads)	GDP Indexed to 1995 = 1.0
1990	28.8	32.1	22.5	81.3	0	0.91
1995	31.3	34.7	24.1	87.3	0.25	1
1996	32.5	35.7	24.6	90.1	0.3	1.035
1997	32.8	35.8	24.7	90.6	0	1.076
1998	33	35.4	25.3	90.9	-0.6	1.12
1999	33.2	35.9	25.7	92	-0.5	1.16

	Buildings Energy (Quads/GDP)	Industry Energy (Quads/GDP)	Transportation Energy (Quads/GDP)	US Energy (Quads/GDP)	Buildings Weather Adjustment (Quads)
1990	31.65	35.27	24.73	89.34	0
1991					
1992					
1993					
1994					
1995	31.30	34.70	24.10	87.30	0.25
1996	31.40	34.49	23.77	87.05	0.3
1997	30.48	33.27	22.96	84.20	0
1998	29.46	31.61	22.59	81.16	-0.6
1999	28.62	30.95	22.16	79.31	-0.5

For 1999, only 10 months of data are available, so we compared 1999 to '98 by 10-mo. ratios.

A.H Rosenfeld, 703 750 6401, ARosenfeld@GETF.org
2 Feb. 2000

Mr. MCINTOSH. Thank you, Mr. Romm. I look forward to our questioning session. Actually, this is going to be a good hearing.

Our final witness is Mr. Mills, who has already been much talked about. Share with us a summary of your written testimony, please.

Mr. MILLS. Thank you, Mr. Chairman and distinguished members of the subcommittee. I really am delighted that you are having this hearing, and I thank you for doing this. It is a fascinating area, and there is one thing that Mr. Romm and I agree about; perhaps only one, but it is that the Internet is a very big deal. As your opening remarks indicated, Mr. Chairman, it is a very big deal and it is going to be a bigger deal.

This subject is particularly fascinating for me for two reasons. My testimony I will summarize very quickly, but I should start with a preamble. As a personal reason it is fascinating. My career started in integrated circuits, telecommunications, and fiberoptics. In fact, I have patents in those areas. I was intimately involved in that business in my early career. I will confess that I had no idea that the field of telecommunications, nor did anybody I worked with at that time in research and development, have any idea that the telecom industry was going to become what it is today, which is the driver of our economy. Nor did I anticipate that that industry, that profession would intersect with my current profession, which is the study of energy and electricity. It is utterly fascinating, and it is delightful to be working with my colleagues again in the telecom industry.

The second point I want to make is that what you have heard is actually dramatized in what I learned in doing this analysis, is that the folks in the energy business don't understand telecom. They have profound misunderstandings and in some cases ignorance of the telecom industry and the technologies of that industry. Not surprising, because the energy industry and the environmental community and analysts that have grown up around it have basically been brought up on the culture of the oil era that started in 1973, and telecom is quite different.

We have been told for 20 years by forecasters like Mr. Romm that efficiency measures were going to stop electric load growth. I published a long monograph in fact for CEI documenting dozens and, in fact, hundreds of forecasts for 20 years that we were going to stop seeing electric demand grow because of efficiencies of all kinds. I should like to point out for the record that EIA's data does show that in the last digital decade, and I am a firm believer as a physicist that you can't tell a trend from one data point; 1 year doesn't help a lot. This past decade I have called the digital decade, and in the past digital decade where there has been an explosion in the purchase and installation of telecommunications equipment of all kinds, we have not only seen our economy grow, but the consumption of electricity has grown by 650 billion kilowatt hours. Just for perspective that would have required the additional electrical capacity equal to all of the electric output of Central and South America. So it is a fairly significant addition to the U.S. electric supply system driven, I would submit, primarily by our digital economy. Not specifically by the Internet, but by our digital economy.

The principal objection, and we will do this in the question and answer, there are two principal objections to the analysis that I detect. One is the efficiency sufficiency argument, that I didn't count it, or my colleagues and I ignored it. We didn't. We weren't seeking to look for the efficiency information. We were seeking the answer to a simple question, and I will put it to you this way. It is based— and, in fact, this whole analysis started with a very simple premise. Every single piece of equipment in the digital economy, every piece of information technology equipment has two plugs, one for bits, one for power. All of them have power plugs.

The purchase rate of hardware in the information economy today is running at $400 billion a year. In the last several years we have added $1 trillion of telecom hardware to the U.S. economy. We have added trillions of dollars of hardware that has been plugged in, net-new hardware in the last digital decade. In looking at this, it sort of begged the question, wouldn't it be reasonable that all of this hardware at some point would begin to consume a reasonable or significant amount of electricity?

What we found in trying to seek an answer to this question was that the data collection mechanisms aren't up to the task. I am a personal fan of EIA; I think their data is the finest, in fact, in the world. I study data from all kinds of countries. EIA does a great job, but the problem is they don't have a collection mechanism to find what we need to find.

Let me just give you a real quick example of the profoundness of the misunderstanding of the Internet and one example of the very disappointing analysis that the Lawrence Berkeley folks undertook that Mr. Romm has summarized. It is profoundly disappointing and misleading as well as being factually wrong, which is a problem for scientists, but it does happen. We all make mistakes.

The first problem is that folks keep interpreting the Internet as the PC on your desktop. The PC on your desktop constitutes a tiny fraction of the portal to the Internet. The Internet comprises the hundreds of millions of pieces of equipment that are in the network that create, shape, move, route and feed bits into the entire network. In fact, when one looks at the analysis, you not only find that the PC itself constitutes about 20 percent of a total energy appetite of the Internet, the critical fact is that you can take the PC out of the picture totally, and you still have electric use growing for the Internet.

The folks at Lawrence Berkeley did an analysis that rebutted themselves. Their own rebuttal of my study contains statements of fact which contradict their own analyses from 5 years ago. They also contradict analyses from the National Academy of Sciences, from the Environmental Protection Agency and other organizations. It is an embarrassingly shoddy piece of analysis, frankly, and I was surprised that they would not do better research. I will be happy to give you more examples in the question and answer.

Let me just finish with an observation about efficiencies. Quite obviously, the Internet is driving economic efficiencies, and it is certainly driving some energy efficiencies. Where it is driving efficiency largely is in the transportation sector. I would submit to you that that means that electricity is substituting for oil. This has been going on in the American economy for about 30 years; in fact, for a century. This is a good trend, and, in fact, it is a trend that I analyzed a decade ago and published widely on. I think it is continuing. However, I do believe that what we are seeing is the thin edge of a wedge that, in fact, I don't believe you can see in EIA data yet.

Let me give you one specific example of why you can't. The data you see right here for the commercial sector shows you that the largest category after lighting for a commercial building energy use is "other." "Other," if I understand the data correctly, and Mr. Hakes will correct me if I'm wrong—but "other," if I understand it, includes telecom equipment. I will remind you again, telecom equipment is the Internet.

Now, if we have a disagreement about how much electricity the Internet uses, I submit to the Lawrence Berkeley scientists and I submit to my other colleagues, let's start then with the telecom industry, and then let's ask telecom experts, what share of the telecom industry is being driven by the Internet. I think you will find that they will say that it is the driving force. But we can at least agree to start with a broader definition to begin to understand the broader electrical appetite of a digital age. It is enormous, it is growing.

When I started this analysis, it was not to shoot holes into Kyoto or EIA or forecasters, but to answer a very important question that is still not adequately answered by EIA, Lawrence Berkeley, by Mr. Romm, or by anybody else. How much electricity is the digital economy using specifically, and, as a subset, how much electricity is the Internet using?

I will tell you since I published my study, I have engaged in substantial additional research with my colleagues in the telecommunications industry. All of the data strengthens my original conclusions, it does not diminish it. Thank you, Mr. Chairman.

[The prepared statement of Mr. Mills follows:]

"Kyoto and the Internet: The Energy Implications of the Digital Economy"

Testimony of Mark P. Mills
Science Advisor, The Greening Earth Society
Senior Fellow, The Competitive Enterprise Institute
President, Mills-McCarthy & Associates, Inc.

before the
Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs
U.S. House of Representatives

February 2, 2000

Thank you, Mr. Chairman and distinguished Members of the Subcommittee for inviting me to speak about the energy implications of the Digital Economy. We live in a special time. It is perhaps not a totally unique time in historical terms, but it is a rare one. Times of major inflections in technology, infrastructure and the economy occur only episodically in history. I am not alone in the belief that we are only at the beginning of one of those powerful inflections, driven by what has been broadly termed the Information Revolution. The Internet is a central part of that revolution and it has only just begun to effect profound changes in our economy.

There have been many attempts to attach numbers to chronicle the growth of the Internet over this remarkable past decade. The number of people accessing the Web has grown from thousands to tens of millions. Web sites have grown from practically none to millions. Computers sold annually have risen from tens of thousands to tens of millions. Digital traffic is measured by prefixes formerly reserved for astronomers; not megabytes, or gigabytes, but petabytes. Still, traffic on the Web is doubling every several months. The entire telecommunications industry as been upended, rebuilt and expanded by the digital revolution. Commerce on the Web has exploded from nothing to tens of billions. New companies, new kinds of equipment, new services appear in a continual flow. Employment in Information Economy jobs has risen from thousands to millions. The real growth by any of these measures has been so astonishing that even the hyperbolic language of headline writers appears understated by comparison.

Against this backdrop, last year I put forth a simple proposition with a colleague that has created some controversy. The proposition is really quite simple. The Internet is using a lot of electricity, and it will use even more in the future.

The currency of the Information Economy, digital bits, are themselves simply bundles of electrons. Every single one of the hundreds of millions of devices, PCs, routers, servers, transmitters and so on, have exactly two kinds of connections: one for bits and one for kilowatt-hours. Just how much electricity does the Internet use? We think something like 8% of the nation's electric supply is absorbed by the sprawling and deeply penetrating hardware of the Internet. And when the broader array of all computers and related equipment are considered, in other words the heart of our new Information Economy, the total probably reaches 13% of all U.S. electricity consumption.

These ideas have been previously submitted to this Committee for the record. The basic concepts are set forth in my report for the Greening Earth Society, " The Internet Begins with Coal," (available at www.fossilfuels.org) and an article published in *Forbes* magazine (5/31/99) with my colleague Peter Huber, a Senior Fellow at the Manhattan Institute.

Subsequently, two respected research organizations and a number of environmental activists have exhibited alarm at the proposition that the Internet uses large and rising amounts of electricity. Before addressing the counter claims, and their deep flaws, I should like to consider the broad context for my analysis to lend perspective to the energy requirements of the Internet.

The Internet's Energy Transformation

If the U.S. Department of Commerce is correct, and I believe it is, in concluding that the Information Technology (IT) sector accounts for at least one-third of all GDP growth, then any policy issue that impacts IT must be considered with great caution. Energy policy is just such an issue. Because the explicit and implicit provisions of the Kyoto Protocol would directly impact every aspect of the nations' energy supply, it is appropriate, in fact critical, to consider the energy implications of our emerging Digital Economy.

Energy underpins any economy, in effect because of the laws of physics. Put simplistically, you can't get something for nothing. The Internet has not changed the laws of physics. Even cyberspace has an energy cost. Energy will continue to underpin our economy in the 21st century, just as it did in the 20th. But there will be one difference. In energy terms, the last century belonged to oil. This one belongs to electricity. Oil will not lose its prominent role, but it will take - and indeed, already has taken - second place to kilowatt-hours.

The dawn of the last century saw an explosion of economic activity in the creation of the automobile age. Investors and Wall Street rode chaotic markets investing in new companies. For technology historians, and Wall Street speculators, the dawn of the auto age has important analogs to the dawn of the Digital Age. One consequence of the rise of the automobile was the creation of an enormous and complex oil-related industrial infrastructure to fuel engines in all kinds of vehicles. The engine of the Digital Age is the microprocessor. Its fuel is electricity. Digital bits are bundles of electrons. The billions and even trillions of bits of data created and routed are, perforce, supported and energized by billions of watts. There's no getting around it. Cyberspace, far from virtual, is very real and anchored in electrons. Thus, the Internet, the central driving force of the Digital Age, is both driving and reshaping the electric infrastructure.

The transformation is already in evidence. Our economy today spends four times as much purchasing electricity as oil. This is a profound reversal of the economic positions of oil and electricity 25 years ago. The only basic energy policy that makes sense in this new Digital Economy is to ensure an expanding supply of ever lower cost and ever more reliable electricity, especially considering the trends of the past decade which have been characterized by a dominance of the tools of the Information Economy.

During this past Digital Decade, consumption of electricity has risen by 650 billion kilowatt-hours. For perspective, this growth alone required more new U.S. electric supply than exists in all of Central and South America.

The increase in kilowatt-hour use occurred despite billions spent by federal and state governments and utilities to reduce electricity growth, and despite dramatic improvements in the efficiency of electric appliances, lights and motors. It occurred, I submit, in large part because of the new tools of the Digital Age.

Considering that coal supplied about one-half of the additional electricity over the past decade (about 10% from natural gas), it is easy to see the collision course this trend has with Kyoto-inspired energy policies which are explicitly and implicitly directed at reducing coal use as well as electric consumption.

The Internet & Electricity Demand

Just how much of the nation's electricity demand is a direct result of equipment in the Digital Economy, and more specifically, the Internet? Truth be told, it is hard to draw a bright line between many devices used for the Internet and those that are part of the broader Digital Economy. Nonetheless, we made just such an attempt, precisely because the Internet is at the epicenter of the Digital Revolution.

It would be exceptionally challenging to catalog all the wide array of devices that comprise the Internet and Digital Economy. Instead, we chose a technique known as sequential approximation. This well-established technique permits one to gain a reasonable order-of-magnitude estimate of a complex factor without a detailed inventory. One can, for example, use sequential approximation to estimate the number of people in a stadium by considering an inventory of hot dogs and soft drinks. Some approximations are required, but the outcome will be in the right ballpark.

The ballpark estimate: the Internet in all its facets, likely consumes 290 billion kilowatt-hours, or about 8% of the U.S. electric supply system. The broader category, the entire array of all types of computers and computing-related devices (such as storage systems), in homes, businesses and factories which fuel our Digital Economy likely uses 13% of all the nation's electricity.

These numbers encompass much more than PCs on desktops. One must include for example all the hardware behind-the-wall in the telecommunications and Internet networks which includes, but is far from limited to, such things as routers, the hardware of the dot-coms such as servers, and even the silicon and PC factories. Determining Internet and Digital Age electricity use requires collecting and assessing data across many sectors and boundaries.

It is clear that traditional data sources and methodologies are not adequate to the task of clearly tracking the electric needs of the Information Age. For example, most of the necessary data for the commercial sector is invisible in traditional Energy Information Administration energy accounting. EIA does report on PC electric use in commercial buildings, but all of the other types of information technology hardware (which comprise over three-fourths of Internet energy use) are thrown into a general grab bag category called " other." EIA notes cryptically that " other" includes telecommunications equipment. The data lost in " other" was irrelevant two decades ago at the dawn of the Digital Age. Today, the " other" category of commercial electric use is over 300 billion kilowatt-hours and is greater than all other categories except lighting - and will soon overtake lighting.

Before addressing a few points of contention regarding my estimate of 290 billion kilowatt-hours for the entire Internet, it is useful to ask first, is such a result in the ballpark? Much of the confusion and controversy surrounding the issue arises from a key question. In effect, how much of the electric use of a PC (or any IT equipment) is directly attributable to the Internet? Since the Internet is an integral subset of the Digital Economy, the easiest sanity check would be to evaluate the electric needs of all Information Technology equipment. For example, how do you count computers used to develop software for the Internet if those PCs were not directly plugged into the Web? Clearly they are part of the bigger picture, the entire Internet-driven Digital Economy.

A useful starting point for a ballpark check is in the simple fact that the U.S. Information Technology industry sold over $400 billion worth of hardware last year. Over the past three years alone, more than $1 trillion of IT hardware has been installed. This hardware represents the engine of the new Digital Economy. Much of it becomes part of the Internet, most is driven by the Internet. Every single piece of this $1 trillion in hardware gets plugged into a wall somewhere.

There's another more specific ballpark check available from the year 1993, the Jurassic Era of the Internet. A 1995 Lawrence Berkeley Labs (LBL) study (the most recent on the subject) reported about 50 billion kWh in 1993 for commercial sector use by PCs, computers and directly related equipment such as monitors and printers.

This 50 billion kWh figure for the commercial sector from seven years ago is a good starting point for the Digital Decade. Let's consider what's happened since then.

- the number of PCs and related equipment in offices has exploded
- the number of PCs in homes, schools, everywhere, has also exploded
- the Internet has burst on to the scene, with all its back-office Web and telecommunications hardware
- an entirely new class of businesses has been created; the dot-coms
- the usage level for all computing and IT equipment is up everywhere

I am quite confident that these factors collectively have brought the 50 billion kWh starting point in 1993 up to my estimates for the broader Internet (i.e., beyond the commercial sector alone) and the Digital Economy today. And if we're not quite there yet, just wait a few more months.

There are some other useful ballpark indicators. The Information Technology Industry Council's tracking shows the total inventory of computers and computer-type equipment has jumped by at least 100 million units since 1993. The inventory is growing at over 40 million a year now. And their data set specifically does not include such Internet equipment as routers, which are functionally computers. Cisco sells about a million routers a year. Nor does the official data track the number of wireless base stations, amplifiers, ports, hubs, information appliances, and so on. All of these have grown rapidly over the past Digital Decade. All of these devices use electricity. Many are already part of the Internet, and those that are not will soon be.

And this is only part of the story. One must also add the electric needs of the semiconductor, PC and IT manufacturing industries. Semiconductor manufacturing alone has grown in the past half-decade to become the nation's largest manufacturing industry. Silicon plants are the steel mills of the 21st Century. Their fuel of choice; kilowatt-hours.

When you think about it, it is inconceivable that the Digital Age and the Internet, do not already account for a significant and growing share of the nation's electric supply.

The Case for 1%

Two organizations have offered rebuttals to the 8% estimate for the Internet's share of national electric use. I believe it important to address these ostensible rebuttals given the importance of this issue to federal energy and economic policy. There is insufficient time here to address all of the details, but a few observations are instructive.

The researchers at Lawrence Berkeley National Laboratory (LBL) have published a superficially analysis of my study " The Internet Begins with Coal." Before addressing a couple of representative examples of the inherent failures in the LBL rebuttal, there are two over arching points that should be made. The first relates to the failure of LBL to step up and take an honest crack at estimating an answer to the core question. The second relates to the strange failure of the LBL team to seek information to clarify their misunderstandings.

First then is the fact that LBL team and others seem preoccupied with rebutting details of my analysis, but are quite unwilling to make their own independent estimate to answer the central and critical question: how much electricity does the Internet use? My recommendation to the LBL team then and now: please undertake a detailed and intellectually honest ground-up analysis of the Internet's electric needs.

The central conclusion of the LBL paper is that 8% is an overestimate of the Internet's use of U.S. electricity by " a factor of eight."

On learning this, I asked the LBL team the obvious question, if you say 8% is an overestimate by a factor of eight:

> "May I quote LBL as claiming/believing/estimating that the Internet uses 1% of the nation's electricity supply?"

Their answer, in full:

> "You may NOT quote LBNL 'as claiming/believing/estimating that the Internet uses 1% of the nation's electricity supply' because your estimate just focuses on direct electricity use, and not the overall effects on the U.S. economy that result from structural changes and substitution effects due to the Internet. You may quote me as believing that your estimate of the direct electricity use associated with the Internet is too high by a factor of eight, but that the NET effect of the Internet on electricity and energy use (which is really what matters) cannot be estimated accurately without assessing the associated indirect effects of the internet on resource use in the economy."

Given what I've outlined earlier, and what practically everyone who reads the news knows, the explosion in Internet equipment is quite unlikely to have led to a reduction in the use of electricity. Data contained in LBL's own research on PCs and computers yields a figure of 2% way back in 1993 and just for the commercial sector.

Furthermore it is disingenuous for the LBL team to state that what really matters is the " NET" effect of the Internet. Certainly it's an interesting issue (more about this in a minute). Fax machines use electricity and displace jet fuel by replacing overnight mail. I believe I may have been the first to publish detailed analyses of this effect of electrification in 1991, and to describe this effect I coined the term " ecowatts" at that time, documenting and publishing widely to extol this important efficiency trend.

But here's a simple arithmetical fact; estimating the net savings from faxing requires, *a priori*, knowing the amount of electricity used by faxes. Accurately calculating the net savings is actually much more difficult than accounting for the electricity used. (Consider, for example, that faxing should have been expected to reduce use of overnight mail; in fact overnight mail has grown.) But LBL suggests that one should not study the use of electricity from PCs, or by inference, faxes or any office equipment " without assessing the associated indirect effects." LBL's own EPA-funded 1995 research on electricity used by all manner of office equipment in commercial buildings does not meet this test - nor should it have to.

The idea that we can or should only study and publish the " NET" effect is the equivalent of claiming that you can figure out the change from dinner without knowing how much money you gave the waiter.

The LBL team dodged the issue.

The second generic point I should like to make arise from the following statement from the LBL paper:

> "Mills' report does not contain enough detailed documentation to assess the reasonableness of <u>many</u> assumptions." (emphasis added)

This is a fair complaint. I note for the record that the LBL team, in full possession of my e-mail, phone number and address, and despite a couple of very general e-mail exchanges with them, made absolutely no attempt to contact me to obtain clarification or expansion on specifics for any assumptions. Considering that clarification was and is necessary for " many assumptions," their failure to do so leaves one wondering if they did not want clarification, and that the rebuttal was motivated by something other than the requirements of technical scholarship.

That the LBL team has, so far, dodged the central question is clear. Thus far their only contribution to this debate has been an attempt to cast doubt on my analysis. The LBL rebuttal contains numerous serious errors. Let me briefly outline two that are representative.

The first technical point: In the LBL paper, the authors take issue with the claim that the desktop for an Internet-configured PC (i.e., including necessary peripherals) is about a 1,000 Watt device. Setting aside the question of whether it is 1,000 Watts (it is), the LBL researchers know full well that the relevant number used in the calculation is NOT the peak watts, but the quantity of kilowatt-hours used in a year. In analogous terms, what really matters is how much gasoline you use in a year, not the horsepower of your engine.

In this regard, my analysis for an Internet-configured PC is based on **750 kWh/yr** and is consistent with many other analyses, including their own at LBL.

• In their 1995 study, LBL finds that a PC and printer uses **650** kWh/yr (" Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties," LBL, December 1995, p. 15.).

• In an unrelated 1995 EPA study, annual PC electric use was estimated to range from **450 to 2,000 kWh/yr**.

(" The Green PC," S. Anzovin, Windcrest, 1994, p. 5).

• A more recent National Academy of Sciences report put annual PC/workstation electric use at **1,000** to 1,800 kWh/yr.
(IEEE Spectrum, January 2000).

Despite the readily verifiable above noted facts, the LBL paper nonetheless concludes that " With these corrections [to Mills' assumptions], PCs in offices use about 7.2 TWh, a reduction of 84% from Mills' estimate."

Surely the LBL team noticed the bizarre inconsistency in this conclusion. Their own 1995 seminal study showed collective commercial sector PC electric use at 50 TWh more than <u>five years ago</u>. How could their " correction" to my analysis yield 7 TWh today?

Let me turn now to a second example of poor analysis in the LBL paper, but of a slightly different 'flavor' of error.

One entirely new category of computer use since 1995 is in Web servers. Servers are really computers ranging in type from PCs, to workstations, and up to mainframes that host the Web sites. Servers run 24-7 and are frequently arranged by the hundreds in enormous banks of racks creating a " server farm" for mid-sized to large Internet Service Providers. LBL claims that we need to adjust downwards both the power used by servers and the total number of servers. The power use issue for servers is essentially the same as I've just outlined for PCs.

At the time of writing my report, I used an estimate of 4 million servers for 1999 based on an extrapolation from data for the number of Web sites. The LBL team 'adjusted' my estimate arbitrarily to conclude that the " correct" number of servers should have a downward correction of " 80%" to 1 million. LBL could have undertaken some modest additional research, as I did subsequently, to learn that there is hard data on the number of servers in operation in 1999 that does not require any extrapolations. The actual number of servers last year was 4 million (Netcraft Internet Survey, www.netcraft.com/Survey/Reports/). Clearly my methodology was more accurate than theirs. As a point of interest; there were fewer than 20,000 servers in 1995. Servers are only one piece of a very big digital pie, but quite indicative of the electric trends.

In general LBL sought to ignore the basic methodology I used, sequential approximation, and instead clearly sought to undermine the integrity of my work, without attempting their own honest analysis. They also failed to note the explicit mention in my report that we did not count the electric use of a wide variety of other relevant Internet related devices, totaling in the millions.

The LBL researchers are right about one claim, that it is difficult to cleanly separate Internet equipment from all information technology equipment. Thus, I asked the LBL team to consider the conclusion offered in the study and the *Forbes* magazine article, that microprocessors of the Digital Age, in all categories including the Internet, consume about 13% of the nation's electricity. We have yet to receive a response.

The Case for Zero

While the LBL team dodged the specific question of how much electricity the Internet or even the Digital Economy uses, a Cool Companies study led by Joseph Romm was braver. The Cool study has two central contentions that merit brief discussion. One contention, incredibly enough, is that the Internet's electric use is zero. And the other central contention is that the efficiency gains from the Internet offset any putative energy needs. Let me briefly address these two contentions.

The Cool study conclusion about the Internet simply and astoundingly concludes:

> "The authors found that the Internet itself is not a major energy user, largely because it draws heavily on existing communications and computing infrastructure."

This observation reflects such a deep misunderstanding of the telecommunications revolution that it is difficult to know how to respond. Just what exactly do the authors think the past half decade of over several trillion dollars in new investment in telecommunications and computing equipment has been for and driven by, if not the Internet?

The exponential growth in equipment (and related Wall Street valuation) constitutes the electric-intensive infrastructure of the Internet. None of it was " existing." Equally important, it is still rapidly expanding. The entire telecommunications industry has been visibly up-ended and expanded by the Internet. The purchase and installation of hundreds of thousands of miles of fiber optics, and the entire attendant infrastructure has been almost entirely driven by the Internet. Digital traffic now dwarfs voice traffic on the telecommunications networks. And every telecom expert forecasts traffic to grow, and for the growth to be utterly dominated by bits, not voice. The driving force for bits is the Internet.

The Cool study authors would have us believe the Digital Economy is some kind of virtual overlay on existing infrastructure. This is the equivalent of asserting, in 1950, that the several decade build-out of the nation's Interstate Highway system, to support all the new cars and trucks moving into the economy, would not entail any investment (in dollars, materials or energy) since drivers would be using an existing highway infrastructure. It is 1950 for the digital highways.

But the Internet Improves Efficiency

It is widely recognized that the Internet is improving economic efficiency, sometimes astonishingly so. Indeed, this central fact is the very reason that the market is so rapidly consuming digital bandwidth and all of the equipment to create and serve that bandwidth. But economic and energy efficiency are not the same thing. Indeed, economic efficiency can fuel increased energy demand.

There are two aspects to the efficiency argument. One is macro-economic; is the general, overall effect of the Internet to reduce energy and material use? The second, micro-engineering; does the Internet reduce material and energy use in specific applications?

The Internet serves as a kind of economic lubricant. According to the Department of Commerce (Digital Economy II), information technologies drive at least one-third of the GDP growth, and further two-thirds of ALL investment in capital equipment. These results suggest the answer to an oft-posed question from economists and digital skeptics, " when will we see the putative economic effects of the massive investments in computers?" We're seeing them now. Indeed, Chairman Greenspan appears to believe that the reaction is even a little overheated.

Regardless, so far the net effect of the Digital Age at the national level has been to increase energy use. In the last digital decade, total air miles flown have risen from 4.3 to 5.8 billion a year. People are flying more than ever. Planes use fuel. People are driving more than ever, and in bigger vehicles. SUV and light trucks account for one-half of all vehicle sales - doubling in the past Digital Decade. Transportation fuel use is up 12%. Similarly, the digitally-accelerated economy has driven up the size of homes and the spending on home improvements. Whether you think this is good or bad is not relevant to the fact; so far, it has all generated greater energy use.

A robust economy tends to use more energy. To be sure, we're more efficient. But there is no evidence yet in human history, much less the past few decades, of rising economies with sustained declines in energy use. Obviously, improvements in efficiency moderates a growth rate; but the operative word is " growth."

What about the application-specific efficiency argument? The idea, in a nutshell: the Internet is so powerful that it will improve efficiency faster than the energy consumed by the hardware on the Network.

The energy used per dollar of GDP is the favorite efficiency metric of both environmentalists and business leaders seeking environmental coverage. By this measure, the U.S. is incredibly more efficient than just a decade ago. Total U.S. energy use per dollar of GDP has dropped 16% since 1990. Today's economy, operating at the energy efficiency of 1990, would need 15 Quads more fuel - in oil terms, that would be a 40% increase in total U.S. oil use. Interesting, but largely meaningless. The nation still uses more energy today than a decade ago. And more importantly for a Digital Economy, we use a lot more electricity. Increased supply to meet electric growth in just the past five years is equal to the total generating capacity of Italy.

There is a real problem with the dollars per BTU metric for energy efficiency, and easily illustrated. Considering, with this metric, who is the most energy efficient person in America? Bill Gates. Despite enormous energy use in his legendary home, personal jet and so forth, Mr. Gate's wealth yields an efficiency measured as energy per $ that would shame a Sudanese hunter gatherer - only because his wealth is so great. The economic path the U.S. is on, with the Digital Era accelerating economic gains out of proportion to relatively modest energy growth, means that the U.S. economy is following the Bill Gates method for energy efficiency: increase wealth faster than you increase energy use.

What then of the specific energy efficiency gains of the Internet, especially the efficiencies of buying " on line" via e-commerce - what might be termed Amazon-dot-com effect? The jury's still out on whether more or less energy/material infrastructure is used to warehouse and deliver e-commerce products. Books from Amazon via 747 and trucks may use less or more energy than driving an SUV to the book and grocery store. It is far from clear, however, what the final, overall effect will be in retail e-commerce, especially since it is still only a tiny fraction of total retail. The 24-7, send-it-overnight e-commerce economy could increase energy use if aircraft begin to substitute for trucks and trains for product delivery. Many analysts believe that competition in e-commerce will drive business increasingly to delivery overnight. Developers are already building new, dedicated airport hubs that can handle multiple 747s loading-unloading specifically as for e-commerce. ("Developers Rush to Meet the Demands of E-Commerce," 1/23/00, New York Times.)

Even if the net overall impact of the Amazon-effect is improved energy efficiency (it probably is in many cases, if not specifically the Amazon case)- reduced transportation oil use still comes with increased use of electricity. This in fact has been the general macro-energy trend of the past decade.

The Cool study continues also with one long-sought goal of environmental activists. The paperless society. The Cool study sees the Internet saving " 2.7 million tons of paper every year by 2003, as it reduces the need to print newspapers, catalogs, direct mail, and the like." (" The Internet may give a boost to energy efficiency," J. Romm, Yahoo.com, 01.24.00) Perhaps. But this sounds eerily like the paperless office touted as the result of word processors a decade ago. So far, paper use is up.

Then too there is the long-promised energy savings from telecommuting. Certainly telecommuting uses less fuel than driving your car. But auto and air travel is up even with the rise of telecommuting. The reasons are complex, but even the co-inventor of the Internet himself has concluded:

> " The Internet has the funny effect of increasing the amount of travel."

(Vinton Cerf, Senior VP of Internet Architecture, MCI WorldCom, actual co-inventor of the Internet, Engineering Tomorrow, IEEE Press, 2000, p.10.)

Where does Internet Electric Demand Go From Here?

Up.

Will there be continued growth in the hardware of the Digital Age? Is the Digital Age fully formed, IT appliance invention, production and utilization fully saturated? All indicators point to the fact that we're just at the beginning. The number of applications, and the range of microprocessor-based devices, the magnitude and extent of the communication networks needed to integrate all the devices is still at that so-called knee in the hockey-stick curve.

One hundred million computers today will become hundreds of millions in a few short years; globally, billions. As the Internet moves increasingly into a wireless mode, power use will grow disproportionately because it is inherently less efficient to broadcast than pipe information. The Palm VII and similar handheld devices and their wireless access to the Internet are only the beginning of an explosive trend. Add to this the ever expanding appetite for faster Internet access, and more broadband services. This is just the beginning.

Thus will the Information Economy keep driving demand for electricity? Or will the market's use of new electric devices reach saturation, and efficiency gains combine to flatten out load growth? These two key questions have been posed repeatedly over the past two decades with regard to electric use in general, and are even more critical to understand today, at the dawn of Internet era.

The old conventional wisdom was that PCs and their kin would follow the efficiency trend of all other electric appliances. In one sense they have. Certainly PC monitors are more efficient today, as are many PCs. But unlike lights, chillers and refrigerators, the number of PCs and PC type devices has grown geometrically in a few short years.

In the past, some prominent forecasters have been confident that demand for electricity would stop growing because of efficiency gains and market saturation. We hear much the same language today, with much the same reasoning.

In 1980, a study from the Union of Concerned Scientists predicted:

> "Because saturation levels for most major appliances are achieved, only minor increases in electricity consumption [will] occur."
> (Energy Strategy, Union of Concerned Scientists, 1980)

In 1981, a study from the then Solar Energy Research Institute, since re-named the National Renewable Energy Lab concluded:

"It appears that the demand for electricity is unlikely to increase significantly during the next two decades."
(A New Prosperity: Building a Sustainable Energy Future, Solar Energy Research Institute, 1981)

What happened since 1980? Electric demand grew nearly 60%. What went 'wrong'? The analysts completely misunderstood the technology trends of ever greater applications for electricity, uses that more than offset improved efficiency. The same mindset is in place once again with regard to the information age and the Internet.

More recently, researchers at LBL concluded in 1995, just five Internet years ago:

"While total energy use for office equipment has grown rapidly in recent years, this growth is likely to slow in the next decade because the US commercial sector market is becoming saturated (especially for PC CPUs and monitors)."
(" Efficiency Improvements in U.S. Office Equipment," LBL, December 1995.)

To be charitable, forecasters even five years ago could hardly have forecast the growth in electricity-consuming IT-type equipment. But this has not stopped the refrain from continuing. The indicators for future trends are nothing less than amazing.

There are literally trillion of objects manufactured each year. We are rapidly approaching a time when everything will be manufactured with a silicon device of some kind, and where virtually all of them will communicate. Even if the energy needs of this trillion chip industry, and trillion petabyte bandwidth are trivial in per-chip terms - the aggregate electric needs will no doubt be astonishing.

As bandwidth demand rises, power use rises, as does the market's use of the services. Yes efficiency will rise too. But for some time, as we build out the new infrastructure of the Digital Age, efficiency gains will be overwhelmed by sheer growth. Electricity is the fuel of the Digital Age, and the Internet at the heart of this revolution.

No energy policy, including and perhaps especially the anti-electricity aspects of the Kyoto Protocol, should be considered without passing it first through a Digital sanity test. The integrity, reliability and low cost of the national electric infrastructure will be more, not less important in the future. A juxtaposition of key facts illustrates a policy collision course. Kyoto Protocol advocates call explicitly for the reduction, even elimination of fossil fuels and especially coal from the nation's energy infrastructure. Yet the nation gets 70% of its electricity from fossil fuels (three-fourths of that from coal). EIA forecasts that more fossil fuels will be needed to support economic growth. And while EIA forecasts natural gas will dominate the growth, they also forecast coal use will rise to support the economy. Clearly energy policy and the Digital Economy are tightly linked.

Mr. MCINTOSH. I thank all of you.

Mr. Kucinich has to go to the floor, but let me ask unanimous consent that the record be held open, and if Mr. Kucinich has some questions that he would like to pose to any of you, I ask that you answer them in writing.

Mr. KUCINICH. I just want to thank the Chair for doing that. Unfortunately, I have to go to the floor right now. A bill that I am involved in is in debate.

So I want to tell you, I am very impressed with this panel. There are differences of opinion, and I wish I could stay. But if we have another Member come, they might want to ask the questions that I have. But if they don't show up, I would like them inserted in the record.

Mr. MCINTOSH. In fact, let me ask unanimous consent for questions from any of the members of the subcommittee.

Mr. KUCINICH. Mr. Chairman, thank you.

Mr. MCINTOSH. Thank you, Dennis.

Mr. Mills, I called this hearing because some of your data made its way into one of our hearings on Kyoto. Today, you made some pretty conclusory statements that you are right and they are wrong. It appears from this chart that we were given that there is a factual question on the magnitude of Internet-related electricity demand, and that you and your critics are using the same definitions, or is there an explanation for why the Lawrence Berkeley people using your definitions came up with lower numbers?

Mr. MILLS. Well, let me, Mr. Chairman, give you an example. In their analysis to adjust my data down, they looked at web servers. This is one representative example. There are many, and it would take far too long, but this is typical of what they did wrong. They said that I counted the number of servers incorrectly.

One of the things you said in your opening remarks is that we are having a hard time measuring the Internet right now. In fact, there is a great debate figuring out what the metrics are for it. I wasn't looking at how much e-commerce was going on, but how much hardware exists. A server is the computer box that contains the website, and it can contain one website, or it can contain 100 websites.

It turns out that there are organizations that do something called ping the Internet. They send signals up, and they ask computers, are you there, are you a server. Every server has an identity, and it says, yes, hello, I am here.

In my original report, I estimated the number of servers by looking at the number of websites and doing an extrapolation. I came up with the number 4 million servers in the United States. By the way, that number is growing geometrically, but that number was 4 million last year. Lawrence Berkeley said, no, no, Mills' assumptions were wrong, it should be reduced by 80-some percent to 1 million, because there are more websites per box.

What I have done subsequently and they obviously decided not to do is to find out what the actual hard data is for the number of servers; not websites, but the number of physical boxes. The number is 4 million. So their adjustment now of my web servers by a factor of 80 percent is simply completely wrong.

Now, they have done this over and over again in other areas. It is that kind of methodological failure on their part that made me wonder if they were seeking their own conclusion rather than seeking to get the facts, because they clearly did not look into this data properly.

Mr. MCINTOSH. OK. Would you for the committee go through an analysis of the different ways in which they have done that? Frankly, we are going to ask them to justify their work as well.

Let me ask this question to Mr. Romm, because I actually think that it is possible that Mr. Mills or Mr. Romm are actually looking at the same thing from 2 different perspectives.

Part of what your chart there demonstrates is this. As we have seen growth in the economy, acknowledged by all of us to be driven by the technology, computers and telecommunications, we are seeing a reduction in the growth of energy and electricity use in particular, but energy overall, and therefore the growth in emissions from energy production. That means, essentially, that there are jobs being added into the economy driven by that technology sector. The flip side of that, and we see this in my district, there are jobs leaving the economy that are the old manufacturing jobs that were more electricity-intensive. So you have a shift going on from the older economy to the new.

Now, that doesn't necessarily mean that you don't also have an increase of use in electricity, because if you assume that that decrease in manufacturing jobs were to occur regardless of the technology revolution, what could be happening is that we might, had we not seen the technology revolution, have seen the growth in electricity be even lower. Is that not right?

Mr. ROMM. Well, you ask a very complicated question, because one has to try to figure out exactly what is going on in every aspect of the economy. I think that part of what you are saying is certainly correct, although it is worth saying that U.S. manufacturing output has not declined. As I am sure you know, Bethlehem Steel and other companies in Indiana have gotten more productive, far more productive in the last few years, so they have been able to generate more output with the same or fewer workers.

I think the main point is that a very large fraction of our growth is coming from the computer industry, the software industry, the telecom industry, industries that do not consume as much energy as the steel industry would. And so——

Mr. MCINTOSH. Let me ask you, what does that mean, "consume as much"?

Mr. ROMM. In other words, let's say——

Mr. MCINTOSH. Is that per dollar of GDP?

Mr. ROMM. Per dollar of GDP. In other words, what we are seeing here is, in some sense, the measure that is used of overall U.S. economic efficiency is to divide the total energy number each year, the growth in energy, by the growth in GDP, to come up with a metric called energy intensity. You can clearly see that the Nation became a lot more—a lot less energy-intensive in the last 3 years because we had big growth in GDP, small growth in energy. What this suggests is that in part, we might get $1 trillion in economic growth from the information technology sector, but if we had gotten

$1 trillion in economic growth from the steel industry, that would have used, you know, easily that much energy.

Mr. MCINTOSH. So you are seeing a shift from manufacturing and therefore manufacturing jobs into technology and technology jobs, which use less electricity?

Mr. ROMM. By and large, yes. I think—there has been a study done by the EPA and Argonne which roughly says that that structural change which you have just described is about a third to a half of the explanation for this trend. There is another trend—there are two ways the economy can become more efficient at using energy or less energy-intensive. One is the structural change that you have described. The other is to put in energy-efficient light bulbs, to replace trips to the mall with working at your desktop. That is becoming more efficient.

Mr. MCINTOSH. Exactly. Which leads me to my next question, and then I will come back for some of the other witnesses.

If—and as I understand by your testimony, that structural shift can account for a savings of about 300 million metric tons by 2010, and that that is approximately two-thirds of what the obligation under the Kyoto protocol would be for the United States, my question is, wouldn't we be better off allowing that invisible hand of the marketplace to work, rather than bringing in a regulatory structure when you are going to be able to see those reductions and savings because of the structural shifts in the economy?

Mr. ROMM. Sure. Well, I know that we probably take different views of some aspects of this issue. Let me try to answer the question this way: I believe that greenhouse gas emissions are going to grow more slowly because of the Internet and other factors than EIA does, and that will certainly make it easier to meet the Kyoto targets. Those of us who think that it is important for the country and the world to reduce greenhouse gas emissions still feel strongly that some market-based signals help show businesses that we don't want to reduce energy consumption per se. What we want to do is pull CO_2, greenhouse gases, out of the U.S. economy the way we pulled sulfur out of the electricity grid and lead out of gasoline. It is my belief that a relatively low market——

Mr. MCINTOSH. Unless you move to hydroelectricity or nuclear fuels, you can't do that.

Mr. ROMM. No, that is not true. The utility system right now is only 28 percent efficient in converting fossil fuels to electricity. It is very inefficient, in part because we have had a regulated monopoly.

The average coal plant is only 30 percent efficient. There are gas-fired, combined-cycle units which are 55 percent efficient. There is cogeneration, the simultaneous generation of electricity and steam, which is 90 percent efficient. We can have, you know, what is called fuel-switching or more efficient conversion. We can have some renewables. I don't think——

Mr. MCINTOSH. All of that depends on the price signals.

Mr. ROMM. Well, what is very clear is that there are a lot of low-cost measures, and it appears, from Mr. Hakes's report on voluntary actions by companies, that a lot of companies are taking voluntary actions to reduce their greenhouse gas emissions. Most of those, I believe, are utilities.

I think it is quite interesting that in 1998, U.S. global greenhouse gas emissions dropped, and total energy use in the world actually dropped for the first time since 1982.

I think you will find that there are a lot of steps that companies and governments can take that do not require a very big price signal, and that are very—obviously, we have shown that you can have low CO_2 growth and high GDP growth at the same time, so it is certainly difficult to argue that having lower CO_2 growth harms GDP.

Mr. MCINTOSH. Let me let Mr. Ryan ask questions, and then, Mr. Hakes, I will give you your opportunity which you asked for in your testimony.

Do you have a set of questions?

Mr. RYAN. Sure.

Actually, Mr. Hakes, you haven't had a chance to talk about any of this. I would like to get you involved right now, if I may.

I was intrigued with what Dr. Romm said about EIA's overestimation of Kyoto's costs. EIA estimates that the Kyoto protocol would increase average electricity prices from 20 percent to 86 percent in 2010.

Dr. Romm, I think you said in your testimony that that is wholly irrelevant to the real world.

Could you comment on that, your assessment of Dr. Romm's comments?

Mr. HAKES. Well, this is a very detailed study that we did for the House Science Committee, and my view is that it has held up well over time. I think the analysis is quite good; I think there is material in there that somewhat supports the view of Kyoto critics, and I think there is some conclusions that do not support the views of Kyoto critics.

I think that we have suggested in there that carbon emissions would grow a little bit over 1 percent a year; you know, a little bit larger than the population growth.

If you look at Mr. Romm's chart for CO_2, you can see in the last couple of years it grew at a slower pace. Why did it grow at a slower pace? The main reason was the mild weather; it wasn't because of some new efficiency gain. People have to use less heating oil, less heating from their space heaters and less natural gas. The other reason was there was an economic decline in Asia that reduced the demand for a lot of products that are energy-intensive.

If you look at the preliminary data for 1999, which is not official yet, it looks like carbon emissions will grow about 1 percent a year. In 2000, we are having a very cold winter, maybe they will grow more.

On the issue of Mr. Romm's attacks on our forecasts, he has launched a lot of grenades here, but let me mention one that he suggests in his written testimony—that EIA doesn't have foresight on the Kyoto treaty. Critics like Mr. Romm have said we have overestimated costs because we don't allow people to adjust before 2005. It is just flat wrong, and it has been corrected in the public record.

We allow perfect foresight by the electric utilities. In other words, in our model we assume that it started at the date of our study, which is now more than a year old, and is fully operational now, which is I think very overly optimistic to his side. We have also assumed perfect foresight in the refining industries, so the voluntary programs by BP and others that tend to focus on refining are already fully incorporated and obviously a lot of companies are not doing this. So if there are other industrial sectors that don't have foresight, I think it all adds up.

We treat, I think, foresight in our study very, very fairly and very balanced, and maybe even perhaps tilted a little bit to Mr. Romm's point of view, and yet he continues to repeat over and over again, even when it is shown by us to be very clear in the document itself, if you actually read it, that we allow foresight rather amply throughout our system.

His attacks on our oil price forecasts; our forecasts are very highly respected among energy experts. There was something that happened last March. OPEC cut world production by about 3 million barrels. We do not have a pipeline by which OPEC tells us whether they are going to cut production or not, but that was certainly the main reason that everybody's signals on oil prices were reversed. And once they made that policy decision, we said that prices would be going up into the basic range that they are now.

Of the big errors that he mentioned, and I certainly admit to, one of the things that EIA does as a Federal agency, as a public agency, is to bend over backward to point out ourselves any previous mistakes we have made. But the one he was talking about in the Science Committee was talking about the early 1980's, the first one or two forecasts we did at the time of deregulation.

I think our forecasts in the 1990's have stood up extremely well. We had some arguments. The administration had a study in 1993 saying that voluntary programs would cause carbon emissions in the year 2000 to be what they were in 1990. We said, "No, we don't think that will work, they are going to grow in the 1990's." I think we were basically correct, and I think we have been more correct than some of the optimists like Mr. Romm.

One other point on electricity that is very interesting. In our forecasts, consistently in the 1980's, we have underestimated the growth of electricity because we had too much built in for appliance efficiency. So EIA, who Mr. Romm you seem to portray as always underestimating these efficiency gains, actually consistently overestimated them in the electricity sector in the 1990's.

We try to do a balanced job. I think we don't always get it exactly right. I don't think there is a systematic bias, particularly since we have put more attention on technology issues in recent forecasts.

Mr. ROMM. Could I just—very little—many things that Mr. Hakes said are just factually incorrect. In their latest annual energy review, which they just released in December, they predict for the next 7 years that CO_2 emissions will grow 1.8 percent for 7 years, not 1 percent, as Mr. Hakes said.

I think the key point is there is no question that the EIA occasionally stumbles onto the truth. If they would be more humble about the fact that they are often wrong and not release reports that are called Impacts of the Kyoto protocol on U.S. Energy Markets and Economic Activities, but even Possible Impacts, or A Scenario of Impacts, but they continue to believe over and over again that they are correct, and over and over again they are proved not to be correct. I will leave the rest of the corrections for the record.

Mr. MCINTOSH. Let me actually have a followup, because while Mr. Romm is critiquing them from one direction, Mr. Mills, in your testimony you seem to think that they had underestimated the impacts of the digital economy on electricity demand. Can you explain your viewpoint on that?

Mr. MILLS. Well, let me explain it from two perspectives. One is forecasting, and one is from the history. Actually, I think that—well, for the record, I actually believe that EIA is—not that I want to get into the middle of a battle between the lovers and haters of EIA. I actually think that their track record is remarkable. Mr. Hakes is absolutely correct. The track record in the 1980's was pretty abysmal. After that it has gotten very good. They have gotten very sophisticated in understanding the markets and have overestimated the impact, as Mr. Hakes said, of efficiency measures in the economy, partly because it is an engineer's dilemma. When more efficient refrigeration exist, people tend to use more of it. The markets are a little more complicated than that, as Mr. Hakes' analysts know.

I think what we have seen in the last digital decade is, in fact, the information economy effect. In the last decade there has been an enormous increase in the efficiency of lighting, in refrigerators, in motors. We have spent in this country tens of billions of dollars on these so-called demand-side management programs for the last 20 years, and the fruit was born in the 1990's. If you go by sector, you will find, yes, they are incredibly more energy-efficient in lighting of buildings and air conditioning of buildings, and yet demand went up. The growth rate wasn't as high as the 1970's and 1980's, but it still went up. It went up in aggregate by an enormous amount.

The most fascinating thing to me is that it went up so much in the category that used to be a grab bag, and this is—not that I am pleading for funding for EIA, but it is a funding problem.

In the old days, you threw things that you couldn't count into the "other" category, and everything else took up 90 percent of electricity demands. So the 10 percent in "other," who cares? If you look at commercial building electric use in the EIA data now, "other" is a third of all electricity used in commercial buildings. "Other" is growing faster than anything else, and "other" is exceeded only by lighting. It is 300 billion kilowatt hours of "other" stuff, which was where I contend a lot of the Internet hardware is showing up, because it is not tracked. In fact, many of the organizations that track data like refrigerators and motors don't even track servers.

Cisco is everybody's pick. They hope they bought into Cisco 5 years ago. Cisco is selling a million routers a year. Cisco's routers don't show up in information technology industry data books because they didn't exist when they created the data books. They don't track them. Neither does EIA track them. There is a methodological problem which is inherent in the new economy.

Mr. MCINTOSH. And so if you are correct and the energy use is going to grow dramatically because of the electricity demands of the equipment that drives the Internet, what explains the decrease in electricity growth with the increase in economic growth? Is it that we are losing manufacturing jobs faster than we are replacing them with the demand for the Internet equipment?

Mr. MILLS. We found one other area where Mr. Romm and I agree. There is more manufacturing in America. There are fewer jobs, but there is actually more manufacturing output.

Just as an aside, the manufacturing sector in the last decade has decreased its consumption of combustible fuels and increased its use of electricity. It has become more electrified. Steel mills are a great example. Five percent of steel mills in 1970 were electric; now it is 40 percent. So they are very electric intensive, very efficient. They are computerized, and they have fewer jobs. The jobs have gone to the information and technology and service sectors.

Let me explain more clearly my forecast is that I think that EIA is close to right and, in fact, Mr. Hakes's testimony says he thinks the Internet could take it either way, lower or higher. My guess is that it will take it higher. But a 1 or 2 percent range in load growth in the electric sector as big as ours is a very big number. We are not a small country. When we move electric demand a few tenths of a percent it makes a huge difference.

The explanation for the efficiency numbers is something like that, and I don't mean to be facetious, but I call it the Bill Gates effect. We have a tendency, energy analysts, to measure energy efficiency the way Mr. Romm was showing you: BTUs per dollar of GDP. I would submit to you that this is interesting but probably totally irrelevant and indeed enormously misleading. If we have an economy like our economy where the Internet is consuming more energy, not enormous amounts, but more energy, not less, but it is bootstrapping economic growth even faster, which is the effect we see from an Amazon.com, if you like, what you get from that is modest continued energy growth from a huge base. Also huge GDP growth. So the energy efficiency improves.

Let me put it to you this way. Who would be the most energy efficient person in the world today by this measure? The answer is Bill Gates.

Mr. MCINTOSH. Let me take it one step further. If you have a public policy, such as the Kyoto protocol, that says we are going to increase the cost of electricity for the social good of eliminating or reducing carbon dioxide, what is the impact on the new emerging computer and communications industry compared to the other sectors of the economy?

Mr. MILLS. It is a serious impact, and it would have been modest, if not irrelevant, 20 years ago. But once you take—once you state the premise that the information economy is at the core of our economy as the Commerce Department has estimated a third of GDP, real growth, once you know that it is no longer trivial, web-serving firms are huge, electric-consuming beasts, the price, supply and reliability of electricity become the central factor in our economy, not secondary. They become, I would argue, more important than oil.

It is now—oil is still extremely important, but the price, supply and reliability of electricity are now more important than oil to our economic future. To me that suggests that things like Kyoto and the Kyoto protocol that create enormous risk in the electric supply sector are dangerous to move quickly on for that simple reason. It is so important now.

Mr. MCINTOSH. I will share with you just one example from my home State in Indiana where EPA has filed a ridiculous lawsuit against the electric utilities saying that if you try to maintain your plants you are going to be in violation of the Clean Air Act. What is driving that policy is a desire to stop the utilities from using coal. If you remove coal as an electric power source, that does a huge amount of damage to the economy in the Midwest, driven by these other social goals.

Mr. MILLS. One of the things that we are seeing here is that EIA, regardless of whether we think their forecast is accurate or not, I think it is pretty good, sees the demand for electricity rising. So we have, as Mr. Hakes said, about half of our electricity—a little over half comes from coal in America. In the future, we will need more electricity and not less. If we implement policies that reduce the base while we still have an increased demand, we create enormous risks.

Mr. MCINTOSH. I have one question for each of you, actually. Are there any forecasts out there if you double the cost of electricity, what that does to impede the growth in the technology sector?

Mr. MILLS. Well, I did an analysis like that 2 years ago on the commodities basis, but I will be happy to defer to Mr. Hakes first if you have looked at this.

Mr. HAKES. If you are talking about a Kyoto scenario, it depends on how you would implement the Kyoto scenario. One of the scenarios that economists have used is that you auction off the carbon credits which are then recycled back into the economy, perhaps through a Social Security tax cut. If that was done, your energy-intensive industry, your coal industry would be net losers, but some of your low intensity users might actually be winners. But there is a whole range of policies there that have not been addressed in any systematic way, so without those kinds of considerations, it is hard to assess the total impact on an industry.

Mr. MCINTOSH. You mentioned, Mr. Hakes, recycling through a carbon tax. At least as far as I can tell, there are no proponents for that, either in the administration or here in Congress. How about some of the other scenarios where it is just done through a command and control pricing increase policy?

Mr. HAKES. Well, everything that I have seen has been proposed to cap carbon in some way. You can do that by either grandfathering people in or you can auction credits. There are different ways to do that. I don't think that those types of issues are being discussed very much, because they tend to be somewhat sensitive. There are large economic impacts. But you couldn't implement the Kyoto treaty without making some judgments in those areas. You probably would have to use some revenues to compensate the coal industry in some way, since they would be such obvious losers in a transition.

Mr. MCINTOSH. But if you grandfathered people in and you see the shift from oil to electric generation, which is generally done through coal, then you could cause some distortions in the growth in the economy.

Mr. HAKES. It would probably help some areas and hurt others.

Mr. MCINTOSH. I guess my question is, on which side of that equation would technology and communications fall?

Mr. HAKES. Depending on how it was recycled, they might be net beneficiaries.

Mr. MCINTOSH. But that is assuming there is a tax. In the absence of a tax.

Mr. HAKES. Without it, they would be less hurt than, say, the aluminum industry or the refining industry or the auto manufacturing industry, who are very energy intensive industries, or the airlines industry, who have high energy costs and therefore it would affect their bottom line a lot more. I think for the computer companies, this is not as big an issue for them, although, clearly, they do have energy costs and have a great interest in the reliability of the electric system.

Mr. ROMM. Let me make a few points.

First of all, certainly the worst-case scenario, electricity prices aren't going to double under Kyoto.

B, even in the most pessimistic analysis, which is Mr. Hakes, he says that we could comply with Kyoto with "no appreciable change" in the long-term GDP growth rate. So the fact is that it would not harm the economy.

The third is that Mr. Mills—Mr. Mills is testifying that, on the basis of his study, he can tell you that Kyoto would be bad for the U.S. economy, and yet he has only looked at the electricity used by the Internet. He has not looked at the electricity saved by the use of the Internet in the economy. Therefore, his study is wholly inadequate to draw that conclusion.

I am not going to testify here today that I know for a certainty that everything that I wrote is true. That is why we called our work a scenario. But it is very clear that if you look at the data, electricity, the rate of growth of electricity consumption has dropped, energy growth has dropped, CO_2 growth has dropped, and GDP growth has grown. So I don't see how anyone can argue with the premise that we can have lower CO_2 growth and higher GDP growth.

Just to correct one other misstatement by Mr. Hakes, we have done a weather correction. It is very clear that the United States is getting warmer. NOAA has—you know, the National Oceanic and Atmospheric Administration has acknowledged that, EIA has acknowledged that. When you do the weather correction, we have had a slightly warm 1997, very warm 1998, not a particularly warm 1999 compared to 1998. The weather correction brings annual energy growth up to slightly under 1 percent and the same for CO_2. It explains about one-quarter of this remarkable graph here.

Mr. MCINTOSH. And I think I am going to have to leave; but, Mr. Hakes, you have a comment you want to make.

Mr. HAKES. Mr. Romm talks about this remarkable graph. I would like to introduce into the record the intensity gains and losses in the U.S. economy going back to 1960. You look at 1981, the intensity gain was 4.6. If you look at 1983, the gain was 4 percent, greater than we have seen in the last 2 years. So in 1984, you have Amory Lovins saying, we see electricity demand ratcheting downward over the medium and long term, much as Mr. Romm is saying today, and he actually had more convincing data at that time than Mr. Romm has today.

So what happened in the next few years? The pattern reversed itself. Because things go in cycles. Weather goes in cycles. The economy in Asia goes in cycles. If we were to use Mr. Romm's approach, if you take the 4 years before 1997, the intensity gains in 3 of those 4 years rounded out to zero. We didn't change our optimism about continuing intensity gains because we thought those statistics were aberrations.

Mr. Romm didn't come to us at that time and say lower your intensity gains because we got these very low intensity numbers. So he picks two numbers in 2 recent years that raise some interesting questions but are clearly highly relevant to weather, where you don't see energy use going down, you don't see carbon going down, and tries to argue that it is a brand-new trend. I think the data are much less convincing than the data from 1981 and 1983.

Mr. RYAN. Mr. Mills, could you comment on that as well, please?

Mr. MILLS. Well, the energy intensity trends of the economy, it again masks two things. One is, are we getting more energy efficient by this measure? Which again I contend is a misleading measure. What you see in these graphs is, regardless of what the growth rate is, the operative word is growth. The economy is growing. Consumption of energy is growing. The emissions of carbon dioxide are growing. None of it is declining.

So my conclusion, which Mr. Romm misstated—misrepresented, was not that the Kyoto protocol harms us. It is that the kind of policies that would tamper with the electric supply system of this country, which is the single most important part of our economic infrastructure at the root, are dangerous given the rising importance of electricity, not its declining importance.

Let me add one other point just as an overlay on this to get back to an earlier remark I said about the challenge we have here is understanding this new economy. Mr. Romm, I don't believe, understands it. Mr. Hakes knows that it is complicated and has said—in fact, I have seen in their data their analysts are struggling to figure out how to fit it in, and we don't have the data collection mechanisms.

But one particular conclusion in Mr. Romm's study that is breathtaking in its erroneousness I have to just put on the record. His conclusion about how much energy the Internet uses states that it is not a significant energy user because it uses the existing telecommunications infrastructure.

I have to say, this is laughable if you talk to people in the telecom industry and go to any hearings in the Congress on telecom. The telecom industry has been turned upside down by the Internet. We have had trillions of dollars of new infrastructure built because of the Internet. There was no existing infrastructure. It was created for the digital economy and for the Internet. This would be like saying in 1950 that the interstate highway system existed and was an existing infrastructure, did not require energy or materials to build out over the next 40 years. It didn't exist. It had to be built. We are in the build-out phase. This is 1950 for the digital highway right now.

Mr. RYAN. Mr. Romm, I am very intrigued at his confidence in this chart and the confidence in these 2-year sets of data——

Mr. ROMM. Three.

Mr. RYAN [continuing]. 3-year sets of data indicate a trend. Let me ask just left from right, Mr. Mills and then Mr. Hakes and Mr. Romm at the end, to comment on that. Does 3 years of data indicate a trend? Have we severed the tie?

Mr. MILLS. I will make this answer short. Three years does not set a trend. A decade, 5 to 10 years is useful. I do not believe we have severed any ties of any kind. I think there are some important structural changes, but, no, 3 years is interesting but not a trend.

Mr. RYAN. Mr. Hakes.

Mr. HAKES. He has averaged the 3 years, but you can hide a lot of things with averaging. The intensity gain in 1996 was 0.2 percent. That happened to be a cold period, so that is not surprising. So the real intensity gains that he is talking about are only in 1997 and 1998, 3.4 and 3.9, and because of the unusual weather and economic conditions, as I have said before. There are a lot of people around town, economists and others, in the administration and others, and I think most of them agree with us that weather was a big factor. This is certainly worth watching but does not indicate a significant new trend.

Mr. ROMM. First, to just correct Mr. Mills, the paper makes very clear one of the things the Internet does is take advantage of the fact that everybody had computers or a lot of people had computers before the Internet and that consumed a great deal of electricity. For Mr. Mills, if the economy was consuming a lot of electricity, if someone had a PC and it consumed electricity, they spent any time on the Internet, that is all Internet electricity, even though the economy was using it for other purposes beforehand.

Let me make a few things clear. In Mr. Hakes's testimony, he believes I am talking about 1997 and 1998. We are, in fact, averaging in the first 10 months of the 1990 data—the 1999 data. What is interesting about the 1999 data is that it has nothing to do with weather, because 1999 was not as mild as 1998. We have talked to EIA's analysts. We have done the weather correction. We have talked to EPA. The weather correction is only 25 percent of this effect.

Mr. RYAN. Let me interject at this point. Mr. Hakes, what about the Asian meltdown? How much of that is significant to this data?

Mr. HAKES. We think that it is part of the drop in natural gas usage in 1998. I think the chairman was getting at this point earlier. You can talk about intensity gains, but if you are relating this to Kyoto, you are not getting Kyoto gains if the economy grows faster and energy consumption stays the same. So we are sort of talking about apples and oranges here.

Intensity is a little bit irrelevant—it is a factor, but the real issue is how much energy is being consumed and how much carbon is being emitted. So the fact that we have had this incredible economic growth in the last few years and its improved intensity, doesn't necessarily mean energy use will go down.

One other point I think the committee might be interested in is that the Commerce Department has changed the way we calculate

GDP and that is it gives us statistics that are higher not because the economy is growing faster but because the statistical calculations are different, which means that all of these intensity numbers are going to be adjusted upward in the next year or two, so that you will see more improvements of intensity because there is a better measurement system now for GDP. You can sit around and celebrate when that statistical adjustment is made and say that this makes Kyoto easy, but, the bottom line, it doesn't change energy consumption; it just changes the ratio between energy and the economy.

Mr. ROMM. What I would like to end up by saying is as follows: We put out our scenario on the table because it looks like something very interesting is happening in the economy. Mr. Hakes is supposed to be representing an objective, independent, energy analytical agency. They ought to be very interested in what is going on in the economy. And yet he comes here and he tries to tell you nothing is going on, I can explain it all, even though—and I would like to introduce into the record a chart that we have done that shows that, in fact, energy intensity in every sector has improved, including the transportation sector. In fact, the transportation sector, which is completely—almost completely independent of the weather, has seen the biggest 2-year drop in the intensity of travel per GDP in 30 years of data.

The fact of the matter is that something big is going on in the economy, and I just challenge EIA to be curious about it.

To give you an idea of what they did in their last annual energy outlook 1 year ago, they projected 8 years of 1.6 percent CO_2 growth. We had no growth in CO_2, 0.3 percent, in 1998. And instead of saying, oh, something big may be happening in the economy, we should lower our CO_2 forecasts, they actually jacked them up to 1.8 percent, which suggests to me that they are not sufficiently curious as to whether something big is going on in the economy that might affect forecasts that people make very important decisions on.

Mr. RYAN. OK. Before I go with a final question, Mr. Mills, would you like to respond to that?

Mr. MILLS. I just want to make this observation about the forecasting challenges and energy intensity. One of the things that is very clear and that is important to the subject at hand is that we haven't stopped building out the Internet. Regardless of what we decide that the consumption of electricity is that is ascribed to the Internet, it is still growing exponentially.

We are at the buildup phase. We are building up everywhere, not just .coms and servers, but homes, multiple PCs in home, cable modems, wireless telephony, wireless data access, wireless palms, all of these things use electricity and they are growing at exponential rates. They will increase the consumption of electricity reasonably, and it will bootstrap the GDP even faster.

So when we combine that effect with the readjustment in how we measure the GDP, we are going to get an even bigger appearance of improved energy efficiency by this fallacious measure which is BTUs per dollar of GDP, but we will still use more energy, which is a critical thing to keep in mind.

Mr. RYAN. How important is the comparisons of growth rates versus nominal mall growth?

Mr. MILLS. Well, what matters from the reality of physics and materials is growth, not the rate. And from a fundamental perspective, we want to know how much stuff are we using, where is oil, gas, coal, steel, aluminum, are we going to use more stuff next year. The rate can change, depending on how you measure the rate, per person, per house, per dollar. You can get very odd results with statistics. There is that old Mark Twain saying: there are lies, damn lies, and then there are statistics. Rates are tough things. But the absolute growth tells you a lot about the materials.

And we have used more stuff, and we will use more stuff and the biggest increase in stuff will be kilowatt hours. That is where the risk is in Kyoto. It is not this rate discussion and forecast into the future. The one forecast I can make confidently is that we will use more. We don't know exactly how much more. That is the challenge.

Mr. RYAN. I was a fan of the Presidential debates which we have seen over the last few weeks, and I think we had some interesting dynamics in those Presidential debates and that was where the candidates asked each other a question. I think this has been a very informative hearing, it has been interesting. We have some unique personalities assembled here today. I would like to interject that little trend here, so to speak.

Let me do this, how about in no particular order or reason, Mr. Mills, why don't you ask Mr. Romm a question; Mr. Romm why don't you ask Mr. Hakes a question; and Mr. Hakes, why don't you ask Mr. Romm a question. We have been asking questions, but I would be intrigued to watch a dialog between the three of you, each of you asking each other a question, and then we will wrap it up. Mr. Mills.

Mr. MILLS. Thank you. I think the critical analytic question to ask Mr. Romm is that while it is clear that there are efficiency effects from the use of Internet, it is A minus B equals C, C being the net result. You have to know what A is first. You have to know how much energy the Internet uses to calculate how much energy it saves.

So I guess my question is really simple. Does your organization intend to try to figure out on their own, independent of my analysis, through their own analysis, perhaps with Lawrence Berkeley, to figure out how much electricity the Internet uses?

Mr. ROMM. Well, as you know, we have had many e-mail exchanges on this very point. I think Lawrence Berkeley labs is one of the most recognized authorities on how the economy uses electricity and energy. EIA uses them, everybody uses them. The international energy bodies use them.

Their five scientists did a very comprehensive analysis, in an admittedly difficult area. They came to the conclusion that you were wrong by a factor of 8 and that they won't say specifically, but I am certainly prepared to say that the Internet, specifically the Internet uses about 1 percent of U.S. electricity maximum.

However, you know, I think this is an important point for the committee. If Mr. Mills were right and his numbers were correct, which is that electricity consumption has soared since 1997 because of the Internet, these numbers couldn't be true. So the fact that electricity consumption rates have slowed since the Internet took off is, in my mind, prima facie evidence that he can't possibly be right. So he can engage in a very complicated and elaborate analysis to show that the Sun goes around the Earth, but the Sun doesn't go around the Earth, and so his analysis is pointless. We have put on the table our explanation of why his methodology is wrong and why he comes up with the wrong answer, which the macroeconomic data clearly shows is wrong. So I don't think we need to do any more work.

Mr. RYAN. In keeping with the Iowa and the New Hampshire tradition, we will give the questioner a 30 second rebuttal.

Mr. MILLS. I think 2 things are relevant to this. The adjective "soar" is an adjective. The electric use went up when all of the forecasters in Mr. Romm's camp said it would stop going up. More to the point, I will take the 1 percent, that is fine. Given the growth rates on the Internet and let's say it is starting at 1 percent today, I will tell you that we just have to wait a few years, and it will be 8 percent and then more. Because the growth rate is astonishing.

So the real issue is not so much whether it is 1 or 2 or 3 or 4, but that it is a positive integer. I am glad to hear Mr. Romm recant the "0" that is in his study.

Mr. RYAN. Mr. Romm, would you like to ask Mr. Hakes a question?

Mr. ROMM. I realize, to use the full New Hampshire format, he asked for the specific number of the Internet use of electricity: 1 percent. The net impact of the Internet on electricity which would include not only the energy used by the components of the Internet, but what the impact of the Internet is on the economy, I believe the Internet saves electricity and far more than electricity, it saves energy. So that having the Internet is why the electricity growth has slowed.

The question that I would ask Mr. Hakes is, you know, first of all—let me think about this for a second.

If it were the case—well, let me ask you this question. If it were the case that the energy intensity were, in fact, changing in the last 3 years, and that, in fact, energy intensity has averaged from 1997, 1998, and 1999 about 3.5 percent, although you project that it is going to improve 1.1 percent, so we think, you know, currently you have been wrong 3 years in a row by a factor of 3, if it were the case that that was happening, would EIA—and we could convince you that that was happening, would EIA be willing to modify its forecasts?

I take your point that you have cited, very high energy intensity declined in the 1980's, but that occurred when oil prices were doubling and tripling. We have never had energy gains this big when energy prices were low and even declining. So that is my question. Is EIA open to exploring this very important issue and perhaps changing its forecasts?

Mr. HAKES. We have extensive internal dialogs about these issues and external dialogs, and we certainly would take this into consideration. But I think again you are mixing apples and oranges. It makes a big difference if the intensity improves because the economy is going up or it improves because energy use is going down. Because if, for instance, you take the scenario that energy use stays about the same and the economy goes up, then you would be asking us to adjust our intensity estimates, but you would also be asking us to adjust our GDP estimates. We estimate GDP to grow at about 2.3 percent a year. So if Mr. Romm wants us to take the last year as the statistical call trend, we would then have to raise our GDP rates to about 4 percent a year, which might conceivably make it harder to meet the Kyoto protocol.

Now, if there was a comparable gain in intensity, it would be a wash.

So you can't just change one part of the equation and take the part you like and not add in the other point you don't like. So are you arguing, Joe, that we have too low a growth rate for the economy and we should jack up economic growth which will create more new energy usage than we have in our model?

Mr. ROMM. Actually I am arguing that EIA has done what you just accused me of doing. In fact, if you look at EIA's forecasts this year and last year, they jacked up the GDP level in 2005, but they didn't change the energy intensity level. So they actually predict, even though we have had 3 amazing years, they have predicted higher GDP growth, but no improvement in energy intensity, which is why this year's forecast, even though oil prices are higher than they were a year ago and even though they have another year's data that something is going on in the economy, they actually raised GDP, but they don't raise the energy intensity, which is why they have higher CO_2 levels predicted this year for 2005 than they did last year, which I would argue suggests that they are defending a perspective which is to say higher CO_2 growth rates, as opposed to saying gee, maybe something is happening in the economy.

Mr. RYAN. Since we are talking about your chart so much, why don't we have Mr. Hakes ask Mr. Romm a question and then we will conclude.

Mr. HAKES. Back in 1996, carbon emissions went up about 3 percent and EIA took the position that a lot of that was weather related, and we didn't jack up our carbon emissions growth-rates. In fact, we, I think, came down a little bit, because we thought that was a specific aberration. Why didn't you come to us in 1996 and express your concerns that we were underestimating carbon growth because the data for that year showed it was much higher than were in the EIA estimates?

Mr. ROMM. Well, I take your point that 1 year's worth of data is not something that I would change your forecasts on. We started this report when we had about 2½ years worth of data. I think we now have 3 years worth of data.

You can certainly say that OK, we have to wait for a 4th year and then a 5th year and a 6th year. I would pose that 3 years worth of data is very impressive. We have never in U.S. history seen this improvement in how the Nation uses energy at a time of low energy prices. The only data that he could cite was 1982. Oil prices doubled in the early 1970's, they doubled again in the late 1970's, this is why energy intensity improved. He has to explain how it is that we had GDP go up and energy growth rates go down.

As I say, we have talked to EIA to understand how they do weather analysis. When you do the weather correction, I will be happy to go over this with you, because we used your numbers in our second case, it only gets you up to 1 percent. The fact is that over the last 3 years, weather-adjusted energy growth has been under half of what the weather-adjusted energy growth was in the previous 4 years.

Mr. HAKES. I would point out that the period you cover just coincidentally happens to be a period that was highly unusual historically in not having a heavy cold snap. It will be very interesting to look at the 2000 data where we obviously have had some months here where we have had heavy demands for heating oil and natural gas that we haven't seen for several years, and I think that will balance out our perspective quite a bit.

Mr. RYAN. That was going to be my last question. Mr. Romm, you said something that intrigued me. You made an assumption that Internet efficiencies are going to lead to less energy consumption. I would like to ask the other 2 gentlemen, Mr. Mills to start with, if the digital economy increases wealth, will it or will it not increase demand? If the digital economy makes us wealthier, won't this increase the demand for TVs, computers, cars, air travel, energy-producing products?

I represent the First Congressional District of Wisconsin. We produce the Chevy Tahoe, Suburban, medium-duty trucks, the Jeep Cherokee, the Wrangler, SUVs which are gas-guzzling vehicles. We are selling them like hot cakes. It is producing a lot of jobs where I live. Could you comment on that?

Mr. MILLS. Sure, and really there are two issues. The one issue is the wealth effect. I think there is no question that the digital economy is driving the wealth effect; and as Mr. Hakes has said, that is one of the complications. As you push the GDP up because of the lubrication, if you like, of the information economy, you get more purchases of SUVs, bigger houses, more renovations, more travel. In fact airline travel is up, driving is up, everything is up.

So the measures of efficiency are really misleading. Yes, there is so much more money which drives up the energy efficiency metric. The efficiency of driving measured in miles per dollar is better, but that doesn't matter. Driving is up.

The narrow point, of course, is that in the electric area, that as you keep adding this infrastructure, you get net more demand for electricity. Yes, it drives efficiencies in oil and transportation; yes, it drives efficiency, it controls lights better. But what we already see happening is that the growth rate is still a growth. So that the fundamental problem we had, and what I heard in this exchange just now between Mr. Hakes and Mr. Romm, is measuring the growth, in fact the reason we started our analysis.

Much of the energy discussion that is going on triggered by Kyoto is locked in a historical way of looking at our energy economy and has not fully accommodated the profound structural changes that the information age has brought. It specifically has not accommodated the demand side of it. Not because it is going to necessarily soar—I used the word "soar" because I believe that is a big increase over what would have been claimed to be zero. But for me, a growth equal to all the electricity of Central and South

America, that is soaring. But I use that phrase to point out this is an enormously important growth held against the desire to back out the coal industry.

So the answer to the question is I am very confident in saying that the wealth effect will keep driving electric growth, that I am confident the telecom sector will be the recipient.

Mr. RYAN. Mr. Hakes.

Mr. HAKES. Well, I think motor vehicles are a very interesting issue, because it is something we all deal with every day. Mr. Romm was pointing out that he sees some tendency here of improved intensity. We are still taking some pre-1988 vehicles off the road which does create some efficiency gains. But the fact is that new vehicles today are less efficient than ones from the early 1990's.

And what happened is we have had a lot of advanced technologies go into these vehicles, but we have had a lot of service requirements added on to the vehicles and those seem to be offsetting these new technologies. So where this is going to come from, it certainly is not showing up in the data at this point. The new vehicles today are less efficient than the new vehicles in the early 1990's.

Mr. ROMM. I this—I—the Internet can't affect the efficiency of vehicles, but it can affect how they are used. EIA in October—excuse me, in November, acknowledged that there has been a breakoff in the historical relationship between economic growth and transportation. It is very clear, although it is too early to say it is a trend, because it is only 1 or 2 years' data, that vehicle miles traveled in the last 2 years have slowed noticeably.

I won't repeat all of the ways that the Internet economy increases efficiency. I had the 30,000 word report on that subject. Compared to traditional companies, Internet firms require less square footage and under one-tenth of the building energy consumption per dollar of sales; companies are using the Internet to cut inventories 25 to 50 percent; and more or more firms like IBM and AT&T are reducing square footage for their mobile workers because of the Internet. Some firms are even auctioning off empty space on cargo trucks, I am sure you read about that, making the freight system more efficient.

So I believe that we have only scratched the surface in understanding all of the ways that the Internet is making the economy more efficient. But I put it to anyone else to explain what is going on in the economy, if the Internet isn't playing a role in making it more efficient.

Mr. RYAN. Those are interesting anecdotes, and I wonder if they encapsulate the whole picture. I was just wondering, you said 1 or 2 years of data doesn't indicate a trend in the automobile industry, but it does in your chart here. I find that to be quite a contradiction.

Mr. ROMM. I think 3 years worth of data in the entire U.S. economy suggests something big is going on. We titled our report a scenario, because I don't think anyone can testify that they know exactly what is going on. I mean I think we know enough to know that Mr. Mills has to be wrong, and that Mr. Hakes's forecasts are probably wrong. We have offered the best explanation for something big going on in the economy. I am not certain that—and we just want people to say gee, we better look at this because it is important.

Mr. RYAN. Well, I appreciate your candor.

Mr. HAKES. His saying that I am probably wrong is the nicest thing he has said all day.

Mr. RYAN. I will let Mr. Mills have the final say because of that salvo.

Mr. MILLS. Let me just end with a Lawrence Berkeley number to put the whole thing into perspective. I agree that the Internet drives efficiency. That is fine. But Lawrence Berkeley guys said that the commercial sector's use of computers: PCs, monitors, printers collectively in 1995 was 50 billion kilowatt hours. That was Lawrence Berkeley in 1995 for 1993 consumption of that whole class, not just PCs. Seven Internet years ago. My study says that that class of devices not just nor the Internet is up in the 300 to 400 billion kilowatt hour range. I would just submit to you that in that 7 Internet years, I don't think it is obvious that I am obviously wrong.

Mr. RYAN. Point taken.

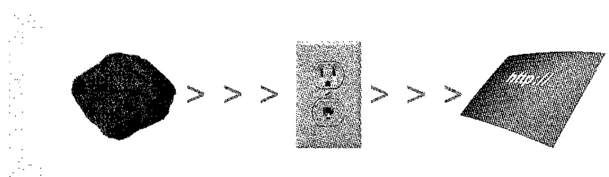
Gentlemen, thank you very much for very interesting testimony. This hearing is adjourned.

[Whereupon, at 12 noon, the subcommittee was adjourned.]

[Additional information submitted for the hearing record follows:]

THE INTERNET BEGINS WITH COAL

A PRELIMINARY EXPLORATION OF THE IMPACT OF THE INTERNET ON ELECTRICITY CONSUMPTION



GREENING
EARTH
SOCIETY

THE INTERNET BEGINS WITH COAL

A PRELIMINARY EXPLORATION OF THE IMPACT OF THE INTERNET ON ELECTRICITY CONSUMPTION

A GREEN POLICY PAPER

FOR

THE GREENING EARTH SOCIETY

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Contents

Preface

This study was catalyzed by a simple question posed by Greening Earth Society President, Fred Palmer: "What are the electricity implications of Intel's vision?" Intel's vision, featured in their current annual report, is that there will be one billion PCs (personal computers) on the World Wide Web in the near future. Seeking the answer to this question has been enormously revealing. My immediate answer to Fred Palmer's question was that a billion networked computers will consume a whole lot of kilowatt-hours. Perhaps this is obvious, but it turns out that nailing down the answer to this question revealed just how new the Internet industry is, and the paucity of relevant data collection methods, sources, and even standards.

Many people were helpful in directing me to appropriate data and providing important insights. The goal of this study, as the subtitle points out, is to explore in a preliminary way the electricity demand implications of all the kWh-consuming boxes that comprise the current and future Internet.

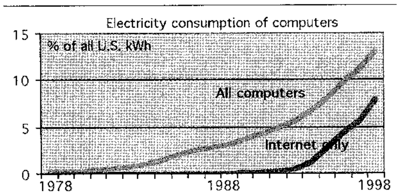
This study uses conservative approximations based on the best data and insights available, and within the scope and intent of this preliminary review. While it is clear that much more work can be and needs to be done in assembling data for the purpose of estimating (and forecasting) Internet electric demand, and in order to support the growing challenge for high reliability on the Internet, I am confident that the results presented here understate the true impact of the microprocessor and Internet revolution on the electric industry.

Executive Summary

Every measure of the Internet shows explosive growth in numbers of users, number of Web sites, bandwidth, and the billions of dollars in e-commerce. However, there is one measure that has been absent from consideration thus far—the quantity of electricity needed to keep the Net hot. Two decades ago, this metric, like all others for the Internet, didn't matter. The number of computers and microprocessor-based devices on the Internet was counted in the thousands. Now there are at least 100 million.

Preliminary calculations reveal that the electricity appetite of the equipment on the Internet by itself has grown from essentially nothing ten years ago to 8% of total U.S. electricity consumption today. In all likelihood, the Internet is responsible for one-half to two-thirds of all the growth in U.S. electricity demand in the last decade.

This analysis finds that for every 2,000 Kbytes of data moving on the Internet, the energy from a pound of



coal is needed to create the necessary kilowatt-hours.

When other uses of computers are included (many of which are linked directly and indirectly to the Internet economy), the share of all U.S. electricity consumed by computer-based microprocessors jumps to 13%.

The turmoil of de-regulation and competition for electric utilities has generated a scramble for structure and revenue in the emerging competitive era for electricity. Underlying much of this activity is the implicit and often explicit assumption that the business of providing electricity is largely saturated, a holdover from the old industrial age and out of place in the new info age.

Today, utilities and the orbit of regulators, experts and consultants in the electric industry preoccupy themselves with brand, identity, merger and "stranded cost" issues. Meanwhile, the Internet is building a tsunami of old-fashioned electron demand the likes of which utilities have not seen in half a century. All of this electric growth comes from the avalanche of equipment essential to create, access and operate the Internet.

Many are investing on the assumption that use of microprocessors and the Internet in particular has just begun. If so, then the implications for electric demand, reliability and utility architecture portend nothing less than a revolution. Every PC-type of microprocessor is like a light bulb energized by 50 to 100 watts; but unlike lights, many integrated circuits, are on all the time. In addition, on the Internet, demand begets more demand. The microprocessor and the Internet help explain why great strides and billions of dollars invested in traditional electric efficiency have not flattened overall electric load growth. Efficiency gains in lighting, motors and refrigeration—the anchor products of the first electric age—have been more than offset by the electric needs of the products of this next info-electric age.

Lost in the rhetoric of the power of bits to transform industries is a simple fact: every information technology device has two connections—one to move bits, another for power. Unlike the dominant stand-alone computers of a decade ago, networked computers generate demand for other devices. Every PC on the Internet is connected to a myriad of other electricity-consuming boxes in the network. The worlds of power stations and desktops seem far apart, but are connected by the power cord on the back of every box, and the power of geometric growth. The implications are clear in the arithmetic of the growth of PC use.

There are already 50 million PCs in households, another 150 million computers in businesses and 36 million more being sold every year. Not only do the desktops and the peripherals need electricity, but so do all the other microprocessor-based boxes in the network that push, amplify, transmit, receive, route and manage the bits. There are millions of these boxes too. Not only is electricity needed to operate these boxes, but they are fabricated by one of the most electric-intensive industries in the country. The $50 billion/year semiconductor industry is now the nation's largest manufacturing sector, surpassing the auto parts sector in 1995.

At the worldwide level, this analysis shows that Intel's vision of one billion PCs on the Internet represents a global kilowatt-hour demand equal to the entire output of the U.S. electric grid. The magnitude of the appetite of the Internet and information age for electricity has powerful implications for those in industry and policy makers. It now seems reasonable to forecast that in the foreseeable future, certainly within two decades, 30 to 50% of the nation's electric supply will be required to meet the direct and indirect needs of the Internet.

On top of the sheer need for power, the very nature of the Internet and information age creates an unprecedented demand for reliability. Keeping a gigawatt-based network "up" 24hours per day, 7 days a week sets a new standard for high power reliability. As a consequence, the architecture of the electric supply industry will be forced to adapt to the demands of the Internet. Indeed, reliability will take on an entirely new meaning for electric engineers in the decade to come. Furthermore, issues pertaining to electric price and supply, largely irrelevant two decades ago, now assume a central importance for the companies which comprise the networked part of the economy.

While environmentalists and utilities have been standing on desks to screw in light bulbs that save 10 watts here and 50 watts there, the owners of the desks have been plugging in PCs and peripherals that gobble 1,000 watts and more – and create an echo on the Internet requiring still more power. The debate over what sources of power we should encourage the market to use, which dominates the electric restructuring debate, will be buried by the market's info-age driven demand for lots of power, cheap power and increasingly reliable power. Over the next decade, issues like so-called "green" power, will lose urgency in the face of the overwhelming need for "smart" power tailored to meet the Internet economy.

1. Introduction: Electric Trends

At the turn of the last century, the development of the light bulb and electric motor ignited an explosion in electric demand. Myriad uses evolved for these two core electric devices and together they shaped much of the 20th century's economy. The market's appetite for lighting and all the other devices that used electric motors (industrial drive systems, pumps, refrigerators, air conditioners, etc.) was the driving force creating an entirely new infrastructure, the electric industry as we know it today.

As saturation was reached in new applications for the electric devices of the first electric age, growth in electricity use began to slow and track general growth in the economy and the number of buildings, people and related products.

Inevitably, technology progress began to substantially improve the efficiency of traditional electric devices–a trend spurred on by the energy price shocks of the 1970s. The drive for electric efficiency was accelerated by billions invested in national and state programs to implement "Demand Side Management." For most of the last two decades enormous utility and government conservation programs have been devoted to reducing the growth in electricity consumption. By its own accounting, the U.S. Evironmental Protection Agency has thousands of businesses engaged in the "Green Lights" programs where every participating company has effected extensive retrofits in lighting to reduce demand. EPA claims "billions saved" in lighting costs. Similar success has been claimed in electric motor programs. A new refrigerator uses 60% less electricity today than 20 years ago, air conditioning uses 33% less, and freezers 70% less.[1]

There is no doubt that great strides in electric efficiency were achieved over the past two decades, and especially over the past decade. Successful market penetration of efficiency measures should have, by all accounts, substantially stemmed if not stopped electricity demand growth. Indeed, some enthusiastic forecasters were certain that electric growth had finally ended.

"Because saturation levels for most major appliances are achieved, only minor increases in electricity consumption [will] occur."
— Energy Strategy, Union of Concerned Scientists, 1980.

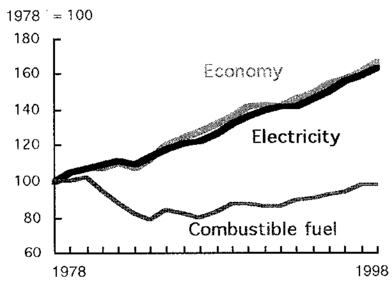
"We see electricity demand ratcheting downward over the medium and long term. ... The long-run supply curve for electricity is as flat as the Kansas horizon."
— Amory Lovins, interviewed in *Business Week*, July 23, 1984.

Yet, as illustrated in Figure 1, the demand for electricity over the past 20 years continued to grow with the booming economy, at a pace greater than the number of houses, people and commercial buildings. Some of this demand came from fuel switching – combustion-based devices and manufacturing processes giving way to electric devices and processes such as electric steel making, electric infrared paint drying, or laser welding, etc.

Nonetheless, the continued increase in demand was puzzling against a backdrop of extensive efforts to stifle load growth. Total demand rose by 750 billion kWh from 1978 to date, a growth of 65%. The resource implications of this trend continue to frustrate those who seek to reduce national energy use in general, and fossil fuel use in particular. Coal has supplied 60% of all growth in electric supply, and still supplies 57% of all electricity. Frustrated by the apparent failure to reduce electric demand, the U.S. Department of Energy (DOE), environmentalists and conservation advocates have proposed that efforts to improve efficiency be re-doubled.

It may be, however, that efficiency efforts have been effective. Instead, the putative 'problem' may be that load growth is coming from an entirely new area, the information economy and its tools. The energy needs of the information economy are almost entirely met with electricity. As Figure 1 illustrates, it is clear from the trends that the activities and technologies added to the economy over the past two decades are almost exclusively electricity-consuming, and furthermore have created a demand for electricity that has more than offset the savings achieved in efficiency programs.

Figure 1
Economic & Energy Trends 1978 - 1998



Source: DOE/EIA

Excludes transportation data: transportation is 99% oil-dominated; less than 0.1% of electricity is used in transportation. Thus including transportation energy use confuses and masks the economic relationship between energy, electricity and the non-transportation parts of the economy (industrial, commercial and residential sectors) which, in any case, comprise 90% of the GDP.

Over the past two decades, U.S. industrial output has increased 150%, and the commercial sector economic output increased by 250%. Against this growth, efficiency measures resulted in an absolute decline in the use of combustion fuels (principally gas and oil). Vastly greater efforts were devoted to improving electric efficiency over that time period, but total electricity use still rose in both sectors. Industrial use of combustible fuels declined by half a Quad (a Quad is 1,000 trillion BTUs, and is equivalent to 170 million barrels of oil), while electric use rose by over 2 Quads. In the commercial sector the use of combustible fuels declined by over 1 Quad, and electricity use grew by 8 Quads. These transformations in energy use are direct indicators of the transformations of equipment used in the two major sectors of the U.S. economy. (Similar trends also occurred in the residential sector.)[2]

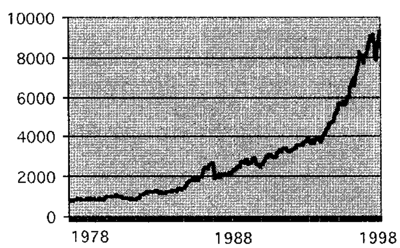
Forecasters no longer expect significant growth in electric use for lights, refrigerators, etc. for the next two decades even as the number of conventional appliances grows with the economy and population. But forecasters (including this one) expect net electric demand to keep rising anyway, just as it has for the past two decades. The basis for current forecasts appears to be rooted in the fact that the amount of electricity needed per dollar of GDP continues to be stubbornly linked. If one forecasts a rising GDP, one must also apparently forecast rising electric use.

National electricity use rose 3.5% in 1998. In an economy where news is dominated by information technology companies with double digit growth rates, 3.5% seems like a paltry figure. However, this growth is on top of the enormous base consumption of over three trillion kWh per year. For example, it would take the total output of all power plants in Taiwan to fuel last year's growth in U.S. demand. Continuing a 3.5% growth rate would nearly double total use in two decades. Whether such a growth rate continues, and what the related resource implications for the electric industry might be, depends entirely on what technologies have been driving electric demand in recent years. As we shall show, information technologies in general, and recently the Internet in particular, are driving not only Wall Street and the GDP, but also the nation's kWh growth.

2. Electricity, The Information Economy & The Internet

The Dow Jones Industrial Average has been adopted as the de facto reflection of the economy's growth and health.[5] An important issue for analysts and policy makers (and investors) is the extent to which basic technology factors are responsible for driving growth, and the DJI average. (See Figure 2.) For those in the energy supply business, it is not possible to undertake reasonable planning and forecasting without understanding the driving forces of economic growth.

Figure 2
The Dow Jones Industrial Average



Source: Dow Jones

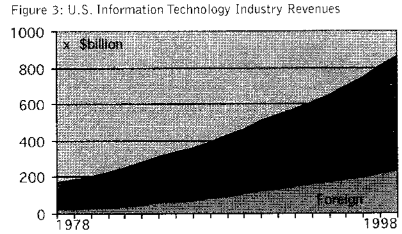
Analysts in practically every venue are writing about the "new" or "information" economy as the engine of growth. Any growing economy will drag along electric demand, with more office buildings, more lights, more homes, bigger homes, more appliances, etc. If the only connection between the "new" economy and electric growth is this so-called second order effect, then there's not much of a story on the electric supply side. Even as a growing economy boosts electric use, rising efficiencies will substantially offset any net growth, leaving the electric sector of the future holding a place as a vital primary commodity, but in a passive and secondary role.

However, careful examination of the fundamentals makes it clear that the 'old' electric sector is not in its twilight years, but instead has entered the beginning of a renaissance that arises from a stealth revolution in electric demand. The reasons are anchored in the same trends that analysts believe are largely responsible for driving the Dow and the economy.

The trends illustrated in Figure 3 contain the root driving force of the "new" economy. The production of the entire class of products and services broadly categorized as "information technologies" has grown from under $200 billion per year of revenues in 1978 to near $1 trillion/year today, and is climbing fast.

The information technology industry encompasses the telecommunications and the computer industry sectors. (Excluded from these data are revenues from other micro-processor-based businesses associated with games and 'smart' conventional equipment. Also excluded are revenues associated with e-commerce.) As Table 1 shows, while U.S. telecom revenues have grown $244 billion over the past two decades, the computer-related part of the information economy has grown by almost twice as much: a growth of $452 billion over the past two decades. The revenues from computer equipment sales alone exceed the growth in all telecom revenues.[6]

Figure 3: U.S. Information Technology Industry Revenues



Source: Information Technology Industry Council

The implications of this kind of growth go beyond Wall Street. The digital revolution is directly relevant to the electricity business. Certainly, as a minimum, one would expect that industrial and commercial activities entailing $1 trillion in revenues in an $8 trillion economy would be responsible for a significant share of total U.S. electricity consumption. This broad 1-to-8 ratio implies, all other things being equal, that the information economy might consume at least 12.5% of all electricity supply. But that ratio would only apply if the information economy were as dependent on electricity as the economy at large. As we shall see, this is far from the case. The information economy is *more* dependent on electricity than the economy at large.

Table 1
Information Technology Industry Revenues (x$billion)

		1978	1998	Growth
Telecom	**Total**	**92**	**336**	**244**
	Equipment	31	93	62
	Services	61	243	182
Computers	**Total**	**73**	**525**	**452**
	Equipment	56	301	245
	Services	17	224	207

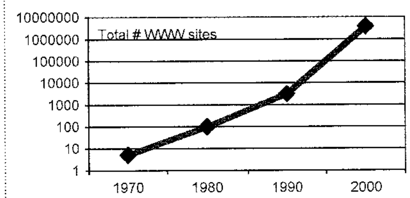
Source: Information Technology Industry Council

The Internet is widely believed to be the underlying driving force behind the explosive growth in the overall information economy. Certainly the astounding growth in the computer industry, and the very recent astronomical rise in the use of the Internet, have been responsible for the lion's share of the recent surge in "technology" stocks and so-called dot-com companies. The growth of the Internet is so recent and rapid that many of the implications have yet to be understood or fully evaluated.

Two decades ago, the number of Web sites was counted in the hundreds; a decade ago it was still a few thousand. Today there are millions. (See Figure 4.) While global activity is picking up rapidly, the majority of the Web sites, traffic and equipment are in the United States.[5] The U.S. share of the Internet is estimated to range from 50% to 75%. The future will see the U.S. share of total Web traffic and architecture shrink, but the growth in the absolute size of the U.S. market shows no signs of slowing.

The data shown in Figure 4 does not count, although it is reflective of, the total amount of Web traffic in terms of number of users, or in terms of the gigabytes of digital traffic. Both of these indicators are difficult to measure and indeed are subject to enormous uncertainties. Measuring Web traffic in terms of users is an infant industry and fraught with confusion and misunderstanding.[6] User data are vital for advertisers and businesses in order to attach financial value to Web usage. The most recent data suggest that nearly 100 million people now access the Internet, with 60 million classified as "active". (Nielsen/NetRatings) However, in order to evaluate the electric implications, it is not the use of Net that is a critical variable, but the equipment that is needed to access and operate the network.

Figure 4: Total number of WWW sites



Source: Hobbes' Internet Timeline at www.isoc.com & IEEE Spectrum

The kind of growth experienced over the past decade in digital traffic, product manufacturing, start-up companies and corporate revenues, all defy the ability of business writers to find new adjectives. All of this growth points to more than increased traffic on wires, fibers and the airwaves. It is a direct indication of dramatic increases in the fabrication and use of thousands and millions of devices, many of which did not even exist 20 years ago. From a supply side perspective, the hidden story is the extent to which electric demand is impacted by the furious pace of building and installing equipment to operate all the products that comprise the Internet.

The implications of the Internet for the electric industry are likely to reflect the Internet's impact on the telecom industry. The Internet has already dragged into its vortex the architecture of the telecom industry. Not only is convergence underway at the corporate level in terms of mergers, acquisitions and alliances, but at the functional level forecasts now show that data traffic which was a fraction of a percent of total telecom traffic ten years ago will account for 50% of all telecom traffic within two years. Will the transition from voice-dominated to data-dominated traffic on telecom wire lines be emulated by a shift from dumb electron to smart electron traffic on power lines?

3. The Kilowatt-hour Appetite of the Internet

It is common to hear about electric companies with telecommunications activities, with improved customer billing or smart load control. Many have alliances to route and maintain telecom cables. Utilities collectively own 17,000 route-miles of fiber optics and 40,000 route miles of wire cables. Some are leasing high-power transmission towers to wireless telecom tower companies. One has even transformed from a provider of hard power into a purveyor of bits by selling all of its generating assets and operating instead a national optical fiber information backbone. Many, if not most, electric utilities have telecommunications subsidiaries; rural cooperatives have been in telecom for decades.

The connection between the new Internet industry and the old kilowatt-hour industry begins with an obvious fact: Every piece of equipment that comprises the information economy has two connections—one for bits, and one for kilowatt-hours. Certainly designers of PCs, Web servers and data routers know that their boxes must be plugged into an outlet. But in the course of extensive interviews and discussions with dozens of experts in Internet-related companies, it was abundantly clear that they had not considered the aggregate kWh impact of their work. Understandably, just meeting the Internet's voracious appetite is a full-time job. Understandable.

The new age of electricity, which essentially began a decade ago and is now only in its infancy, is being driven by the electric appetite of microprocessors and integrated circuits housed in the millions of different kinds of boxes that constitute the information age's tools. Just as the use of light bulbs and motors drove electric demand at the dawn of the last century, so too will electric demand today follow the market's appetite for info age devices.

Interestingly, the average light bulb has about the same power requirement as the average integrated circuit. There are a number of important differences between a typical 60 watt light bulb and a 60 watt integrated circuit (IC) that bear on the aggregate electric demand from info age boxes. These characteristics, summarized below, illustrate why it is that every 60 watt IC in an info age box can easily represent 1,000 watts or more of total demand.

- Many integrated circuits supporting the Internet stay turned on 24-by-7 (24 hours a day, 7 days a week). As the retail and banking use of the Internet grows for people expect that round-the-clock operation of millions more microprocessors will come into play.
- While technology progress for light bulbs will result in increasingly lower wattage, technology progress is driving up the wattage of the average IC.
- While most light bulbs operate alone, an IC operates in a box connected to a large number of related kWh-using devices and equipment both inside the info box, and to other boxes on the desktop.
- A typical light bulb is a "stand alone" device; it produces no echo of demand except for minor, cooling needs in the summer. Meanwhile, an IC inside a PC on the Internet creates the need for a myriad of other PC-type devices in the network.

It is old news that the proliferation of PCs in commercial buildings has started to use measurable amounts of electricity. The DOE undertook a survey of business PC use in 1992 and then again in 1995. They found 30 million PCs in business use in 1992, increasing to 43 million in 1995 – a rise of 13 million installed PCs in just a few years.[7] They further estimated that all of these PCs used about 98 billion kWh per year, or about 13% of total commercial sector electric consumption. (This was about 4% of total U.S. electric use in 1995.)

As significant as these results are, they are only the tip of the iceberg, for a variety of reasons:

1. PC use in businesses continues to explode – industry data shows that growth since 1995 likely exceeds that experienced in the three years prior to 1995.

2. PCs are used in many venues other than businesses such as homes and schools.

3. There are many other types of computers in use that are not classified as PCs, including so-called "minis" and mainframes, not to mention an enormous and growing array of PC-type devices.

4. Perhaps most importantly, once a PC is connected to the Internet, the network drives demand for other PC-type devices. A computer on a network is the visible manifestation of many other devices in the network. And networks are a primary driving force increasing the demand, number and types of PCs and PC-type devices.

Thus the electricity needs of the Internet itself, rather than PCs in general, is not only more interesting but more important to understand. The Internet not only plays a central role in driving PC use, but the unique character of the Internet presents additional implications regarding power use; keeping a network "up" is much more challenging than keeping a group of discrete devices "up". For conventional electric devices and appliances, determining aggregate electric demand is relatively straightforward. The situation with the Internet is quite unlike its historic analog.

During the growth of the first electric age, companies like GE and Westinghouse were not only building the electricity-using 'boxes' and devices that consumers and businesses purchased, but they were also intimately involved with the electric supply industry. Indeed, at the dawn of the first electric age, companies were engaged in the entire electric food chain, from making light bulbs, electric motors, or electric trolleys, to making the distribution system, as well as the power plants. (The now three-quarter century old Public Utilities Holding Company Act, which broke up the vertically integrated monopolies, is on the table in Congress for repeal.)

Today, there is no business structure analogous to the first electric age. Even though the boxes manufactured by the likes of Intel, Amdal, IBM, Cisco or Compaq are primary engines of electric growth, such companies have little interest or involvement in the electric infrastructure.[8] Instead they are pre-occupied with the challenges presented by the chaotic growth and fierce competitive pressures of the Internet industry.

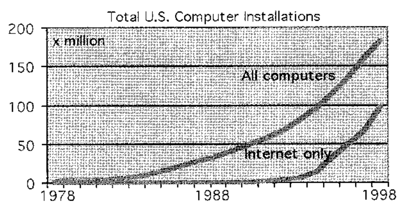
Whether they provide microprocessors, PCs, routers, Internet Service, or data networks, manufacturers are focused on the enormous challenge of meeting the million-fold growth in Internet traffic. From an electric supply perspective, all of this activity has resulted in an unprecedented number of "boxes" being plugged in that need power, boxes that never before existed – indeed most didn't exist five or ten years ago – and that constitute a unique new form of electric demand.

The range of devices and appliances that employ integrated circuits has increased so rapidly that data tracking systems put in place in the early 1980s have not adapted to the market. For example, data tracking the total inventory of computers includes so-called micros (largely PCs), minis, and mainframes. But the data series do not include Web TVs (which are essentially PCs), the entire range of information appliances (many of which are also small PCs), or home game systems (which are increasingly a new class of computer with the newest offering Internet access).[9] These few examples already number in the millions of units manufactured and installed. Also excluded from the data tracking are routers, which are microprocessor-based devices used to route traffic on networks, especially the Internet. Router sales a decade ago were practically non-existent. The router market is now, by itself, a multi-billion dollar industry. In 1998, there were over two million routers shipped globally, and almost one million in the U.S. alone.[10]

Figure 5 contains the essence of the entire electric story for the Internet. The total number of computers installed in the United States has grown from just over two million in 1978 to nearly 200 million today. The number of those computers dedicated to feeding bits into, routing bits around, and drawing bits off the Internet has exploded from a few thousand a decade ago to at least 100 million today.

It almost doesn't matter what assumptions are made about the individual electric needs of that many kilowatt-hour-consuming boxes. With 100 million and growing, and many (soon a majority), operating 24 hours-a-day, 7 days-a-week ("24 by 7" in Internet parlance), the aggregate electric demand has to be substantial.

Figure 5 : Growth in the use of computers overall & those dedicated to the Internet



Source: Information Technology Industry Council & MM&A Inc (Note: The top line "all computers" does not include such microprocessor-based devices as routers. The "Internet only" line includes routers. The total router universe of over 2 million machines installed, while significant, does not change the general relations illustrated. Furthermore, the router market was only in the tens of thousands a decade ago.

Estimating Kilowatt-hour Demand

In principle, calculating the aggregate electric appetite of the Internet involves only two steps:

- Estimating the total number of boxes on the Internet, and
- Estimating the average annual kWh use for a typical IC-based box.

There is no single data source that tracks the number of devices or boxes installed in the architecture of the Internet. Nonetheless, it is possible to make a reasonable approximation of the Internet universe using a variety of sources.

In simplistic terms, there are four distinct categories of boxes using electricity and which, in effect, comprise the architecture of the Internet.

1. The devices that consumers and businesses use to access the Internet, this is currently dominated by PCs.

2. The devices that make the Internet possible: routers, amplifiers, transmitters, switches, etc.

3. The devices that are used to feed information into the Internet – the Web servers and computers that are the heart of so-called "dot-com" companies, retail Web pages, educational sites, corporate sites, etc.

4. The companies (factories) that manufacture all of the above.

The focus of this analysis is on electric consumption in the United States (and only on those devices on the Internet). The global implications of Internet electric use are also interesting, and will be increasingly so, but the U.S. is the source of the primary traffic and equipment use on the Internet today. And, in any case, the first level of interest in this question is driven by the resource implications for U.S. policy makers and energy supply companies.

The methodology used here leads to an estimate of the total amount of hardware on the Internet in 1998. This figure can be used to extrapolate, backward, the growth in the Internet architecture. A time-line can be assembled that reasonable echoes the growth rate in digital traffic on the Internet.

End-use devices – accessing the Internet

PCs constitute the primary end-use devices, the hardware people use to access the Internet. Not only has the declining price of PCs been driving the growth of this industry, but so too has the growing value of the Internet. Not even a decade ago, it was a rare household with a PC. The share of households with PCs now exceeds 50%, representing over 50 million residential PCs. Of those, the estimated number "on-line" ranges from 15 million up. *Money* magazine estimates that at least 5 million people use the Internet for investment alone. Furthermore, there are already (according to Intel) over 17 million homes with two or more PCs, and there will be 28 million with multiple PCs in five years. This explains the driving force behind Intel's recent introduction of yet another microprocessor-based box; the easy-to-use home (or small business) networking system to link multiple PCs and peripherals.

PCs are also proliferating in the business environment, as noted earlier. The most recent Energy Information Administration survey found 43 million PCs in business in 1995 (split almost equally between large and small businesses). Given annual sales figures of 36 million units per year, of which only half go into consumer markets, there is no doubt that the current business inventory is dramatically higher, even accounting for replacement and attrition.

The typical PC on a desktop is rarely a solo, or stand-alone device, especially in homes. In addition to the PC and the monitor, one finds an array of devices including printers, scanners, drives, modems and so on. The aggregate peak electric needs of the collection of devices can exceed 1,000 Watts, sometimes even 2,000 Watts.

In order to calculate the typical annual electric needs of a PC connected to the Internet, we assume that the PC and its peripherals are only on when the Internet is being accessed. This clearly understates actual electric use since it is a rare user who executes a full shutdown of all systems at the end of every session. Indeed, the evidence increasingly points to virtually continual operation. According to recent surveys by Forrestor Research, the average time on-line for home users is 12.1 hours per week.

The combination of the above facts yields something on the order of 1,000 kWh per year per home PC accessing the Internet. For PCs used in designated "home offices," we assume twice the Internet utilization – 20 hours per week. Presumably home office workers are telecommuters, enabled by the Internet. PCs in office buildings using the Internet are assumed to be on line only as often as those at home, 12 hours per week. And finally, it is assumed for electric calculation purposes, that office PCs are also turned completely off when the Internet is not being accessed. All of these assumptions significantly underestimate actual use.

A note on non-PC Internet connectivity

There are many other ways to access the Internet, and analysts believe that the non-PC or "information appliance" access of the Internet will shortly dominate the market. There are several million people already using a Web-TV, part of the growing category called Internet appliances. Then, too, one increasingly sees the emergance of new or enhanced devices ranging from GE's Internet microwave oven, Electrolux's Internet refrigerator, Internet–enabled vending machines, and an enormous category of Internet-linked manufacturing equipment. Finally, there are Internet-enabled telephones (both wireless and wired), and PDA's (personal digital assistants) of which the Palm Pilot™ has been the most successful.

It would be reasonable to include the electricity consuming aspects of all of the above devices, including the kWh for manufacturing the devices and the disposable batteries, as well as the electricity for recharging batteries. With product volumes already in the tens of millions, the numbers may well be significant. But current data suggest that PCs are the dominant portal to the Internet. Thus, this analysis does not include any of the electricity used by any of the non-PC Internet access devices. This is, however, a category that will be critical for forecasting purposes.

Network devices – enabling the Internet

It takes kilowatt-hours to transport digital bits around, just as it takes gasoline to move books. While the efficiency of transporting bits is higher than transporting paper, the quantity of bits moved and the growth rates are astronomically greater.

The Internet is, by definition, a network. The network is not a mass of dumb wires, cables and optical fibers. Rather the network is an enormously complex, some say "organic," array of devices and communications media that permit the efficient flow of literally thousands of gigabytes of data each month. An indication of the growth in the network is evident in all aspects of the communications industry.

A decade ago, voice traffic comprised 99% of the wire line network for telephones. Data traffic reached

20% of the conventional telecommunications network only three years ago, according to Dataquest. By the year 2000, data traffic will consume 50% of the conventional telecom network, and will likely consume 70% of the network three years later. The companies that manufacture the switches, and routers in particular, that move data traffic have grown from literally non-existent a decade ago to multi-billion dollar firms in the past half-decade.

From an electric consumption perspective, there has been an unprecedented proliferation in devices to manage, move, route, store, protect and amplify data. In addition to the growth, the movement and management of data entails an order of magnitude, or more, increase in power requirements for each box compared to the equipment needed to manage and route old-fashioned voice-only traffic. Thus, not only has the quantity of traffic on networks increased, but also its character has changed from low-bandwidth low-power voice traffic, to high-bandwidth high-power data traffic.

There are three general areas of the network: telephone wires, cables, and wireless. For the purposes of this preliminary analysis, and to continue with the goal of conservatively estimating the actual total electric impacts, we considered the electric use of only two broad categories of network devices:

a) The major telecom data switches (so-called central offices) devoted to data traffic.

b) The primary data routers used in wide array networks and the Internet.

Omitted from the calculation are the kilowatt-hours associated with cable modems, cable amplifiers, nodes and hubs, digital switches and related peripheral devices. Also omitted are the parts of the cellular and digital wireless networks that are used for Internet traffic and thus the amplifiers and related equipment to receive, filter, route and broadcast wireless data. As traffic volume rises, new types of equipment are needed to eliminate noise, ensuring data integrity and clarity. An entirely new class of devices has emerged, for example, cryogenically-cooled superconductor-based filters for use at digital wireless base stations.[11] These sources of electric demand will become significant in the future as wireless traffic continues to grow.

As the use of wireless devices to access the Internet grows, one expects to see the geographic reach of the wireless nodes shrink into ever smaller cells. Smaller cells will increase the number of total devices. Cells will shrink down to wireless networks in offices where each cell encompasses hundreds of feet at most, linked to other cells covering a thousand feet, and so on. The total number of wireless nodes will explode into the hundreds of thousands, even millions – all requiring electrical power.

When it comes to moving the gigabits of data on the Internet and in wide area networks, Cisco is the big player in the router market. An estimated 80% of the traffic on the Internet moves through Cisco routes. The Cisco 7500 series can handle 400 Mbs of Web traffic and their next generation Cisco 12000 series will handle 2.5 Gbs of traffic. While the power demands of both devices are essentially the same (more bits per kilowatt-hour), the Internet's appetite for data traffic makes the only relevant data set the total number of routers installed on the system. In the case of the average electric load for routers, the analysis uses 0.5 kW and 1 kW as the baseline for two broad (simplistic) classes of routers. Note that the backbone routers cited above are 1.5 kW machines. It is assumed that routers operate 24-by-7.

Only three years ago, there were fewer than 300,000 routers per year shipped into the North American market. The market exceeds one million routers this year and is forecast by Dataquest to exceed two million per year by 2002. While these are very big numbers from an architecture and electric use perspective, from a fiscal perspective it is easy to see why investors are fascinated with router companies like Cisco, Cabletron, Nortel and others. They are part of a $4 billion/year equipment market now, and will break $6 billion/year in a few years even as the average cost per router keeps dropping.[12]

Devices for the Internet's Information Source – supplying the Internet

In addition to creating new demand for electricity, the Internet is creating a new nomenclature in the English language. "You've got mail," is already iconic. AOL reports that their system "lights up" after school when kids go on-line to chat and check e-mail. Behind the scenes of the information providers is an entirely new class of devices with new nomenclature too. The servers, computers, modem, routers, switches, back-up devices and Internet Service Providers have created the notion of a "Web farm." A Web farm utilizes hundreds of servers in a complex network designed to handle the gigabits of flowing information, often along with minicomputers and even (in the case of major dot-com companies) mainframes. A big "farm" with its infrastructure can reach into the megawatt level of power. The new info world will see thousands of these farms.

The Internet's driving force is the ease with which information can be obtained and business transacted. This means of course that there must be a provider of such information. The Web pages and so-called "dot-com" companies comprise the information input into the Internet. The kinds of information sources range from the trivial (personal Web pages) to the monumental (Amazon.com, Schwab and the Library of Congress). All of them have in common the need for servers to host and house the information and serve the requests coming in from the Internet.

Feeding the system at the low-cost end are "server appliances" which are forecast to be 19% of the server market in three years. Current shipments of server appliances are $500 million per year – forecast to be $13 billion/yr by 2002. At an average of $2000 per machine, this yields a current market expansion rate of 250,000 machines per year, reaching 6 million per year by 2002 – and that's for 19% of the market. Note that the total number of Web sites, which has grown exponentially, reflects, but is not the same as, the number of boxes serving as the home for the site. There can be many small sites per server.

As the dot-com competition heats up and mainstream retailers enter the digital age, the recent model of Barnes & Noble following Amazon is increasingly typical. In addition, traditional companies from American Express, to Federal Express, banks, insurers and manufacturers, increasingly move traffic into the digital age with their own main-frames and superservers. Charles Schwab, with the world's most active encrypted Web site, has just installed its third mainframe. Many will follow Schwab and others.

At the "heavy iron" end of the server market, one bellwether for Internet-driven demand for computing power to feed the Net is mainframe sales figures. First, despite the common myth that PCs put mainframes out of business, there are 60,000 more mainframes in the U.S. today compared to ten years ago. Second, with the current need for processing power to handle millions of "hits", the sale of mainframes has hit a new renaissance. Last year, when IBM brought its S/390 mainframe computer into the market, they sold 1,000 in the first 100 days.[13] These beasts run $1 million to $3 million each and, with infrastructure, can consume a megawatt. IBM has just announced its latest mainframe, which in reflection of the market demand, is named the S/390 Parallel Enterprise Server.[14] It's goal, according to IBM, is to provide "the capacity, bandwidth, and flexibility that customers need to run an integrated e-business."

In order to arrive at a preliminary estimate of the total electric demand for the server side of the business, we divided the market (again simplistically) into two categories: major "dot-com" companies with superservers, and everybody else using relatively small server appliances. Here again, conservative assumptions were used regarding average demand for each site. But all of the sites were assumed to be up and running 24-by-7.

Manufacturing all of the above devices – building the Internet

The business of manufacturing the boxes that fit into the three categories is, by itself, one of the major electricity consuming parts of the economy. It is reasonable to assign the electricity requirements of this industry to the share of all boxes manufactured for the Internet. According to Forrester Research, over 80% of all computers now fabricated for the consumer market go onto the Internet.

There are over 36 million PC-type boxes shipped each year in the United States.[15] Manufacturing integrated circuits, and all the related microprocessors and devices, is one of the most electric intensive industries in the nation. It takes about 9 kilowatt-hours per square inch to make an integrated circuit.[16] Fabrication and shipment of microprocessors numbers in the hundreds of billions per year. Perhaps not surprisingly, the semiconductor industry is now the largest manufacturing industry in the United States, surpassing motor vehicle parts and accessories in 1994. Only a decade ago, the semiconductor industry was the 17th largest U.S. industry.[17]

The microprocessor fabrication plants, so-called "fab" plants, number in the several hundreds in the U.S. Each represents an electric load in the 10 to 15 MW range, rivaling the scale and electric intensity of a steel mill. Already, fab plants alone require nearly 10 billion kWh of electricity per year.[18] This demand approaches 0.5% of all U.S. electricity production. When the balance of the industry directly linked to fab plants is included, the amount of electricity allocated to fabricating integrated circuits and microprocessors alone (without regard to the rest of the boxes) approaches 1% of the total U.S supply.

The fab plants are supplied and supported by an entirely new infrastructure industry – the semiconductor equipment and materials industries (with their own trade association, SEMI). North American production of equipment to supply the hardware that makes fab plants work is over $15 billion now, up from $5.3 billion in 1993. The materials supply side for fab plants is an industry that is over $8 billion in the U.S. alone (specialty gases, chemicals, etc.). And the software and services devoted exclusively to supporting fab plants make up a $14 billion industry, half of which is in the U.S.[19]

Considering the above facts, it makes sense that the amount of electricity used to make a single PC is about 2,300 kWh, according to a study by the Microelectronics and Computer Technology Corporation in 1993.[20] For the purposes of this analysis, we used an average figure of 1,500 kWh to fabricate a PC in order to allow for some improvements in manufacturing efficiency since 1993. Furthermore, we assumed that the same amount of electricity is needed to make all devices on the Internet, including the larger routers and multiple processor devices (undoubtedly an underestimate of actual fabrication energy costs). Only devices fabricated for use on the Internet are counted i.e., stand-alone PCs and similar devices are not counted. These assumptions will serve to underestimate the total electricity allocated each year to manufacturing boxes to feed the growing Internet.

Summary Table: 1998 Electricity Use for the Internet
The following table summarizes the results of the research and calculations used to estimate the approximate total electric requirements to power the Internet. As explained above, only major classes of devices have been included in this preliminary analysis. Excluded are PCs for non-Internet use, Internet appliances such as Web TVs, most telecom equipment, as well as the entire class of data switches used in networks. We did include the proportion of telecom central office switches devoted to data traffic. The detailed assumptions and data sources for these calculations are contained in the extended table at the end of this document.

The estimated total amount of electricity required by the Internet is compared, at the bottom of the table, to the nation's total electricity for all purposes and to the total growth in U.S. electricity supply.

The results show that the approximately 100 million boxes on the Internet consume 8% of the total U.S. electric supply. (Note again that this does not count all other uses for computers.) This is more electricity than is consumed by the entire metal processing industry (including steel and aluminum), or more than is used collectively by all industries involved in the chemical, petroleum and paper production. By itself, the Internet is already one of the biggest, albeit widely dispersed, parts of the electric-consuming infrastructure of the U.S. economy. Unlike other sectors of the economy, the infrastructure of the Internet is growing monthly at double-digit rates.

A reasonable "sanity" check of this estimate is available in the 1995 report from the U.S. Department of Energy's Energy Information Administration survey of PC use in commercial buildings.[21] Commercial buildings will under represent the total universe of Internet-related in commercial buildings. Nonetheless, the EIA survey should provide a value that would be in the same order of magnitude.

According to the EIA survey, the 43 million PCs in commercial buildings used 98 billion kWh in 1995, or about 2.2 billion kWh per million PCs. This analysis finds an Internet universe at the end of 1998 of about 100 million PC-type devices using 290 billion kWh, or

Table 2: Summary of analysis.
Note: The table includes only devices used on the Internet. PCs for other uses and other types of information appliances (e.g., WebTV) are not counted. For details, see section 7.

Category of Internet 'Boxes'	Estimated Total Number	Estimated kWh/yr (billions)	Types of BOXES
Electricity in manufacturing	**20 million/yr**	29	Manufacturing the integrated circuits and all related components for PCs, routers, servers. (Only for WWW)
User boxes	17	25	PCs used in homes & businesses.
Routing boxes	1	2	Devices used to route data traffic.
Supply boxes	2	2	Servers for sites & dot-com companies.
Using boxes to access the Net	**81 million**	75	Operating PCs in business & homes for accessing the Internet.
Home	41	31	PCs at home office & home offices.
Office	40	44	PCs in offices; includes some WAN.
Boxes feeding info into Net	**4 million**	124	Hosts & dot-com companies using servers, server appliances.
Boxes moving bits on Net	**3 million**	67	Using routers & 40% of telecom central offices.
TOTAL	**108 million**	295	
Growth in Internet kWh		285 kwh	1988 - 1998
Growth in total U.S. electric		700 kwh	1988 - 1998
Internet share of all growth in kWh		40%	1988 - 1998
Internet share of ALL U.S. kWh		8%	U.S. 3,300 billion kWh total.

computers (as a result, home PCs and most routers and related switching devices won't be counted). In addition, a 1995 survey will account for substantially fewer computers than exist today. The growth from 1992 to 1995 in the EIA survey was from 30 million to 43 million PCs about 2.9 billion kWh per million PCs. The close correspondence between these two surveys makes sense when one considers the higher duty cycles for the Internet compared to many office computers (many Internet devices run 24-by-7). The higher results for this analysis are also consistent with our inclusion of the electric requirements to fabricate (not just operate) the PCs.

Finally, as a further check on the 100 million Internet devices derived here, the total universe of all computers in the U.S. inventory at the end of 1998 was just over 200 million. Given the growth in Internet use and the fact that the total U.S. inventory was 80 million computers in 1993, the general results obtained here appear reasonable in terms of total allocation to the Internet.

The results derived in this analysis suggest an overall approximate relationship of 3,000 kWh/year per PC-type of device on the Internet. This result is consistent with the general proposition that an average PC-type device requires about a kilowatt (this would include relevent desktop and network peripherals) and operates on average (across all types of devices) 3,000 hours per year. The 3,000 hours per year is the rough average of the 650 hours a year typical for a home PC on the Internet, compared to the 8,760 hours per year for a 24-by-7 Internet routing or serving device.

The fact that hundreds of millions of microprocessors in over 100 million boxes would consume so much electricity makes sense. However, the growth is so recent and so rapid that the result is surprising. Journalists visit supercomputer centers and wax poetic about at the thousands of parallel processors and memory devices used to provide a thousand-fold power over a desktop machine. They only note the need for a dedicated several-megawatt power source to power and cool such info beasts. But thousands of processors take the same power whether sitting in parallel with each other in the same box (a supercomputer) or linked in parallel and distributed across America in thousands of boxes in many homes and businesses.

As revealing as these conclusions are regarding the current total electric appetite of the Internet, it is equally important to gain a picture of the growth rate of the Internet's kilowatt-hour demand. The trend will reveal much about the near future, with potentially important implications for electric supply, price and reliability.

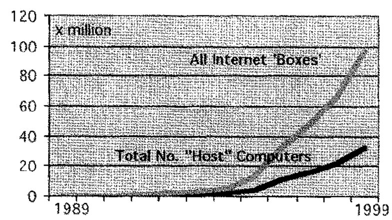
Historic growth in Internet electric use

The 1998 estimated electricity consumption and total Internet box count can be used as a benchmark to extrapolate backward in time to reveal the growth in the Internet's use of devices and kilowatt-hours. The key to this reverse extrapolation is a reliable historic record of Internet-connected devices. Much of the historic data for the Internet is inaccurate and inconsistent. The number of users is determined by still relatively unreliable surveys, most of which only go back a few years at most. The number of Web sites and domain names is interesting and broadly indicative of the traffic on the Internet in commercial terms or data bandwidth terms, but it is not a useful metric for counting hardware on the Internet. Multiple Web sites and domain names can be located on individual servers.

The most reliable single, hardware-based indicator of Internet activity in terms of specific pieces of hardware connected to the network is the tracking of total number of "hosts."[22] A host is a specific computer with a registered "ip address." The total number of hosts has been accurately tracked since 1969 when there were four host computers. In 1979 there were 188. By 1989 there were 80,000. At the end of 1998 there were over 40 million. Since the universe of hosts includes the World Wide Web, we have allocated 70% of the hosts to the U.S. market. The year-end 1998 benchmark of 30 million hosts on the Internet, compared to a total universe of 100 million PC-related devices, provides a ratio of total Internet devices to hosts. This ratio can be used to approximate the historic growth of Internet devices by using historic host data.

Figure 6 plots the historic record of total number of host computers in the U.S. on the Internet. The ratio derived from this study for the 1998 year-end status, about 3 total Internet devices per host computer, is also plotted, and is shown as the line for "All Internet Boxes."[23]

Figure 6: Growth in the host computers & inferred total Internet devices

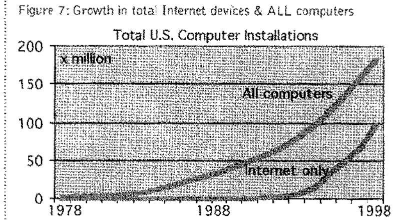


Source: Information Technology Industry Council, Hobbe's Internet Timeline, & MM&A Inc

The relationship developed in Figure 6 can then be integrated with another relatively reliable data series – the total universe of installed computers. Note again that the data for "all" computers does not count devices such as routers, which are included in the Internet count. This omission on the part of the data collection source is a result of the fact that routers were a virtually non-existent device compared to computers and PCs a decade ago. The annual growth in the inventory of routers in the U.S. has increased from 300,000 added in 1995 to one million added last year. Thus, the "all" computer series somewhat understates the current total inventory on the order of several million boxes. The error would not be visible on this data series several years ago, and is only relevant to forward, not reverse, extrapolations.

Figure 7 plots the total derived inventory of all Internet computers with the total inventory of ALL computers. Since the Internet is widely credited as the primary driving force for the growth and use in computers over the past five years or so, the relationship shown in Figure 10 makes sense. In fact, average annual shipments of all computers in the late 1980s and through 1991 ranged from 9 to 10 million units per year. Annual shipments started rising exponentially in 1992, reaching 23 million in 1995 and 36 million last year. In short, the Internet is the primary force pushing up the total inventory.

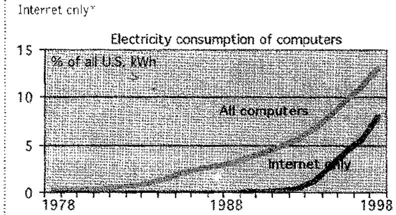
Figure 7: Growth in total Internet devices & ALL computers



In order to illustrate the historic growth in electricity used by computers on the Internet in particular, we apply the average electric use per million computers used on the Internet for each year. Figure 8 illustrates this trend in Internet electricity use, and further compares it to the use of electricity by all computers (including those on the Internet).[24]

The electricity consumption of non-Internet computers is derived from the inventory data of the Information Technology Industry Council, with relevant annual electric use assigned to the three broad categories of computers in the data set: micros (includes PCs), minis, and mainframes. (See Table 3.)

Figure 8: Computer share of all kWh used: All computers & Internet only[v]



Estimated annual electric consumption for U.S. computers using annual inventory from ITI Data Book, and the following assumptions for each device type: 90% micros run 4hr/day 300 days @ 1kW incl. peripherals, 10% run 24-7; 80% of mini's 4hr/day and 20% 24-7 @ avg. 3 kW; mainframes, all 24-7 @ avg. 10 kW. Total and compared to total annual U.S. kWh use from DOE/EIA Annual Energy Review. Note the approximations used here yield a 1995 result of 8% of all U.S. kWh for total inventory of 113 million computers; DOE/EIA 1995 survey of computers in commercial building (i.e. not total universe) found 43 million consuming 4% of national electric supply.

Table 3: Growth and inventory of computers in the U.S.

Year	Total		Micros		Minis		Mainframes	
	Ships	Install	Ships	Install	Ships	Install	Ships	Install
1989	8,700	42,000	8,500	40,200	228	1,550	12	97
1998	36,000	190,000	35,000	170,000	265	3,200	12	160

Source: Information Technology Industry Council
Micros are classified as computers costing $1,000 to $24,999 (although the lower end dominates this category), minis from $25,000 to $349,999, and mainframes over $350,000.

Bits/kWh: The Fuel Economy of the Internet
Having derived a reasonable approximation of the total quantity of electricity required by the U.S. Internet, it should be possible to calculate, very roughly, the "fuel economy" of the Internet – in other words, the amount of electricity needed per Kilobyte of data moved on the network.

There is a common misperception that the digital age, cyberspace, is free of the constraints of the physical world: bits replacing atoms, in the language of Nicholas Negroponte, MIT's digital sage. To be sure, bits do replace atoms – the use of e-mail instead of physical ("snail") mail, teleconferencing instead of flying are the two examples. There are many more.

However, it is a mistake to believe that the bits are somehow free. As this analysis has shown, the laws of physics apply to electrons on the Internet just as they do everywhere else. It takes a lot of power to make and energize an electric infrastructure of the magnitude of the Internet. A total annual consumption of nearly 300 billion kilowatt-hours requires a substantial amount of fuel to be consumed. This power requirement exceeds the total electric output of Italy. This is not the kind of power you can get from solar cells or handheld calculators.

On the U.S. electric grid, which is 56% coal-fired, nearly a billion tons of coal is consumed – thus the Internet's share of fuel use is on the order of 70 million tons per year of coal alone. (The balance of the current electric fuel mix is about 20% nuclear, 10% natural gas, 10% hydro, 5% oil and the rest miscellaneous. Renewables such as geothermal, wind, solar, etc., total under 0.1%.

The amount of fuel needed to create, maintain, access and operate the Internet can be reduced to very basic terms if we know the amount of traffic on the Net in bytes per year. This number is notoriously difficult to nail down because of its inherent complexity and the rapid growth in traffic. However, telecom sage George Gilder has estimated that total Web traffic grew from 30 terabytes per month at the time of the Internet's privatization in 1995, to four petabytes (15 zeros) per month in mid 1998. Traffic is estimated to be growing at roughly 10 fold per year, which would yield total 1998 traffic of something like 500 petabytes. The 300 billion kWh used in 1998 to move all those bytes provides for about 1,700 Kbytes per kWh.

To put this in more familiar terms, moving about two Megabytes on the Net uses:

- The same amount of energy as running a 50 W light bulb for 10 hours.
- The amount of energy released by burning a pound of coal.

So roughly speaking, when a book is ordered from Amazon.com or an MP3 music file is downloaded, somewhere in America half a pound of coal is burned to make the hard power to energize those soft bits.[25]

4. Architectural Implications of the Internet: A New Electric Reliability Paradigm

Anyone on the utility front lines interacting with business customers has noticed the growing demand for reliability. The trend has just begun a predictable ramp-up and is driven almost entirely by the information age and the Internet in particular. It used to be that utilities could count on customers acknowledging the remarkable level of reliability achieved in delivering power over thousands of miles of exposed wires and all the complex electrical engineering problems that attend thereto. But that is no more, and not because reliability is lower. Instead, the "new" economy is demanding ever higher levels of reliability. In effect, a significant and rising share of the electric supply system must now emulate the reliability demands of a communications system. As engineers in both communities know, this is a quantum change.

The telephone system and traditional telecommunications industry have achieved a level of reliability unmatched in statistical terms by any other industrial activity. The 'old' telephone system had a distinct advantage over the electric system (and the Internet) in terms of achieving reliability; the bandwidth and associated power requirements for moving voice traffic is very low and can be effectively protected from power outages by using batteries (albeit, in some cases, fairly extensive battery arrays). However, you cannot back-up megawatts and gigawatts with batteries. The architecture of the Internet, and the magnitude of the bandwidth and traffic, have driven the power needs in digital communications to entirely new levels, levels more typical of electric power systems than of telecommunication systems, creating new and unique demands for power quality and reliability.

Recognizing this new universe, Ericsson recently initiated a study group to explore the implications of providing reliable power sources for digital traffic as the traditional telecom system converts to handling data primarily, instead of voice traffic.[26] Ericsson, in fact, produces their own line of battery-back-up and diesel generator systems for data network system reliability. In a similar vein, the conversion of traditional telephone traffic to the data-based Internet, and to cable-based Internet services, also brings enormous new challenges for power reliability. The first public indications of this concern are just now being voiced. According to Milo Medin, CTO for @Home (soon to be part of AT&T):

> *"Of course, to guarantee fault-proof phone service, the (digital) network also needs robust, reliable power. So we may put in new generators or other power supplies, too."* [27]

Observations like this should send a clear message of concern to those in the electricity supply businesses and, perhaps, signal opportunity to others.

The "canary in the mine" indicators for the direction of reliability demands, in the computer age are visible in recent customer surveys. A 1998 survey by RKS found that one-fourth of businesses are troubled by sporadic outages or power fluctuations, with over one-third "less than very satisfied" with the quality of their power. The survey found two-thirds of businesses already taking some kind of action on their own to redress interruptions, with 20 percent willing to pay a premium for more reliable power.[28] An IBM study found that a typical computer experiences 120 "power problems" per month.[29] A survey of small businesses (the engine of economic growth in the nation) found 90% reporting at least one outage in 1998 with average costs per outage of $7,500.[30] The sensitivity to, and self-assessed costs of, small outages are a measure of the increased need for reliable power, which can only be a surrogate measure of the increasing role of computers and communications in all types of businesses.

Businesses across the country are already deciding to pay premiums for greater reliability. They're buying uninterruptible power sources (UPS) solutions. This reali ty has been the driving force behind the rapid growth of companies like American Power Conversion (APC). APC has become a market leader in UPS equipment for everything from desktops to mainframes. (The challenge for utilities in providing this service is the psychological conversion of a negative, an "unreliable" core product, into a positive customer program.)

When E*trade went down for a couple of days earlier this year, it wasn't because of an electrical outage, but because of a software glitch. But the reverberations from that outage have implications in the exploding world of e-commerce. When an entire business depends on staying on-line "24-by-7," there are two critical issues: Keeping software from crashing and keeping power up every one of the 8,760 hours in a year. Commerce on the net grew from nothing a decade ago to $8 billion last year, and is forecast to reach $326 billion by 2002. A recent ranking of the top 100 "Net Economy" companies (based on a survey of 600 candidates) found that their combined Web revenue was $48 billion in 1998.[33] The stakes are high in keeping the Net on line.

Operations such as Schwab's Internet brokerage operation and that of Amazon.com are only the tip of the iceberg. Big e-retailers have 100 kW to 1 MW loads and must have emergency power back-up solutions. But with dot-com companies exploding from the woodwork (Barnes & Noble followed Amazon into the Internet and many others are following), the demand for big-time UPS solutions and major back-up power solutions will skyrocket.

American Superconductor stands to benefit from those who need heavy iron UPS capability. Their refrigerator-sized superconducting storage system can handle the awesome task of smoothing out millisecond dips for several megawatts of power. They recently unveiled another application for their Superconducting Magnetic Storage Devices (SMEDS). By undertaking a network analysis of regional transmission systems, strategic placement of dozens of SMEDS can actually increase total transmission reliability and power quality. This kind of capability, heretofore impossible, comes just in time for the power quality needs of an Internet-driven electric system.

Firms such as Wartsilla and Caterpillar, with their ultra-clean diesel gen-sets, are likely beneficiaries at the upper end of a growing on-site back-up power market. Increasingly, one can expect to find 100 to 300 kW clean diesel gen-sets in the basements of buildings housing Internet Service Providers (with the fuel source either natural gas or oil, depending on price and circumstances). Rounding out the Internet-power package, entire building power systems can and will be completely isolated from the 'noisy' or 'dirty' bulk power grid. Active Power of Austin, TX, uses one-ton flywheels to serve as UPS systems for building loads up to 250 kW. Already, some developers are designing buildings with two entirely separate power systems; outlets for dumb appliances (lights, etc.) and outlets for "smart" clean power, the 24-by-7 reliable power that comes from super-UPS systems with back-up generators.

While major dot-com companies already number in the tens of thousands, it is the other end of the spectrum where the action is especially hot. There are at least 4 million Web server systems in the U.S. – computers on-line hosting Web sites. And in between the servers and the users, which need to be on 24-by-7 with their servers and drives, are the millions of routers that keep the net hot (and the millions of transmitters that keep the emerging wireless Internet running). These numbers don't even count the 80 million home Internet users who, while perhaps slightly more tolerant than businesses, don't like to put up with power hiccups while on-line. Of comparable interest for reliability are the 17 million telecommuters with one to two PCs who depend on reliability as much as any business. One should expect to see increases in markets for back-up generator and power systems for home offices with sensitive loads. The market opportunity is already generating interesting products. The Auragen 5 kW generator is installed under the hood of a Suburban or Expedition (or similar size truck – later to be available for certain cars). Why buy an engine-based back-up generator for home use when homeowners already own an outstanding engine under the hood of their SUVs?

The growth in the demand for power reliability on the Internet has just begun. It won't be just the e-commerce retailers and home offices that drive it. With the growing trend of "manufacture-to-order" in the industrial sector, along with just-in-time delivery economy, everyone depends on the Internet and communications. Hewlett-Packard, typical of modern info-economy high tech manufacturers, reckons a 20-minute outage costs a manufacturing plant $30 million. The hundreds of companies in their supply chain are just as sensitive. No one can afford to be down. Even telephone systems now need a UPS, because many modern office phone systems are really computers and even for relatively small offices can gobble several kilowatts.

The nature and magnitude of electric demand driven by the Internet ultimately suggests that the electric supply and delivery system will need to emulate the architecture of the Internet itself to achieve the levels of reliability required.

One should expect to see increased use not only of UPS and distributed on-site generation, but power nodes with remote generation and storage, and even a second wire. When telecommunications deregulation began two decades ago, no one imagined that homes and small businesses would ever want or need more than one communication wire to the home, and everyone was certain that the costs of providing additional "redundant" wires would proscribe their widespread use. All the experts were certain that the national communications infrastructure was so expensive that it was a natural monopoly. The national communications backbone has been built now several times over – and construction of backbone bandwidth continues. Now two wires to a home are common (phone and cable, soon more wireless and even fiber).

All of this suggests a similar heresy in the electric power business: the second power wire is inevitable too, not as the only reliability solution, but as part of the portfolio of reliability solutions. Expect to see it first in business centers where office buildings, already steeped in the hub and node modes of the Internet, will start to install distributed generation and storage hubs and nodes. The emulation of Internet architecture will move up the power lines to substations where one can expect to see installation of several MW turbines, essentially placed between central power plants and major load centers.[34] This not only relieves transmission constraints, but also increases reliability.

Did anyone really think that the power demands and reliability needs of 100 million PCs and tens of thousands of major dot-com loads would leave the electric market the same as that demanded by light bulbs, motors and induction furnaces?

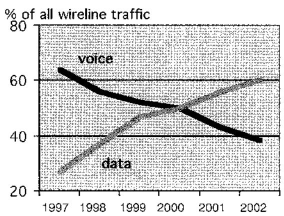
The rate of growth in the use of devices related to the Internet, and the resultant electric needs, suggests that those on the data side and those on the power supply side of the Internet don't have a lot of time to consider the implications.

The telecom industry is being rapidly transformed by the Internet. A decade ago, data accounted for only a marginal amount of the traffic on the traditional "wireline" networks. As Figure 9 illustrates, in a couple of years over one-half of all the traffic on the traditional old "voice" network will be digital. This trend is not only responsible for major equipment and technology transformations, but it is also fundamentally altering the entire telecom and communications industry, and is a driving force behind major investments, mergers and acquisitions.

Consider then an analogous situation. Figure 10 represents the growth in the share of total electron "traffic" on the traditional utility system network, powerlines. A few years ago, over 98% of all powerline electron traffic was in kWh to serve 'old' markets or dumb devices (kilowatt-hours to operate dumb devices like lightbulbs, and motors). As this analysis has shown, the share of the powerline electron traffic devoted to the Internet is already 8% and rising rapidly. Given the trends, it seems reasonable (perhaps inevitable) to expect that the powerline network will experience a transformation comparable to that of the telecom wireline network. Once a significant share of powerline traffic is occupied by the Internet, one can expect major infrastructure and business transformations of the same character as are now occurring in the telecom industry. How soon this transformation could occur will depend on the growth rate of the Internet. Based on recent history, and not assuming any acceleration in the Internet's utilization, the magic cross-over to 50% of all electric supply consumed by the Internet would occur around 2020.

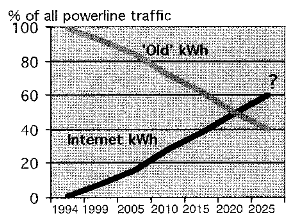
Transformations by the Internet

Figure 9: Telecom traffic on wirelines



Source: Dataquest [35]

Figure 10: Electron traffic on powerlines



Source: extrapolation of Figure 8 in this analysis

5. Future Trends: Driving Bandwidth and Internet kWh Demand

Intel has a vision that there will be one billion people on-line globally in the near future. Based on the metrics derived in this study, the Intel vision represents not just $1 trillion in computer sales, it also represents something on the order of a $1 trillion investment in an expanded information backbone – and a $1 trillion investment in a hard power backbone to supply electricity. One billion PCs on the World Wide Web represents a global electric demand equal to the *total* electricity generation of the United States today.

The goal of this analysis is not to forecast the specific future electric demand of the Internet, but instead to establish that it is already significant and is growing very rapidly. That being said, it is useful to briefly consider some indicators of the rate of growth and basic forces that are driving the Internet. If the growth rates are what many analysts and forecasters believe, the impact on the traditional electric sector will grow accordingly.

One important indicator of growth comes from the rapidly expanding world of e-commerce. The share of the total retail and banking markets that are currently executed on the Internet is still tiny. The largest retail activity on the Internet appears to be software sales. But even there, only 9% of all software is sold on the Web. Room for growth is enormous.

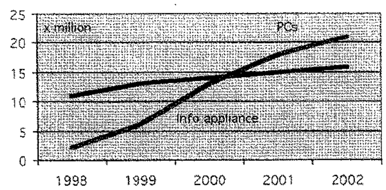
In addition to the forecast growth in PCs accessing the Web, the most rapid growth rates for Internet access are forecast to come from Information Appliances (such as Web TVs, or Internet-enabled telephones) and from portable, wireless PDAs. Even if one assumes that the soon-to-be-realized hundreds of millions of Palm Pilot-type devices used little or no electricity themselves (they still require recharging periodically, or energy to fabricate batteries), the existence of millions more devices linked to the Internet will create enormous demand for bandwidth. This will in turn increase the equipment and electric demand of the Internet, and furthermore will not likely replace or reduce the use of PCs, but simply complement them.

The "hockey stick" shape of the growth curve for devices that will drive bandwidth demand will come from more than PDAs and PCs. Increasingly, everything from refrigerators and automobiles to vending machines and air conditioners, are acquiring intelligence through soon-to-be-ubiquitous low-cost chips and connections to the Internet. Indicative of entirely new classes of devices yet to be invented and deployed is Canon's recently FDA-approved digital x-ray machine. A digital x-ray machine, in essence a PC with super high resolution imaging, will allow instant high-quality transmission of an x-ray to any physician on the planet – and will by itself (and with similar medical equipment) accelerate bandwidth demand and do more than simply replace existing x-ray machines. Because its cost structure will follow that of PCs, expect to see a proliferation of digital x-ray machines in every doctor's office. More bandwidth will be needed to move proliferating traffic in data-intensive x-rays.

The following three figures illustrate some of the core technology trends which portend increased use of the Internet, continued exponential growth in the use of boxes, and continual growth in electricity requirements.

Figure 11 illustrates the current forecast for annual sales in PCs and information appliances in the consumer markets alone. As the trends show, the expectation is for home PC sales to continue to grow (and for the multiple-PC homes, to become commonplace), even as the number of "information appliances" moves into dominance within the next couple of years. Information appliances, unlike PCs, have only one purpose: to link to the Internet.

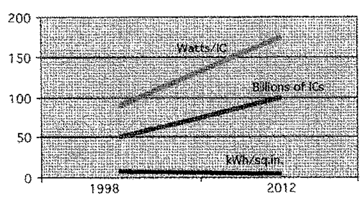
Figure 11: Consumer devices purchased



Source: IDC

Figure 12 illustrates the core trends in the production of integrated circuits (IC). Even as fab plants become more efficient, with the total electricity required to produce a square inch of an IC dropping in half by 2012, the demand for the total number of ICs produced is forecast (conservatively) to at least double.

Figure 12: Core technology trends in integrated circuits

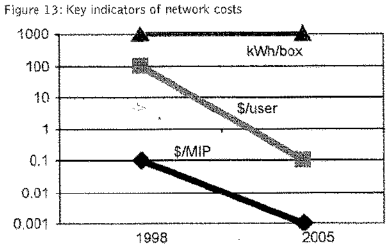


Source: Semiconductor Industry Association National Technology Roadmap

The amount of power used per IC is forecast to keep increasing as the capabilities of the chips continue grow. Today's state-of-the-art IC can be fabricated with 9 kWh per square inch of electricity, and 21 million transistors. It operates at 400 MHz. The IC chip needs about 90 watts by itself to run. By 2012, it will take only 5 kWh/sq. in. to make an IC. But that IC will have 1,400 million transistors operating at 1,800 MHz, and thus the exponentional growth in capability will increase power needs to 170 watts. While this represents a dramatic reduction in watts/unit of processing power – it is still an absolute increase in the power required by the chip.

Figure 13 illustrates the economic driving force behind increased use of networks. The cost of processing power ($/MIP) is forecast to keep plummeting, dropping one-hundred fold. This, combined with other cost reductions, means that the cost per user to access a corporate network will drop 1,000 fold. This kind of cost reduction will exponentially increase the market's use of networks. Considering that the average amount of electricity used per device on the network (kWh/box) will remain more or less the same (probably increasing – see above), the general implications are obvious: electric use from the Internet's growth will keep rising, at a rate far faster than 'old fashioned' efficiency programs can possibly offset.

Figure 13: Key indicators of network costs



Source: IDC & Semiconductor Industry Association National Technology Roadmap

6. Electric Policy Implications

The data presented here suggest that the array of companies that comprise the Internet Industry have more at stake than any other user with regard to the outcome of the future price, availability and reliability of the electric supply system.[36] It should be self-evident that an industry that consumes 8% of the nation's electric supply, and is increasing its use of that supply at double digit growth rates, would have an interest in the outcome of current federal and state deliberations that will determine the future of the electric industry. However, there is essentially no significant presence of the Internet-related industries in these public policy issues.

Many electric utilities have been pre-occupied, along with regulators and legislators, in debates over ensuring the continued availability of electric conservation practices and access to "green" power in a future "deregulated" utility industry. Typical of utility announcements today (other than those associated with mergers and acquisitions, a major distraction in itself) are press releases trumpeting new technologies that can save the average homeowner $15 to $25 a month on the electric bill using new automation technologies. Such initiatives seem anemic in the context of the issues explored here.[37]

True, many utilities have noticed the Internet. Many have started or are considering various telecom activities such as leasing transmission poles for cellular antenna sites, or installing fiber backbones to lease bandwidth, and so on. Many have engaged the Internet to provide services and communicate with customers, and even to sell power. In fact, some analysts estimate that energy and utility sales are the third-largest source of commerce on the Internet.[38] And for some environmentalists, the Internet is where they pin their hopes for accelerating the sales of "green" power. It is instructive to note, however, that regardless of the success in direct sales of "green" power, there is no likelihood that green power sources–usually identified as solar and wind–can come within orders of magnitude of providing a significant share of the electricity needs of the Internet economy.[39]

We are at the beginning of a new convergent age of info-electrons. There has been no challenge like this since the dawn of the electric age a century ago, when the new inventions of the electric motor and light bulb changed American industry and created the electric age. Many electric policy proposals on the table today are on a collision course with the kinds of demand forces explored here. In addition to the inevitable market confusion created by deregulating the enormous utility industry, there is also the supply and cost threat associated with determined efforts by many environmentalists to substantially reduce the use of coal, the nation's primary source of power in general, and cheap power in particular. While natural gas is the dominant fuel source for new power plant orders, there is no prospect of meeting future economically-driven and Internet-accelerated electric demand without retaining and expanding the coal component.

It may seem like a strange alliance–coal miners with Web masters at Charles Schwab and the other dot-com companies. Electrons, the laws of physics and economics link them. Federal and state policies, along with the electric industry, will be dragged along by the power of the microprocessor and Internet. No amount of wishful policy thinking can stop this juggernaut.

7. Detailed Table: Estimating Internet Electric Power Demand

Note: all of the following data are for equipment used primarily or exclusively on the Internet. Computer and telecom equipment manufactured and used for other purposes not included.

Category	Number of boxes (million)	Annual kWh (billion)	Key assumptions
MAKE THE BOXES FOR THE INTERNET Electricity used to manufacture the key PC-type boxes needed to access, supply and route information on the Internet.			• 1,500 kWh needed to fabricate one PC [40] • 1,500 kWh assumed for ALL computers, including devices with greater numbers of processors (e.g. routers, servers) • Note: 9 kWh per square inch required to fabricate integrated circuit [41] • Note: 36 million computers shipped in 1998; only those for WWW use in the U.S are included in this table [42]
PCs for home use of Internet	5	7.5	• Assume 50% of 10 million new PCs purchased by consumers are used for Internet [43] • Note that current estimates are that 80% of PCs shipped are connected to Internet [44]
PCs for office	12	18	• Assume 45% of new/purchased business PCs are connected directly to the Internet, or on a LAN or WAN connected to the Internet (often through a "firewall") • Since total U.S. sales of 36 million computers in 1998 included 10 million to consumers, thus allocate 45% of balance of 26 million sold to business [45]
Servers	1	1.5	• Year-end 1998 4 million servers on Internet compared to 1.5 million year-end 1997; growth of 2.5 million [46] • Assume 50% market for Web servers (and related devices) in U.S. [47]
Server appliances	0.5	0.8	• Low-cost 'low-end' devices assumed @5% market; grows to 19% of market by 2002 [48]
Routers	1	1.5	• Note kWh to fabricate routers will be higher than for PC (probably >3x); but assume same as for PC for conservative estimate. • 1 million shipped 1998 in North American market [49]
SUBTOTAL (nearest million)	**20**	**29**	• Sanity check: total fab plant electric use of 9e9 kWh[50] (Note fab plants excludes suppliers of chemicals, gas, equip., & assemblers of PCs) – IC fabrication represents <50% of all kWh needed

Category	Number of boxes (million)	Annual kWh (billion)	Key assumptions
INTERNET USERS Electricity used by "end-users" while operating boxes to access the Internet.			• Baseline total online universe of approx. 77 million people in U.S. end of 1998[51] • Excludes 6 million using WebTV or handheld computers
PCs @ home	28	17	• 60% of 55 million homes with PCs are "regular" Internet users.[52] • Reduce total by the number of home "power users" below to avoid double count • Average user 12 hrs/wk on line daug.IKW/desktop[53]
PC power users @home (e-traders)	5	6	• Count of households using Internet for on-line trading of investments [54] • Assume power user 2x average consumer time/wk online • Average use rises (one study found a five fold increase) with greater bandwidth access for power users [55]
PC home office	8	8	• Count home offices w. multiple PCs [56] • Assume one PC online avg. 20 hrs/wk
PC @ office	34	21	• Assume avg. office use of WWW same 12 hrs/wk as avg. home use & same 1 kW average per machine • Note: total represents only 30% of all 112 million PCs connected to LANs in 1998[57]
PCs @ office (not directly on WWW but behind 'firewall' supporting Internet access, info. or systems)	5	18	• Assume operation of 70 hours/wk (avg. duty cycle of 10 hrs/day 7 days/week) • Total count estimated by assuming that only 5% of PCs in business that are not directly connected to WWW are used directly as Internet support, connected to networks behind a secure 'firewall'.[58]
PCs used in commercial Internet service support	1	5	• Assume Internet software support & development PCs are 2 kWh/desktop with relevant peripherals, monitors [59] • Assume 50 hrs/wk operation
SUBTOTAL	**81**	**75**	• Sanity check: above derived estimate of 40 million office PCs on Internet only is 30% of installed inventory of 120 million commercial PCs, and estimated 44 billion kWh probably underestimates actual annual kWh by factor of two; survey found 43 million PCs (for all purposes) in commercial buildings in 1995 consumed 98 billion kWh [60]

Category	Number of boxes (million)	Annual kWh (billion)	Key assumptions
INTERNET INFORMATION SUPPLIERS Electricity used in operating the boxes (servers of all kinds) which are the sources of Internet information or commerce.			
Major dot-com companies	0.03	72	• Total "dot-com" company inventory year-end 1998 of 17,500 [61] (Note: dot-com servers can be mainframe-based or "Web" farms using a large number of minis.) • Assume 10% of total 1998 inventory of mainframes of 160,000 yields 16,000 [62] • 1998 inventory of mainframes grew by 12,000 (most, probably majority, used in major server applications) • Assume average load of 250 kW and 24x7 operation[63]
Web sites	4	52	• Assume all servers that are not major dot-com companies using small servers (1 kW plus 0.5 kW peripherals, especially data back-up) • Assume 70% all installed servers located in the U.S.; total server Universe in 1998 of 5 million[64]
SUBTOTAL	**4**	**124**	• Sanity check: the results derived here imply that approx. 12% of commercial building electricity purchases in 1998 were for computers serving the Internet. 12% of total U.S. commercial kWh use equals 115 billion kWh
NETWORK Electricity used by the boxes required to operate and route data on the Net			• Only count two major equipment categories: routers and major telecom "switches"
Routers on Internet	2	16	• Total number U.S. routers from Dataquest [65] • Assume average router at 1 kW and continuous operation [66]
Routers in LANs and WANs	1	8	• Total for two router categories equals total routers installed to date • Note: Background net support provided by local area networks (LANs) with 112 million in LANs in market using routers (and other switching and related hardware) [67]
Telephone central offices	0.01	43	• Allocate 40% of 25,000 telephone central office "switches" to data traffic (Dataquest) • Average central office 500 kW
SUBTOTAL	**3**	**67**	
TOTAL	**108**	**295**	

Internet-related hardware NOT COUNTED in above totals

Item/activity	Number	Comments on electricity use NOT counted in estimates
Office space	-	• Commercial buildings used to house equipment for Internet services should have overall building electric use allocated to the Internet • Information technology services in general account for 8% of all U.S. commercial service revenue: assuming 30% of info services are for the Internet, this would add 23 billion kWh to the total. • Additional cooling, lighting or related space conditioning loads created by the Internet equipment used in residences could also be counted as Internet-required kWh.
Data switches for networks	>1 million	• Shipment of 17 million ports -- ports/switch ranges from 4 to 500 with most at low-end representing perhaps 1 million switches[68] • As ports are provided greater processing power for network efficiency, electric use will become significant
Super servers	>100,000	• Sun Microsystems sold $900 million worth of their new $1million+ superserver in 1998 • Total U.S. shipment of "mini" class of computers at 300,000 units/yr[69] • Analysis here used the same kWh for manufacturing ALL kinds of computers which greatly understates energy needed for super servers as well as mainframes and storage systems (below)
Mainframes	>10,000	• 12,000 per year shipped in U.S.[70] • Majority new mainframes going into Internet server or related uses [71] • Electricity used to manufacture mainframes
Enterprise storage	>10,000	• Hardware to store & back-up mountains of data generated by Internet activities (e-commerce, etc.) using mainframes & superservers [72] • Enterprise storage systems sales have grown >10x in decade • Electricity used to manufacture enterprise storage
PDAs	10 million	• 6 million PDAs today, 56 million in five years • Electricity required to manufacture PDAs used for Internet access
Information appliances	2 million	• 2 million "info. Appliances" shipped in 1998 forecast 7 million 1999, 12 million 2000 (e.g., WebTV, set top boxes) • Electricity to fabricate and use appliances including WebTV (3 million installed today) and handhelds (3.7 million) – IntelliQuest
Peripherals	>80 million	• Electricity to fabricate drives, printers, scanners, UPS
Home networks	1 million	• Fabricate and operate devices for connecting multiple PCs & devices [73]
Telecom	Millions	• Share of cell and PCS phones used for wireless Internet access
Cable modems	Millions	• Fabricate and operate 500,000 cable modems (1998) & related cable system devices
Wireless Internet Base stations	>50,000	• Allocation of digital PCS network used for data traffic on Internet (e.g., wireless access to e-mail, stock market, etc.) • Fabricate and operate wireless base station amplifiers, filters, etc.
Fiber optic and coax cables & hardware	-	• Fabricate cable, fiber optics, related hardware & equipment
UPS	Millions	• Electricity involved in fabricating and operating (typical UPS uses about 5% of energy supported)
Back-up generators	>100,000	• Fabricate back-up systems for buildings, ISPs, etc.

References & Notes

1 "Home Appliances Get Smart," *IEEE Spectrum*, August 1998.

2 Department of Energy, Energy Information and Administration (DOE/EIA) *Annual Energy Review*. Edison Electric Institute (EEI) report, "Capacity and Generation."

3 Certainly many other stock indicators are important, particularly those involving smaller companies than the Dow's big 30, and those in the "tech" sector. Nonetheless, the venerable Dow has become the Rosetta Stone for growth.

4 Information Technology Industry (ITI) Council data does not include such computer-based equipment as Web TVs, similar info appliances, routers, switches that may not be counted in the "telecom" area because they serve the "computer" industry.

5 "Success Strategies for the New Internet Economy," IDC report, 1998. www.IDC.com.

6 "Unaccountable," *Forbes*, 5/3/99.

7 "Personal Computers and Computer Terminals in Commercial Buildings," DOE/EIA, 1995.

8 While IBM has a "utility" business unit, the primary focus of IBM's efforts are in seeking contracts to outsource the data management needs of utilities. Similarly, some telecom companies have modest equipment manufacturers.

9 "Silicon Valley's Awesome Look at the New Sony Toy," *New York Times*, 3/19/99. The Toshiba chip in the new Sony Playstation II performs 6.2 billion calculations per second, compared to a Pentium III at 2 billion and Pentium II at 0.4 billion. Sony uses the processing power to achieve graphic rendition equal to supercomputers of only a few years ago. The game has a port which will allow Internet connectivity.

10 "History and Forecast for the North American Router Market," Dataquest report, 6/18/98; 342,000 units shipped in 1995, 965,000 units shipped in 1998. Also Tim Smith of Dataquest provided world market data year-end.

11 The average annual $10,000 "operating cost" of a typical wireless base station provides some insight into the electric needs. Even if one allocates only half of the essentially maintenance-free base station operating costs to electric purchases, this represents over 50,000 kWh per year per base station. There are tens of thousands of base stations – 65,000 today, with 35,000 more forecast by 2004 (Forbes, "Tower power," 3/22/99). Their collective electric needs could easily exceed a billion kWh/year.

12 "History and Forecast for the North American Router Market," Dataquest, 6/18/98.

13 "Big Iron, Small Iron," *Forbes*, 4/19/99.

14 "IBM Launches Newest Mainframe," *WIRED news*, 5/3/99.

15 Information Technology Industry Data Book, 1998, (Note: currently the export and import of PCs is in rough balance. Thus, total net shipments into U.S. markets are, for now, a rough approximation of total PCs fabricated in the U.S.)

16 "The National Technology Roadmap for Seminconductors," Semiconductor Industry Association (SIA) report.

17 "America's Semiconductor Industry: Turbocharging the U.S. Economy," SIA, 1998. See www.semichips.org.

18 "The Environment," *IEEE Spectrum*, p. 106; 1995 EPA 8,400 GWh for fab plants; forecast to grow 50% by 2010.

19 Data from Semiconductor Equipment and Materials International (SEMI), Elizabeth Shuman (4/19/99 conversation).

20 "Birth of the Eco-computer," *New Scientist*, 10/30/93.

21 "Personal Computers and Computer Terminals in Commercial Buildings," DOE/EIA 1995.

22 Discussion with Robert Hobbes Zakon, MITRE Corporation; see Hobbes' Internet Timeline v.4.1 at www.isoc.org.

23 The internet equipment is allocated 70% to the U.S. market. Note that this will tend to slightly under-represent the total number of hosts and Internet devices because the U.S. was more dominant in the Internet over the past decade than today.

24 The average kWh used per box today is roughly the same as each box (or PC) five and ten years ago. Modest improvements in efficiencies for certain components, such as monitors and drives, has been more than offset by increased number, size and performance needs of the peripherals. Further, the trend in absolute electric use per microprocessor continues to be up, not down. An integrated circuit several years ago consumed less than 30 watts, the state of the art device today requires 70 to 90 W. The increased power requirement comes from the exponential growth in devices per chip. It is the case that the power is declining per MHz, or power per MIPS, or power required per Mbyte of data processing – but that measure, while technologically intriguing, is not the relevant measure for the hardware's net kWh needs on the Internet.

25 "It's Not the Size That Counts, but How You Measure It," *New York Times*, July 5, 1998. NSF reported traffic at 20 terrabytes per month in 1995 with growth of 100% per year at that time; "The Internet Phenomenon," www.cise.nsf.gov/heneral/compsci/net/cerf.html.

NOTES ON THE INTERNET'S FUEL ECONOMY:

This digital "fuel economy" conclusion is, necessarily, a rough order-of-magnitude and depends on a number of variables. Reducing the "fuel economy" of the Internet to a recognizable activity (ordering a book) requires some approximations of course. How much data traffic is created on the Internet for a session to say, order a book from Amazon, or download a music file? One can watch the data transfer rate displayed on screen during a session and see that even a 56K modem often operates at only 10% of its rated capability (pretty typical on the congested info highway these days). This data rate yields a five minute session driving roughly 2,000 Kbytes of traffic on the network.

The fuel economy of the Internet will continually improve. Users will migrate from slow 56K modems to DSL and cable modems, and while 10 to 20 times faster they use only 50% more electricity. All the devices on the network will get faster too. For example, the router kWh/bit efficiency will keep getting better; e.g., Cisco's 400 Mb/s router uses the same 1.5 kW as the 16x faster new gigabit router.

However, it is clear that even as the electric efficiency of the Internet (in terms of bits/kWh) gets better, the aggregate electric demand will keep rising for some time because of the rapid increase in the sheer number of boxes accessing, feeding and using the network. Thus one might forecast that in a year, the Internet could easily have 10 times more bit traffic (Gilder's forecast), and "only" 50% more electric demand (this growth rate from this analysis). Thus the bit-rate fuel economy will be substantially better, perhaps 10,000 kBytes per pound of coal – but the total amount of electricity needed will have risen 50% because the growth in traffic will outstrip the growth in efficiency for some time to come.

As to the current "fuel" needed to move 2,000 Kbytes on the Internet, the calculation is (necessarily) only a rough order-of-magnitude based on the total amount data traffic on the entire Internet now and the total electricity required by the Internet. (Note that the inclusion of the electricity needed to fabricate Internet devices does not significantly distort the fuel needed to operate the Internet since the fabrication component is only 10% of the total kWh derived in Section 7.) The 500 petabytes of traffic on the Internet at the end of 1998 comes from Gilder's published estimate (see citation below), and the electricity required (approx. 300 billion kWh) comes from the analysis summarized in the table in Section 7. The pound-of-coal equivalent is derived from the total energy contained in a pound of coal and the amount of electricity that pound produces (10,000 BTUs of thermal energy in a pound of coal and 10,000 BTUs required at the power plant to generate a kWh). Finally, as a practical matter, 56% of the U.S. electric supply comes from coal, thus the pound-of-coal-equivalent to move 2,000 Kbytes, is in fact about one-half a pound of real coal with the balance coming from the rest of the electric supply's fuel mix (20% nuclear, 10% gas, 10% hydro, 5% oil, 5% miscellaneous). Clearly, electricity in some places ranges from nearly zero coal to 100% coal. But electrons on the electric grid at the national level are all fungible, and the Internet like the electric grid, is a national system.

A rough sanity check of this fuel efficiency can be obtained by calculating the number of Internet sessions the derived fuel economy represents. The half-pound of coal per session can be used see if the total amount of coal used to make electricity would supply a reasonable estimate of the number of Internet sessions in the U.S. A session is roughly five minutes of on-line time at the 2,000 Kbytes of activity level. That session consumes one-half pound of coal. Thus a ton of coal represents the fuel for 4,000 sessions. The U.S. consumes about 900 million tons of coal to make electricity. The analysis derived here finds that 8% of all electricity is used for the Internet, thus 8% of all coal-for-electricity would be allocated to the Internet, or about 72 million tons of coal. The 72 million tons of coal provide the kWh needed to fuel [72 million tons] x [4,000 sessions per ton] = 288 billion sessions per year. All of these sessions divided into the approx. 80 million U.S. Internet users, averages to about 10 sessions per day per Internet user. This is a reasonable order-of-magnitude for an average Internet user, and is also consistent with the Forrester Research figure of 12 hours per week for the average Internet user -- 10 sessions per day at 5 minutes per session yields 50 minutes a day, or about 6 hours/week.

26 "Powering the Internet: Datacom Equipment in Telecom Facilities,"

27 "Fat Pipe Dream," *Wired* interview, April 1999.

28 "Make Your Own," D. Claeys, RKS Research, *energy,* December 1998.

29 "The Problem With Power," APC, American Power Conversion, www.apc.com/english/power/index.cfm

30 "Business briefs," Electrical World, March/April 1999, based on AlliedSignal Power Systems sponsored survey of small businesses.

31 *Wired,* June 1999: $7.8 billion from Forrestor Research and Jupiter Communications.

32 "The Emerging Digital Economy," U.S. Dept. of Commerce, 1998.

33 *Business 2.0,* May 1999.

34 Solar Turbines has produced a 4 MW state-of-the-art gas-fired turbine for this type of application.

35 *Wired,* April 1999.

36 The price volatility of the Gigawatt network (AC power) is very likely the same as it is for the Cyber network. The difference between the off-peak rate and highest traffic rates for a kilowatt-hour is 700:1. This volatility has been hidden in the regulated monopoly system but will become very visible in a competitive market for utilities, and very important to cyber users; after all, if profit margins at Amazon.com are thin (or negative) and a key input for operating a national system see a price peak of 700 fold, it could substantially impact profits. Note also that the peak traffic for telecom use is almost always coincident with the peak 'traffic' for electricity.

37 "Celerity, Battelle Announce Residential Automation System for Energy Savings," *Energy and Housing Report,* February 1999.

38 "Energy E-commerce Comes of Age," *Energy Markets,* April 1999.

39 EIA Annual Energy Forecast: growth rates of 1,000 to 10,000 percent for solar and wind will lead to total share of 2020 electric supply still less than 1%.

40 Average of 2,315 kWh found in 1993 de-rated for this estimate to 1,500 kWh/PC to accommodate (overestimate) efficiency gains in manufacturing since 1993. See "Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics and Computer Industry," March 1993, Microelectronics and Computer Technology Corporation, Austin, TX. See also "Birth of the Eco-computer," New Scientist, 10/30/93.

41 "National Technology Roadmap for Semiconductors," Semiconductor Industry Association, 1998.

42 Imports and exports are in rough balance; thus U.S. purchases of imported PCs, in effect taking credit for foreign kWh used to make those PCs, is offset by kWh used to make PCs in the U.S. that are purchased overseas (See Information Technology Industry Data Book).

43 International Data Corporation: 1997 10 million home PCs, 1998 11 million, 1999 est. 13 million: See "Beyond the PC," *Business Week,* March 8, 1999.

44 "The Digital Decade," S. Morrisette, Forrester Research, www.forrester.com/ER/Press/Talking: Once a market is mature or in a "stead state," a certain share of each year's production will be used for inventory replacement. However, regardless of whether a PC fabricated is for new use or replacement of an old device, this fact only impacts the net inventory, not the electricity needed to fabricate devices each year.

45 Many analysts assume that virtually all PCs now installed in businesses are on networks; analysts further assume that virtually all new PCs put into business WANs are directly or indirectly on the Internet, with the exception of large corporations with private networks completely independent of the Internet. (Re. Conversations with T. Smith, Dataquest analyst: believes that 90% of WANs are Internet connected.) Since these observations were anecdotal, without available data to substantiate, we assumed the 45% figure.

46 "Hobbes' Internet Timeline v4.1" Robert Hobbes' Zakon, MITRE Corp., www.isoc.org/guest/zakon/Internet/History: Note that numbers of Web sites will exceed the numbers of servers as many servers can have multiple sites; see also "WWW Hosts 5 Million Web Sites," 4/20/99, NUA Internet Surveys, www.nua.ie/surveys; again, assume 50% of these sites are in the U.S. and compare to a "1 million web site" count two years ago in the NUA survey. The average growth is 2 million sites per year.

47 "Success Strategies for the New Internet Economy," G. Gens, IDC. Ratio currently closer to 70% in the U.S. – this fact will counterbalance the above overestimate.

48 "Bypassing Windows," *Business Week*, 2/15/99. According to Dataquest $500 million/yr sales of "server appliances" is forecast to climb to $13 billion by 2002 and 19% of market. 5% of market today implies at least 0.5 million server appliances/yr produced globally at an average of $500 per device in a $500 million market – and implies total server market at 10 million per year. This would suggest 5 million servers going into U.S. market instead of 1 million/yr assumed for table.

49 Dataquest, 6/18/98 estimate: 1.2 million forecast for 1999. 1998 world market: 2.3 million units.

50 "The Environment," *IEEE Spectrum*, January 1999; Re. U.S. Census data.

51 "IntelliQuest Study Shows 83 Million U.S. Internet Users," www.intelliquest.com, Spring 1999: 3.7 million using handheld computer, 3.1 million using set-top box or WebTV.

52 "Bringing home the Internet," *IEEE Spectrum*, March 1999.

53 The simple assumption that a desktop PC used to access the Internet can demand 1,000 W conflates a number of issues. First, this a figure is used not so much to derive what a PC uses per se, but what that PC uses because it is on the Internet -- i.e., both the specific PC's kWh use as well as the echo it creates on the network. This is an important point, we were not trying to assess the actual electric use of PCs by themselves, but the entire system of devices (driven by PCs) on the Internet.

As a matter of interest, the 1995 DOE/EIA survey of computer use in commercial buildings (cited elsewhere in the table) provided a useful order-of-magnitude validation. The DOE/EIA survey found that 4% of all U.S. electricity was consumed by computers in commercial buildings in 1995 -- the year the Internet, in effect, took off. Our methodology yielded a 5% figure for total computer use (including the Internet) of all kWh in 1995. We suggest that it is at least 8% today. This result, in all likelihood, understates the actual impact. Since 1995, Internet PC use has dominated both end-user computer purchases and PC-type boxes in the network itself.

Regarding the assumptions for the kWh appetite of a PC on the Internet. The APC web site (www.apcc.com) has an on-line configuration tool to determine the size of UPS needed for various computer systems. A Pentium II with 16-17" monitor, CD-ROM, Zip drive and printer is rated at 205 W. Our analysis assumes a maximally configured PC; i.e., lots of related bells & whistles on the desktop for the current generation of Internet users, and as research shows, many Internet users are not only heavy users of hardware, but also heavy users of on-line time. The 1,000 W figure for the PC nominally accounts for the power needs of otherwise uncounted microprocessor devices on the network (desktop, LAN and WAN) that are otherwise hard to count. It was not possible to count all of the behind-the-wall components in assembling an inventory of the hierarchy of hardware needed to allow a PC to work on a network. Instead, we allocated some of the load that is behind-the-wall but critical to the network (in effect) to a maximized watt-rating for the desktop PC. (In a sense, this is equivalent to counting modems, external drives, scanners, etc. -- just that the network devices are located a little further away, but still linked by hard wires. In a commercial building setting, many of these devices are not very far away, and even "on the desktop" so to speak.)

The duty cycle is a critical variable, rather than the peak power alone -- the work the CPU and related processors and devices actually perform (drives, graphics cards, etc.). A machine that is only 100 W at idle machine can consume 300 to 500 W while processing (otherwise, even accounting for safety margin, the power supply in the 'box' wouldn't be 400 to 600 W). But PC duty cycles are hard to come by. In estimating the aggregate electric use from all the devices on the Net, rather than try to estimate the typical duty cycle of a PC, we use instead an unrealistically low "on" time for the total system. For approximation purposes, this happens to be easier. In other words, we assume that every single PC and all its relevant peripherals accessing the Net is physically turned on and operating only the 12 hours per week from the Forrester Research survey, and otherwise completely off. As a practical matter many (possibly most) are on at least 50 hours per week, many 24-by-7. A 'realistic' weekly "on" time of 50 hours yields about the same rough kWh for a 200 – 300 W duty-cycle-compensated PC as the conservative 12 hour/wk duty cycle does for a 1,000 peak-W device.

It is important to note that this approximation does not double count devices in the network. The inventory of the boxes on the network (and thus the calculation of the network's kWh needs) used here counts only routers and the relevant share of central office telecom switches. This greatly undercounts the myriad devices, switches, amplifiers, filters, etc., that are on the network in all of the various nodes and layers in a communications system. For example, a total of 50 million data ports were shipped in 1998 alone, with an average of only a few to few dozen ports per physical switch. (Of course, every switch consumes kWh too.) Cable modems, by way of example, create substantial powers need upstream (amplifiers, filters, etc.) that must be allocated to the network or the networked PCs. All of the devices on the network dedicated to keeping the PC active are powered up 24-by-7. Ironically, another power-consuming component is the UPS system itself. Ubiquitous for Internet-linked devices, a UPS typically uses 5% to 10% of the input power. One should, of course, count all of the devices on "network" "behind-the-wall" (other than routers) – but as a practical matter it was easier to assume a maximally configured peak kW PC for purposes of the approximation here.

It is important to emphasize that the data used to estimate PC kWh use was specifically only for PCs on the Internet. We did not include the tens of millions of stand-alone PCs and minicomputers that are in use but are not directly wired to the Internet, even though they increasingly are used to indirectly support Internet activities, development, programming, etc.

Finally, it is noteworthy that we did not count the fugitive electric demand for PCs from additional lighting and cooling in homes and offices due to the waste heat. It is well-established in electric utility circles that the average impact of heat-generating (which is to say, all) appliances is to increase cooling loads. While there is a general overall energy, not electric, offset from reduced heating loads in winter, this offset is lower than the fugitive cooling load. In any case the 'saved' heating load is primarily natural gas and oil, while the additional cooling load is almost entirely electric.

"IntelliQuest Study Shows 83 million U.S. Internet Users," www.intelliquest.com, Spring 1999. Identifies 12.1 hours/wk average for 1998, up from 10.9 average the year before. Other surveys show lower averages; e.g. Nelsen/NetRatings March 1999 of 7 hours per month or about 2 hours per week. Note that in either case, the electric use assumption for the purpose of this analysis is that the PC is only turned on 12 hours per week; for casual e-mail users, for example, a computer "on" time of over 20 hours per week is common, even when the actual "on-line" time may be much less.

54 "New Breed of Investors," *New York Times*, 5/16/99, 5.2 million from NFO Interactive; also "The Matte of Logic," Money magazine estimate of 5 million "Americans are engaged in speculating online."

55 "High-speed Habits," *Wired*, June 1999: MediaOne study found cable modem users were online about 5 times longer; 22.5 hrs/wk vs. 4.7 hours per week.

56 "Multiple PC Home Office Households to Soar," IDC Research, March 16, 1999; 7.8 million in 1998, 12.1 million by 2002 "will have multiple PCs". "The Internet will drive the growth of home networking solutions."

57 Information Technology Industry Data Book, Table 4-6.

58 Total PC inventory of approx. 200 million (see ITI data above). Reduce total by 55 million home PCs and 17 million additional PCs used as second computers in home offices (see above notes); reduce total by 35 million commercial PCs assigned here as already accessing WWW – leaves a remainder of 93 million 'unassigned' PCs. Of the universe of 93 million PCs not assigned here as direct connect to WWW, assume 5% are on networks for which their primary or sole purpose is to provide information and related support to a business, educational, or related WWW activity (either information provider or user).

59 Assumptions to allocate PCs to direct Internet support: ITI data. ITI Table 4-5 shows $230 billion in total information technology industry service revenue compared to ITI Table 2-2, which shows a total U.S. service industry of $2866 billion. Information technology services are 8% of total U.S. services. A total commercial sector computer inventory of 140 million implies a ratio of 1 million computers per $20 billion in service revenues. Assume the same ratio for info services (which probably understates computers installed). This implies 12 million computers were installed in the information technology services industry. While a significant, perhaps even major share, may be associated with services for the Internet, assume here that only 10% of all info services (and all info services PC equipment) is currently used by Internet Information Services businesses; i.e., about 1 million computers.

60 "Personal Computers and Computer Terminals in Commercial Buildings," DOE/EIA, 1995.

61 Keenan Vision, San Francisco, 1998 survey/estimate.

62 Information Technology Industry Data Book

63 Conversation with APC Director, Neil Rasmussen; allocate load 50/50 to PC operation and direct cooling needs; many mainframes, or enterprise data centers, can draw a total of 1 MW.

64 "WWW Hosts 5 Million Web Sites," Netcraft survey, NUA Internet Surveys, www.nua.ie/surveys.

65 "History and Forecast for the North American Router Market," Dataquest 6/18/98; annual shipments of 342,000 (1995), 524,000 (1996), 705,00 (1997), 965,000 (1998). Extrapolating backwards to 1991 provides total installation base of at approx. 4 million with 85% in U.S.

66 Cisco 400 Mbs and Gigabit routers both 1.5 kW: see www.cisco.com product information.

67 Information Technology Industry Council Data Book Table 4-6

68 Dataquest, B. Pursely, supplied 5/3/99; 6/18/98 estimate: 24 million ports forecast for 1999: growing to 43 million by 2002 in North America alone.

69 "Big Iron, Small Iron," *Forbes*, April 19, 1999.

70 Information Technology Industry Data Book

71 "Big iron, small iron," *Forbes*, April 19, 1999; "Hewitt Associates, $1 billion benefits consultant in Chicago, bought eight G5 (IBM) mainframes as upgrades to its existing IMB mainframes. Among other things, the G5s will support applications that let clients' employees check on their benefits using the Web."

72 "As data grow, so grows EMC," *Money*, March 1999. A typical system ranges from $250,000 to $4 million; assume $1 million average; sales of $10 billion now equates to 10,000 units.

73 "The Digital Glue of Pervasive Computing," S. Kaldor, IDC. 5 million home network nodes forecast to ship in 1999: 20+ million by 2002 with 12% of homes with active networks. See also "Family connections," U.S. News & World Report, April 19, 1999; Intel estimates 17 million homes today with two or more computers, with 28 million within 5 years as markets for their AnyPoint home network.

ONE HUNDRED SIXTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON GOVERNMENT REFORM

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February 3, 2000

BY FACSIMILE
The Honorable Jay E. Hakes
Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Mr. Hakes:

Thank you for testifying at yesterday's hearing, "Kyoto and the Internet: the Energy Implications of the Digital Economy." As I have come to expect, the Energy Information Administration's (EIA's) testimony was insightful, informative, and fair-minded.

I am writing to offer a recommendation and make a request. My recommendation has to do with EIA's future study of the issues raised at the hearing. Apparently, EIA has not had the time, resources, or research strategy to track the electricity consumption of all the equipment relevant to the Internet or, more broadly, the digital economy. I believe it would be worthwhile for EIA to go beyond measuring electricity consumption by personal computers and find out how much electricity all the devices of the digital economy may be using -- for example, the equipment used by "dot-com" companies and telecommunications (telecom) infrastructure built to handle digital traffic.

While EIA may not be able to undertake such an analysis at this juncture, I encourage EIA to begin a serious effort to determine what kind of research strategy would be required to estimate the electricity needs of the digital economy. For example, as a first step, EIA might explore, with both in-house and outside experts, the key issues and methodology needed to estimate the Internet-driven component of telecom industry investment and to unbundle the very large "other" category of electricity uses in the commercial sector data.

My request has to do with the quality and reliability of EIA's study of the costs of the Kyoto Protocol. In his written testimony, Dr. Joseph Romm argues that EIA's study suffers from five major "flaws" that render the study "irrelevant to the current policy debate about Kyoto." At the hearing, you took issue with Dr. Romm's critique. However, due to time constraints, you were not able to comment on it in detail.

Pursuant to the Constitution and Rules X and XI of the United States House of Representatives, I request that EIA respond to each of the five arguments in Dr. Romm's critique of EIA's analysis. Please deliver your response by February 18, 2000 to the majority and minority staffs of the Government Reform Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs in B-377 and B-350A Rayburn House Office Building, respectively. If you have any questions about this request, please contact Staff Director Marlo Lewis at 225-1962.

Sincerely,

David M. McIntosh
Chairman
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs

cc: The Honorable Dan Burton
The Honorable Dennis Kucinich

Department of Energy
Washington, DC 20585

MAR 2 2000

The Honorable David M. McIntosh
Chairman, Subcommittee on National Economic
Growth, Natural Resources, and Regulatory Affairs
Committee on Government Reform
United States House of Representatives
Washington, D.C. 20515-6015

Dear Mr. Chairman:

We are writing in response to your letter of February 3, 2000, with questions emerging from my testimony of the previous day on "Kyoto and the Internet: the Energy Implications of the Digital Economy." Our response is basically in two parts; first, the recommendation to develop a strategy to develop better estimates of the electricity consumption in the digital economy, and second, a response to Dr. Joseph Romm's criticisms of EIA's previous analysis of the impacts of the Kyoto Protocol.

Electricity Consumption

We have conducted a preliminary evaluation of the resources necessary to be able to estimate the electricity used by the digital economy, both as a source of ongoing data and also as a basis for more detailed analyses of potential future electricity demand. To a large extent, this requires augmenting EIA's current consumption surveys—the Residential Energy Consumption Survey (RECS), the Commercial Buildings Energy Consumption Survey (CBECS), and the Manufacturing Energy Consumption Survey (MECS). Some difficulties arise from the fact that these are quadrennial surveys only. Combined with the time to compile the data, this means that it will take some years for additional data to be available. Also, in response to appropriations reductions in the mid-1990s, EIA has endeavored to reduce the cost and respondent burden of these surveys by reducing some of the information collected, as well as changing them from triennial surveys.

We look at each of the three survey areas in turn.

RECS. For the household sector, we already collect data on the inventory of personal computers, but we should add some new questions on the presence of computer peripherals and other digital equipment, as well as on usage patterns for all digital equipment. We estimate that five minutes of questions should be added to the survey, with a cost of $65,000 for each survey cycle, or an average of about $16,250 per year, for added question development, testing, data entry, editing, processing, and tabulation of results. Reviewing the current survey, we do not see where any information could be deleted without harming ongoing analytical efforts since this survey has already been reduced. These questions could be implemented for the next RECS for data year 2001, with results available in 2003.

CBECS. The commercial sector is more difficult. The survey for the 1999 data is currently being fielded so the next opportunity for CBECS to collect new data is the 2003 survey, with the first data not available until 2005. Also, the CBECS is oriented toward buildings, not business establishments, which would be more appropriate reporting units from which to collect the desired data.

Thus, we recommend a one-time national benchmarking study that focuses on all electricity use for commercial providers in the digital economy (e.g., Internet service providers; software development firms; firms providing computer consulting or training services; centralized transaction processing facilities for credit cards, banks, etc.; cable and pay TV; electronic trade and sales establishments; and telephone/telegraph communications) and digital equipment (e.g., PC equipment and related peripherals; computer terminals; LAN/WAN equipment; servers, mainframes, and other central computers; telecommunications equipment; and retail transaction equipment) in all commercial establishments. A relatively small sample of establishments in various industries of interest would be selected, and that sample would be surveyed to get their profile of digital equipment and the patterns of use of that equipment. Metering could be done on a sample of the different equipment types to get energy use rates per use hour. For a sample of 500 establishments, the cost of such a study could be as low as $500,000 if the survey were restricted to inventory and use patterns, using outside data for energy demand rates. The cost of the study would be about $3,000,000 if observation were necessary to determine use patterns and use rates were determined by metering. The costlier approach may be necessary if equipment metering and equipment use studies are incomplete or if we cannot get information from outside sources for proprietary reasons. Depending on the approach taken, the data could be available in three years from the time of funding.

Following the study, we would use the results to consider what questions should be added to the CBECS on a regular basis. The additional cost for each survey would be evaluated at that time. In the meantime, we will conduct our own study of electricity requirements from personal computer and Internet use in the DOE headquarters buildings and provide an assessment within our current budget.

MECS. For the manufacturing sector, the survey could be expanded to cover producers of digital equipment in sufficient detail to derive consumption data for these industries. For all manufacturers in the survey, we would add questions on the presence and use patterns for digital equipment, from which estimates of energy use by this equipment would be derived if outside information on energy demand can be obtained. The cost would about $250,000 per survey cycle, or an average of $62,500 per year, if none of the current data were eliminated. However, it may be possible to eliminate some data items currently on the survey without seriously damaging our current analysis. If enough questions were eliminated so that digital equipment could be surveyed with no increase in the total length of the form, the incremental cost of the effort could be cut to $125,000, or an average of $31,250 per year. This could be implemented for the MECS survey cycle for the 2002 data year, with the data available in 2004.

In summary, the necessary information can be collected and processed for the residential and industrial sectors for an annual cost between $47,500 and $78,750. The special commercial survey should provide most of the questions in that area at a cost between $500,000 and $3,000,000 and lay the groundwork for some expansion of the recurring commercial surveys.

Dr. Romm's Criticisms

In his testimony, Dr. Romm alleges five major flaws with the EIA study *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, published in October 1998. Dr. Romm's criticisms began even before our study was released to the public. Some of his criticisms are legitimate disagreements common among energy analysts; however, most of his allegations are clearly refuted in the text of the report. When the study was first released, we responded to very similar comments. At that time, both Dr. Romm's comments and our response were publicly available on the Web site of Resources for the Future; however, he has continued to make the same false allegations. Since that time, we have corrected numerous false statements by Dr. Romm, but this effort has met with limited success.

We address each of the comments in his testimony in turn.

Romm Assertion: FLAW #1: EMISSIONS REDUCTIONS DON'T START UNTIL 2005. EIA assumes the country waits until just 3 three [sic] before the Kyoto mandates to start reducing emissions. That means, the country must reduce from a much higher levels of carbon emissions than if it started earlier, such as 2000. Even worse, this assumption gives the country far less time to act, only 3 years to meet the first target, forcing the economy to try to turn on a dime, rather than 8 years if we started in 2000. No consumer or industry who uses energy takes any anticipatory actions prior to 2005. While any person or company could dramatically reduce the impact if they started just a few years early, EIA forbids them from doing so. EIA undoes all voluntary commitments by industry (such as BP and the steel industry, which have said they will reduce to 10% below 1990 levels by 2010). EIA partly fixed this flaw in a later report, but the other flaws continue to render their conclusions indefensible.

EIA Response: Contrary to Dr. Romm's assertions, emissions reductions in EIA's 1998 Kyoto study begin earlier due to anticipatory actions in the electricity, refinery, and natural gas pipeline industries in the National Energy Modeling System. Furthermore, a later study assumes earlier reductions in all sectors.

EIA believes it is highly unlikely that energy consumers will make major changes in their choice of energy equipment or their use of energy services in the absence of price changes or policy initiatives, such as standards or other regulatory actions. Historically, end-use consumers (residential, commercial, industrial, and transportation consumers) have reacted to current prices, as evidenced by the current heating oil situation, not projected future prices of energy when making decisions, and to many noneconomic factors such as size, comfort, style, and vehicle horsepower. Extensive empirical research indicates that energy prices play a minor role in consumers' home or appliance buying decisions. Builders of houses, for example, make decisions based on the cost of equipment rather than life-cycle cost; life-cycle costs are more likely to be used by homeowners who remain stationary for long periods and do not rent. Since, on average, homeowners move every 7 years, the average homeowner is more likely to consider the up-front cost of the equipment than the long-term fuel costs of running that equipment. Profit-maximizing firms, such as electricity producers, refineries, and pipeline distribution companies, have a greater incentive to consider future prices in their capital investment decisions, which is factored into the EIA analysis with their adjustments beginning in 1999. As a result, some reductions in carbon emissions occur prior to 2005.

In preparing the analysis, EIA followed the specific instructions of the Committee in its request to impose a carbon price on energy beginning in 2005. Carbon reductions begin prior to 2005 because of the anticipatory behavior noted above. As a result of the anticipatory behavior by the capital-intensive energy producers and the non-zero carbon price beginning in 2005, the study projects demonstrable progress toward reducing carbon emissions in 2005, which is required by the Protocol.

However, at the request of the same Committee, EIA prepared a follow-on study, *Analysis of the Impacts of an Early Start for Compliance with the Kyoto Protocol*, published in July 1999. In this study, the carbon price is imposed beginning in 2000 to achieve a longer transition period to the commitment period in the Protocol, 2008 to 2012. In 2010, the carbon price is reduced by $5 to $32, or 7 to 9 percent, with the earlier start date. With an earlier start date, the economy experiences a loss in gross domestic product (GDP) beginning in 2000; however, the transition of the economy to the longer run target is smoother. The loss in actual GDP in the early start cases between 2000 and 2005 is between half and nearly three-quarters of the loss in the cases with the 2005 start date between 2005 and 2010. In 2010, the GDP loss with the 2000 start date is about one-third to one-half the loss than with the 2005 start date.

Romm alleges that we undo all voluntary commitments; however, past reaction to voluntary initiatives to reduce energy use has been incorporated to the extent that the reductions appear in the data. Although this approach may be viewed as conservative by Dr. Romm, it is warranted by the response to previous voluntary initiatives, such as those contained in the Climate Change Action Plan (CCAP) of 1993. CCAP was the Administration's response to the original Framework Convention on Climate Change negotiated in the international arena in 1992. Greenhouse gas emissions have continued to grow each year since CCAP was formulated and announced in 1993 although the growth slowed in 1998, and no one now expects that U.S. greenhouse gas emissions will return to 1990 levels in 2000, as CCAP originally projected.

EIA is quite familiar with voluntary actions since it collects data on voluntary reductions of greenhouse gas emissions through Form EIA-1605, "Voluntary Reporting of Greenhouse Gases." However, the meaning and use of these numbers need to be carefully evaluated. Some reporters provide reductions from an anticipated baseline, i.e., the level that emissions would have reached if emissions reduction actions had not taken place, and others provide reductions based on an historical level of emissions actually experienced. To the extent that the reported reductions are in the data, they are already included in our baseline. Thus, counting them as additional reductions would double-count their contribution.

For instance, if an oil company is reducing production of refined products, its emissions would be reduced. However, if the U.S. economy is growing and our consumption of petroleum in the United States is increasing, those reductions would be offset by another refiner and thus not reduce the total emissions projected in the baseline. The evaluation that needs to take place is whether a company's portfolio of emitting assets has changed over time through acquisitions and divestitures and whether the particular action that the company has taken is one that is reflected in the baseline forecast.

Romm Assertion: FLAW #2: EIA ASSUMES THE U.S. GOVERNMENT NEVER INSTITUTES A SINGLE POLICY TO REDUCE THE IMPACT OF KYOTO. EIA assumes that, after waiting until the last possible moment to mandate that the country meet the Kyoto targets, the government passes not a single law or tax break or utility deregulation bill to make it easier to reduce emissions. So this is truly an irrelevant exercise, since it models the one thing that will never happen. EIA even ignores key ongoing policies and trends that would temper their results:

EIA freezes all utility deregulation and restructuring efforts for the next two decades. Competitive pricing (based on marginal costs) of electricity is allowed only in California, New York, and New England, regions which do not account for much coal use. Everywhere else, regulated pricing (based on average price) is used through 2020 even though EIA acknowledges "this may not be appropriate in the near future" and that under competitive pricing "it is easier for suppliers to meet the carbon reduction goals, and the carbon price is lower, than it would be under average cost pricing." As discussed below, deregulation is fostering energy outsourcing, which will likely slow energy and GHG growth nationwide significantly.

EIA Response: As a policy neutral organization, EIA does not speculate on the future development and enactment of energy policies and programs, and this approach is made clear to the readers in all our analyses. This assumption is used in developing the *Annual Energy Outlook* reference case and all analyses performed as a service request, unless the client requests us to incorporate policy initiatives which they have specified. Such a request could easily have been made by Dr. Romm in his earlier capacity as Acting Assistant Secretary for Energy Efficiency and Renewable Energy. In the Kyoto study, the Committee requested us to use policies and other assumptions as incorporated in the *Annual Energy Outlook 1998* (*AEO98*): "use *AEO98* policy, technology and market assumptions—that is, no additional policies or funding should be assumed." By relying on market forces to reduce carbon emissions, the policymakers understand the costs of meeting the Kyoto Protocol in the absence of new policies and legislative initiatives. Even policies and initiatives, such as information programs designed to facilitate the operation of markets, have a cost that may not be fully captured if they are simply assumed to occur, reducing energy consumption and emissions. Also, the assumption of future policies could bias the results of the analysis, since some policies might lower the cost of compliance while others, intended to achieve different goals, could actually raise it. For instance, the Powerplant and Industrial Fuel Use Act of 1978 curtailed the use of natural gas for new generating capacity resulting in additional construction of coal-fired power plants. These plants are currently some of the lowest cost producers of electricity in this country. This policy, intended to make natural gas available to high priority customers, particularly in the residential sector, in fact has raised the cost of complying with the Kyoto Protocol in this country. The impacts of potential policy initiatives are analyzed in the report in cases that explore competitive electricity pricing throughout the country, alternative consumer behavior, actions to preserve the share of coal-fired electricity generation, limitations on biomass generation, and the construction of new nuclear plants.

Regarding the restructuring of the electricity industry, in accordance with the Committee's request, the assumptions for the reference case in the Kyoto analysis and the primary reduction cases are those in the *AEO98*. The changing structure of the electricity industry is explicitly recognized by representing competitive wholesale markets, i.e., no new rate-based capacity, in all regions of the country and by pricing electricity at the retail level competitively, based on marginal costs, in three regions—California, New York, and New England.

Recognizing the potential for increasing competition in retail electricity markets throughout the United States, EIA included a sensitivity case that assumed full competitive pricing on pages 88 and 89 of the Kyoto analysis, in which all regions in the country are assumed to price electricity at the marginal cost. As expected, electricity prices are slightly higher under full marginal cost pricing and the carbon price is slightly lower; however, full competitive pricing does not have an appreciable impact on the cost of meeting the Kyoto Protocol. To date, small retail consumers have generally been slow to adopt options for competitive power marketing; however, the opportunities have been somewhat limited and possibly constrained by other factors, such as transition costs.

All new technologies—fossil, renewable and nuclear—compete to meet the growing demand for electricity. Depending on the economics, the EIA model decides whether to continue operating existing capacity, which is assumed to produce electricity more economically than in the past; retire existing capacity early if it becomes uneconomic to operate; or build new capacity to meet demand. Cleaner, more thermally efficient technologies are chosen when it is economical to do so. In the reference case, more than 100 gigawatts of capacity, mostly oil/gas steam and nuclear plants, are retired and replaced with newer, more-efficient plants. It is for these reasons that electricity prices in the reference case declined by 20 percent by 2020. However, our analysis of the Kyoto Protocol suggests that it will take fairly high carbon prices before it makes economic sense to retire existing coal plants. Despite the fact that existing coal plants are the major source of many emissions, they are extremely economical, producing some of the lowest-cost power in the country. It is true that new, thermally efficient natural gas plants are expected to dominate new plant additions over the next 10 to 20 years, but their costs are not low enough to displace existing coal plants, many of which are fully depreciated. Many of today's coal plants produce power at half the cost of building and operating a new natural gas plant. As a result, in order to stimulate the retirement of existing coal plants in a market-based environment, the carbon price would have to be quite high.

Romm Assertion: FLAW #3: EIA TECHNOLOGY ASSUMPTIONS YIELD "GARBAGE IN, GARBAGE OUT" RESULTS. EIA ignores or artificially limits technologies that every other major study has indicated would play a major role in reducing the impact of Kyoto. Here are just a few key errors:

- COGENERATION: This is widely seen as a major greenhouse gas reducer since it cuts carbon emissions by about half with no increase in energy costs, and, with technology now coming on the market, a decrease in electricity costs. (Britain expects to double cogen from 1990 to 2010, accounting for about 20% of its Kyoto reductions.) Yet, for EIA, even if coal prices rise 700% and electricity prices double, cogeneration rises only 3% to 4% compared to the baseline in 2010—and it remains flat from 2010 to 2020! Even more amazing, with delivered coal prices averaging about 6 times higher from 2010 to 2020, industrial use of steam coal remains flat during that time.

- FUEL CELLS: EIA projects that even under the most extreme scenario, carbon at over $300 a ton, which nearly doubles electricity prices, fuel cells will provide no electricity—not even 100 Megawatts—through 2020. EIA, in examining the potential for fuel cells to achieve 3- to 4-year paybacks in buildings concludes "the likelihood of such substantial improvements in the next two decades is small." This view is contrary to virtually every other technical projection.

- RENEWABLES: EIA artificially constrains key renewables, such as wind. As a result, even when carbon and electricity prices soar through the roof, renewables hardly budge. Utilities are the one sector that (supposedly) acts with foresight—indeed, with "perfect foresight of carbon prices for capacity planning." Yet, knowing that the price of delivered coal is about to jump 350% and electricity prices by 50%, renewable capacity is only 2% higher than the reference case in 2005 and 9% higher in 2010. In the 2010-3% case, where electricity prices nearly double, renewables in 2010 are only 18% higher.

EIA Response: Cogeneration. Since cogeneration has already penetrated the industrial market in the most favorable industries, continued rapid growth is unlikely in the absence of regulatory and market changes. Shipments of new boilers to large industrial facilities have been very low in recent years. Lighter industrial (i.e., manufacturers of industrial equipment, fabricated metal products, or electronic equipment) or commercial facilities are not expected to find these as attractive because of their less intensive energy use characteristics. In addition, many of the existing cogeneration facilities were brought on when utilities were required to purchase their power under the Public Utility Regulatory Policy Act at administratively set avoided costs which were much higher than they are today. In today's market, avoided costs are often set by competitive bid rather than being set administratively. The development of new cogeneration facilities has slowed in recent years because of low wholesale power prices and the creation of exempt wholesale generators (EWGs) in the Energy Policy Act of 1992. With the creation of EWGs, power plant developers, including utilities, are able to develop independent projects without being designated a public utility subject to extensive regulation under the Public Utility Holding Company Act. This has reduced the incentive of power plant developers to build a qualifying cogenerator rather than an independent power facility.

Cogeneration facilities can be very efficient because of their use of the waste energy from the generation of electricity to produce heat or steam for other uses. However, these facilities can be very expensive, especially if they have to be retrofit into facilities that were not originally designed for them. For example, the high costs of tearing up city streets to install piping and conduit for a combined heat and power facility may overwhelm the efficiency savings. Two additional factors reduce the cogeneration potential in the EIA Kyoto analysis. One is that those industries that most heavily use cogeneration are projected to have lower output in the carbon cases, due to the impact of higher energy prices on economic growth and industrial output. This reduces the steam requirements which attenuates the already reduced potential for cogeneration. The second factor is that most growth in cogeneration is projected to involve natural gas rather than steam coal. The price of steam coal is basically irrelevant to the decision to add additional cogeneration capacity. However, the price of natural gas is an important factor in the economics of cogeneration. For example, in the most stringent case in the Kyoto analysis, in which U.S. energy-related carbon emissions were constrained to 7 percent below 1990 levels in 2010, EIA's delivered price of natural gas increases by 290 percent, while the delivered price of electricity increases by 190 percent. Thus, the economics of cogeneration technologies using natural gas do not improve greatly under the Kyoto Protocol, compared to purchasing electricity directly.

Regarding the industrial use of steam coal in the 2010 to 2020 time period, the delivered price of coal follows the carbon price in that period, which declines in five of the six cases. Thus, it is not surprising that the use of coal would not decline.

We note that for the *Annual Energy Outlook 2000*, we have included a more explicit representation of industrial cogeneration in the National Energy Modeling System, as well as distributed generation from fuel cells and photovoltaics.

Fuel Cells. Fuel cells will have to overcome significant challenges if they are to play a major role in central station generation. They are more than four times as expensive and only about 15 percent more energy efficient than new advanced combined-cycle plants. Even with the very high fossil fuel prices in the most stringent case, the slight efficiency advantage of fuel cells over advanced combined-cycle units is not enough to overcome their much higher capital costs. Fuel cells do have the advantage of being smaller, quieter, and lower emitting than advanced combined-cycle units, and this may make them attractive in some specialized applications. However, without significant cost declines, they are unlikely to be broadly competitive.

In the Kyoto analysis, we included fuel cell technology for automobiles; however, it was not economically competitive with other technologies. In the report, we also prepared an analysis of the potential penetration of fuel cells and photovoltaics in the residential and commercial sectors under a variety of assumptions on cost reductions, performance improvements, financing options, and tax credits. Although with the most favorable assumptions possible, payback periods for fuel cells could be reduced to one year, the assumptions required are deemed unrealistic. It is more likely that paybacks within 3 to 4 years would be needed for significant penetration; however, the substantial improvements needed even for the 3- to 4-year payback period are highly unlikely within the next two decades. As noted above, the representation of distributed generation by these technologies was added to the National Energy Modeling System for the *Annual Energy Outlook.*

It possible that fuel cells could play a larger role in providing distributed power in certain niche markets where additional factors might affect the economics of the technology relative to central station generation. For example, some establishments, such as Internet server providers and financial institutions, may have a demand for extremely reliable power and use fuel cells or other distributed generation technologies as a backup source. Other sites may be located at enough distance from central generating plants to make the transmission and distribution costs prohibitively expensive. We are continuing to evaluate the opportunity for fuel cells in certain niche markets.

EIA's analysis shows that the most economical carbon reduction option in the central-station generation sector is the replacement of existing coal plants with advanced gas plants. In our most stringent reduction case, more than 300 gigawatts of new advanced gas technologies are expected to be built. These new gas plants could include a mix of advanced turbines, combined-cycle, fuel cells, and cogeneration units. The role played by each of these technologies will depend on how their cost and performance characteristics evolve over the next 10 to 20 years. In today's market, new combined-cycle units appear to be poised to capture the lion's share of the market for new advanced gas technologies. They are both relatively low cost and very efficient. However, beyond the next 10 years or so it becomes very difficult to determine which of the advanced natural gas technologies will be most important. It may be best to think of the gas plants built after 2010 as simply "advanced gas" rather than labeling them as a specific technology.

Renewables. Renewables are projected to play a major role in reducing carbon emissions from electricity generation. In our most stringent reduction case, renewable generating capacity (excluding cogenerators) is 25 percent higher than in the reference case by 2010, rather than the 9-percent figure cited by Dr. Romm, which appears to be using the case in which carbon emissions can increase to 9 percent above 1990 levels. This pattern continues through 2020, when renewable capacity in the most stringent case is twice the level in the reference case. The increase is even larger when conventional hydroelectric capacity, which is expected to grow only slightly, is excluded. Total nonhydroelectric renewable capacity is 175 and 689 percent above the reference case levels in 2010 and 2020, respectively. By 2020, in the most stringent case, wind and biomass capacity are both 27 times their respective current levels.

The representation of renewables in the National Energy Modeling System reflects the realities of the marketplace, not artificial constraints. EIA represents only real-world constraints on renewable resources for electricity generation and imposes them in three areas. First, prices increase if renewable generating technology construction grows at a very rapid rate, more than 30 percent in a single year, to represent manufacturing, licensing, siting, and any other short-term bottlenecks occurring under very rapid expansion. For each percentage increase beyond 30 percent, the cost of the next plant is increased by 1 percent. In other words, if a particular technology's capacity increased by 35 percent in a single year, its construction costs are increased by 5 percent. This is a very conservative way of estimating the higher costs that are likely to occur as a result of a "crash" program. Second, the penetration of intermittent technologies, such as solar photovoltaics and wind, is constrained to a maximum of 10 percent of any region's total annual generation although for some hours the value can far exceed 10 percent. The 10-percent generation limit represents concerns about regional system stability in the presence of high proportions of rapidly varying intermittent power. Consultations with experts suggested 10 to 15 percent as a practical bound, even though levels this high have never occurred in the United States. Third, after a review of several detailed regional estimates of biomass and wind resource supply curves, we adjusted our supply curves to account for the cost impacts of factors not considered in their original development. These factors included the cost of more difficult or less productive terrain, increased investments required in the existing distribution and transmission systems to accommodate high levels of intermittents separate from interconnection costs, and competition from alternative uses for wind and biomass resources. These costs closely match the more detailed ones developed by State energy commissions and other regional planning organizations.

The Kyoto analysis used cost estimates developed in 1997, at which time our estimate for wind technology cost in 2010 was about $700 per kilowatt, declining from a base cost in 1998 of about $1,000 per kilowatt. However, in light of extensive additional information on current wind cost and performance since the Kyoto analysis and based on actual new wind capacity recently installed in the United States, in 1999 we raised the estimates of current wind costs and slowed the rate of expected future declines. Although capital cost information is very difficult to obtain, the average published capital cost for 350 megawatts of new wind capacity entering service in the United States in 1999 exceeded $1,250 per kilowatt; we found no instance for which the cost was below $1,100 per kilowatt. Furthermore, while we believe that wind technology will continue to improve, we find no empirical evidence that it will reach $700 per kilowatt by 2010. Despite stated expectations of large capital cost decreases for wind power, the installation of hundreds of megawatts of wind power in the United States and thousands of megawatts outside the United States in 1998 and 1999 resulted in no concrete evidence of any discernible drops in wind power costs. Thus, under the reference case assumptions underlying the *Annual Energy Outlook 2000*, released in November 1999, we are of the opinion that wind power costs are likely to remain above $900 per kilowatt through 2010. Comparing our estimated costs to others, our estimate for 2010 is nearly 40 percent greater than the estimate of $675 per kilowatt used by the Department of Energy's Office of Energy Efficiency and Renewable Energy (EE) but nearly 15 percent lower than current cost estimates for this technology. Our capacity factors for wind power average around 34 percent in 2010, very close to EE's estimate for class 4 wind resources of 36 percent.

With respect to photovoltaics (PV), we assume PV would cost about $2,434 per kilowatt and operate at a 28-percent capacity factor in 2010, a substantial decrease for a technology whose current central station cost probably exceeds $4,000 per kilowatt at less than a 20-percent capacity factor. While EE has a lower cost estimate of $1,500 per kilowatt, they also assume a lower capacity factor of 21 percent for thin-film PV in 2010. Adjusting for the difference in capacity factor, our assumptions provide total costs that are comparable with those of EE. As discussed on Page 48 of the Kyoto report, small scale and off-grid PV are even more expensive, less reliable, and less competitive than central station PV. Information available from California and Maryland programs supporting small-scale residential PV suggests an average, commercially-installed cost above $8,000 per kilowatt today.

The major reason that renewables do not capture a bigger share of the market is that they are not cost competitive with other alternatives, particularly advanced gas technologies. Only when the carbon price becomes quite large do these technologies become economical. We recognize that there are many uncertainties in projecting the future costs and performance characteristics of renewables, particularly at the levels of expansion possible if the Kyoto Protocol emission target is met. However, we have not unreasonably constrained or overestimated the future costs of renewables. As noted above for fuel cells, it is possible that the renewable technologies could have a larger role in distributed generation in some niche markets where other factors change the underlying economics, particularly if the costs decline; however, these will remain a small share of total energy consumption over the next twenty years. In the *Annual Energy Outlook 2000*, these technologies are not competitive against retail electricity prices. We continue to evaluate these markets.

Romm Assertion: FLAW #4: EIA uses the "highly inappropriate" DRI model for calculating economic impact. As Dale Jorgenson and William Nordhaus wrote in April 24, 1997 in their review of the Administration's climate modeling effort—an effort that EIA participated in:

> "The DRI model is probably the best known short-term forecasting model for the U.S. economy. This model is especially appropriate for projecting the impacts of monetary and fiscal policy over a time horizon of approximately two or three years. For longer term projections, however, it is highly inappropriate and has some important limitations that are well-known to the community of economic forecasters. For example, the DRI long term projections are extremely sensitive to assumptions about energy prices. This feature is totally at odds with most empirical work and with the practice of government agencies that produce such projections."

In spite of its deeply flawed modeling, the EIA study finds that if carbon tax revenue is recycled through a reduction in either income or social security taxes, compliance with the Kyoto protocol can be achieved with "no appreciable change in the long-term (GDP) growth rate".

EIA Response: The DRI macroeconomic model was used for the economic analysis of this study because it better represents 2008 through 2012, the first commitment period of the Kyoto Protocol, than do the alternative macroeconomic models. Also, in our judgement, it is the best available macroeconomic forecasting tool to determine both the long-run, full employment impacts of the Kyoto Protocol, as well as the mid-term adjustment impacts that would occur as the U.S. economy and energy system undergo a transition to the Kyoto Protocol. The EIA study includes both the impact on Potential GDP, which is the long-run measure expressed in many macroeconomic models that is based on the economy being at full employment, and the impact on Actual GDP, which reflects the unemployment and inflationary aspects that could occur in implementing the Kyoto Protocol. To quote only the long-run impacts, which many studies have done, underestimates the costs of achieving the Protocol. While Dr. Romm correctly quotes the long-run conclusions of the economic analysis in the Kyoto analysis, it is important for policymakers to recognize the transitional costs.

In our design of the project, we investigated two alternative macroeconomic models and obtained results from one of them. These results were determined to be not as reliable as the DRI macroeconomic results by both us and our panel of independent expert reviewers. That panel included William Nordhaus of Yale University, William Hogan of Harvard University, John Weyant of Stanford University's Energy Modeling Forum, Michael Toman of Resources for the Future, and Lorna Greening, a consultant to Hagler Bailly. It was Dr. Nordhaus' suggestion to include the impact on both the Potential and Actual GDP and to include both monetary and fiscal policies in our calculations.

Our study assumes that the Federal government will run an auction to sell carbon permits and that it will recycle the funds back to the economy. The funds are recycled back to consumers via an income tax (lump sum) or social security tax rebate (reduction in the tax rates). This recycling has the effect of moderating the possible impacts on the economy. If the Federal government chooses not to recycle the funds and uses the collected funds to pay down the level of the Federal debt, the near-term effects could be more costly than stated in our study. Likewise, the EIA study assumes that monetary policy will respond to changes in inflation and unemployment in a way which moderates the possible impacts on the economy and returns the economy to its long-run growth path. Again, the loss in output could be greater if the Federal Reserve only responds to changes in inflation.

Romm Assertion: FLAW #5: EIA's long-term projections are invariably wrong and it is making the exact same mistakes it made when EIA overestimated the cost of sulfur permits by a factor of four just a few years ago. In particular, EIA notes that just a few years ago, its first analysis of the cost of SO2 allowances under the Clean Air Act was projected at $423 a ton in 2000 (in 1996 dollars) rising to $751 a ton in 2010. "Currently, the cost of an allowance is $95 a ton, and AEO98 projects that the cost will be $121 a ton in 2000 and $189 a ton in 2010." Why was EIA wrong?

- "There has also been downward pressure on short-run allowance costs because generators have taken actions to comply with the SO2 limitations earlier than anticipated."

- "There has been more fuel switching to low-sulfur, low cost-Western coal than previously anticipated."

- Finally, technology improvements have lowered the costs of flue-gas desulfurization technologies, or scrubbers.... The cost of SO2 compliance was overestimated to a large extent because compliance relied on scrubbing, a relatively new technology with which there was little experience."

These are exactly the reasons EIA is once again wrong by a factor of 4. They have forbidden all energy users — and the federal government—to take any anticipatory actions. They have overestimated the cost and underestimated the opportunity for fuel switching to low-carbon fuels (like gas and renewables). And they have ignored the role of key technologies, including cogeneration, fuel cells, and advanced end-use efficiency. Since this analysis has nothing to do with how the government, businesses, or consumers will act in the real world, the study is wholly irrelevant and has no bearing on "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity."

EIA Response: While analyses performed in the mid to late 1980s had everyone overestimating the sulfur allowance costs that were ultimately realized when the Clean Air Act Amendments of 1990 (CAAA90) went into effect, I must point out that we have been correct in our analyses of other policy initiatives. When CCAP was formulated and released in 1993, most analyses showed that CCAP would achieve its goal of stabilizing net greenhouse gas emissions in the United States at 1990 levels by 2000. EIA was soundly criticized when its first analysis including the impacts of CCAP projected carbon emissions continuing to increase to 1,471 million metric tons in 2000; however, since emissions in 1998 reached 1,485 million metric tons, our analysis appears to have been more correct than others although we recognize that the CCAP initiatives were not funded to the extent initially requested.

There are many reasons why historical projections of SO_2 allowance costs, both EIA's and others, have proven to be much too high. The key factors include changes in the legislation not incorporated in early analyses, such as emissions banking and bonus allowances, falling emissions control technology costs, and much lower-than-expected coal prices. By far the most important of these was the rapid decline in coal prices, particularly for low-sulfur Western coal. The price of coal delivered to power plants peaked around 1982, long before the passage of Clean Air Act Amendments of 1990 (CAAA90), and has been declining ever since. However, analyses performed in the late 1980s and early 1990s underestimated the extent of the decline that continued into the 1990s. This is especially true for low-sulfur coal prices that benefitted from both improved productivity at mines and declining rail rates. Between 1985 and 1990, average real delivered coal prices to power plants, measured in dollars per ton, declined by 26 percent, and between 1990 and 1996, they declined by another 26 percent. This unanticipated sharp decline in the price of coal has made it economical for plants to switch to lower-sulfur coal. It has even encouraged many plants not originally included in Phase I of the CAAA90 to opt in before Phase II begins in 2000.

It is not clear whether the passage of the CAAA90 had any influence on coal prices. However, it is clear that any study is limited by the uncertainty about future changes in energy markets. It is for this reason that EIA's analysis of the Kyoto Protocol includes 18 cases. Each of these cases illustrates the impacts of key assumptions on the results. For example, there are six cases incorporating different U.S. carbon reduction targets in 2010, ranging from 24 percent above 1990 levels (1,668 million metric tons) to 7 percent below 1990 levels (1,243 million metric tons). These cases represent different levels of energy-related reductions needed within the United States to reach the various targets. The remainder of the reductions would be obtained from international activities, carbon-absorbing sinks, and offsets from other gases included in the Protocol. These cases show the importance of various efforts to reduce domestic carbon emissions. The range of cases is also designed to reflect the uncertainties concerning the various flexibility measures in the Protocol, for which the rules and procedures have yet to be determined. In the 24-percent-above-1990 case, where extensive international trading of carbon permits and other flexibility measures account for about 80 percent of the reductions, the carbon price is only $67 per metric ton in 2010. In the 7-percent-below-1990 case, where all reductions are made through domestic, energy-related carbon emissions, the carbon price is nearly $350 per metric ton.

There are additional sensitivity cases which examine the impacts of alternative economic growth, technological progress, and consumer responsiveness assumptions; and also cases which examine the impacts of allowing or not allowing new nuclear or biomass to be built; maintaining some portion of the domestic coal industry; and representing the effect of national competitive electricity pricing. Each case is designed to illustrate the potential impacts of many of the very real uncertainties in future energy markets.

The technology sensitivity cases are of particular interest, considering Dr. Romm's claim that we ignored the role of technology improvements, including advanced end-use efficiency. For the 9-percent-above-1990 case, in which carbon emissions in 2010 reach 1,462 million metric tons, we looked at the impacts of slower and more rapid technology development. The high technology case includes more optimistic assumptions on the costs, efficiencies, market potential, and year of availability for the more advanced generating and end-use technologies and also includes carbon sequestration technology for coal- and natural-gas fired generation. The low technology case assumes that all future equipment choices are made from the end-use and generation equipment available in 1998, with building shell and industrial plant efficiencies frozen at 1998 levels. In the low technology case, total energy consumption is higher by 1.5 quadrillion Btu, or 1.5 percent, in 2010 than in the 9-percent-above-1990 case with reference technology assumptions, and the carbon price in 2010 is increased from $163 per metric ton to $243 per metric ton. This clearly demonstrates the amount of technology improvement available with our reference case assumptions. In the high technology case, total energy consumption is lower by 2.1 quadrillion Btu, or 2 percent, in 2010, and the carbon price is reduced from $163 per metric ton to $121 per metric ton, illustrating the potential for advanced technologies.

Reducing U.S. carbon emissions will be a complex undertaking with many uncertainties. Each of the cases in EIA's report examines the impacts of alternative assumptions in a key area of uncertainty, and the number of cases presented reflects our concern for presenting a balanced analysis. It is not intended that the results of any single case be highlighted. Rather, the results of each of the cases should be examined to gain an understanding of the factors that will influence the costs to the United States to meet the commitments of the Kyoto Protocol, if it so chooses.

Any analysis, particularly one providing projections of future energy market trends, is subject to a wide range of uncertainties and potentials for error. This is one reason why EIA provides a number of alternative cases, both in the Kyoto analysis and in its *Annual Energy Outlook*. Each year we also review past projections, compare them to history, and publish the results. This review is also used as a means of evaluating and improving our methods and projections in the future. As a further check on our work, we compare our projections to those of other organizations, also publishing them in the *Annual Energy Outlook* and the Kyoto report. In the Kyoto report, the alternative projections were carefully reviewed and a lengthy analysis prepared on the differences among the projections and the underlying causes, in order to further enhance the value of the document to policymakers.

Thank you for the opportunity to respond to these questions. We will be happy to provide you with any additional information on these topics.

Sincerely,

Jay E. Hakes
Administrator
Energy Information Administration

cc: The Honorable Dan Burton
The Honorable Dennis Kucinich

ONE HUNDRED SIXTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON GOVERNMENT REFORM
2157 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6143

MAJORITY (202) 225–5074
MINORITY (202) 225–5051
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January 27, 2000

Via Facsimile
Robert Perciasepe,
Assistant Administrator, Office of Air and Radiation
1200 Pennsylvania Avenue NW
Washington, DC 20460
FAX: (202) 501-0986

Dear Mr. Perciasepe:

I am writing to request written comments on the impact that the expected growth in the Internet economy is expected to have on both national energy demand and our ability to reduce carbon emissions.

On February 2, 2000, the Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs of the House Committee on Government Reform is having a hearing on this subject and has invited Jay Hakes, Administrator of the Energy Information Administration, Mark Mills of Mills, McCarthy and Associates, and Joseph Romm, Executive Director of the Center for Energy and Climate Solutions to testify on the issue. I am aware that on December 15, 1999, John A. "Skip" Laitner of the EPA prepared a working paper on this issue. Because the EPA has expertise in this area and the subcommittee has not invited anyone from the Administration to testify, I would like your comments on the issue.

If you have any questions with regard to this request, please contact Elizabeth Mundinger of my staff at (202) 225-5051.

Thank you, in advance, for your assistance in this matter.

Sincerely,

Dennis J. Kucinich

Dennis Kucinich
Ranking Minority Member
Subcommittee on National Economic Growth

cc Subcommittee members

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 6 2000

OFFICE OF
AIR AND RADIATION

Honorable Dennis Kucinich
Ranking Minority Member
Subcommittee on National Economic
Growth, Natural Resources, and Regulatory Affairs
Committee on Government Reform
U.S. House of Representatives
Washington, DC 20515-6143

Dear Mr. Kucinich:

I am pleased to respond to your January 27, 2000, request for our comments on the expected growth in the Internet economy and its resulting impact on national energy demand. I am attaching a draft analysis prepared by my staff on the issue. This preliminary analysis is a work in progress that was presented at a Clean Air Federal Advisory Subcommittee meeting in February. EPA is actively inviting peer-reviewed comments and suggestions.

This draft analysis indicates that the economy is changing as a result of the transition to an information-based economy. Preliminary evidence summarized in the draft study from the last three years seems to indicate that this transition may have an environmentally beneficial impact on the nation's energy consumption: the economy is adding more value in ways that seem to be using less energy. This seems to suggest the possibility that these changes identify a trend toward a somewhat smaller level of energy consumption compared to current economic projections (i.e., that energy use will grow more slowly than previous forecasts have indicated). If this proves to be the case, then the information economy, together with more investments in energy efficient technologies, will benefit the nation's air quality and the global climate while continuing to increase our overall competitiveness.

In closing I would like to note that, EPA and DOE are working with a number of industries to encourage the development and adoption of a wide range of energy saving products, many of which apply the same engineering techniques used by the information and communication technologies. These voluntary industry partnerships increase the nation's overall energy efficiency by promoting the use of energy efficient technologies, including Energy Star computer systems and other office equipment.

I hope that this background proves useful to the Subcommittee. Please let me know how else we might be helpful in this regard.

Sincerely,

Bob Perciasepe

Robert Perciasepe
Assistant Administrator

The Information and Communication Technology Revolution: Can It Be Good for Both the Economy and the Climate?

Discussion Draft

John A. "Skip" Laitner
EPA Office of Atmospheric Programs
Washington, DC

December 15, 1999
(Revised January 31, 2000)

Abstract

The economy has shown a surprising decline in the rate of the nation's energy intensity over the past three years. Measured as the number of Btu's per dollar of Gross Domestic Product (GDP), the average annual rate of change is about -3.4 percent for the period 1996-99. In absolute terms this is significantly greater than the -2.6 percent rate of change in the 1973-86 "oil crisis" period. It is all the more surprising given the absence of any significant price signals or policy initiatives. Several recent papers have attempted to explain the change. One group of analysts cites the weather as the major contributor to the reduction in the nation's energy intensity while a second group references structural change as a primary driver. The latter refers to major shifts away from the energy-intensive industries as a source of economic well being, toward the less energy-intensive commercial services and light manufacturing segments of the economy.

This preliminary analysis is a further inquiry into this issue. The draft analysis extends the idea of structural change by examining the specific influence of the explosive growth within the information and communication technology (ICT) sectors. Preliminary evidence suggests that the growth in the ICT sectors — including the production of computers and peripheral equipment, software and programming services, communication services, and electronic commerce — may explain a significant part of the sharp decline in energy intensity. Moreover, continued growth in these sectors may lessen the growth in energy consumption compared to mainstream economic forecasts. Based upon a "first approximation" of the potential impact of structural change, mainstream projections of energy and carbon emissions may be overestimated by about 5 quads and 80 MtC. At the same time, the paper raises questions about the need to measure and evaluate the direct and indirect impact of ICT sectors on the nation's energy use (and the resulting emission of energy-related greenhouse gases). This draft report is a work in progress for which the author actively invites comments and suggestions.

The Information and Communication Technology Revolution:
Can It Be Good for Both the Economy and the Climate?

The deepest innovations, the ones that are most transforming of our condition, are the ones that are least anticipated or predicted. began to imagine computers in the 1930s (Babbage was too far ahead of his time), but even as the first ones were being built duri no one imagined their potential civilian applications. When the first mainframes were built, no one imagined the PC or the ubiquito Even in the 1980s when PCs came out for the wider market, few imagined the Internet. Yet that progression of innovations is pro having a greater impact on our lives than anything else of the 20th century. So much for long-term forecasting!

Stephen J. DeCanio (1999)

Introduction [1]

Since 1960 U.S. energy consumption has increased at roughly 63 percent of the rate at which the nation's economy has grown. In effect, the nation's energy intensity has declined at an average rate of -1.1 percent in the years 1960 through 1996.[2] For the years 1996 through 1999, however, this trend took a sharp turn, changing at the rate of -3.4 percent per year. In absolute terms this is significantly greater than the -2.6 percent rate of decline that occurred in the "oil crisis" years of 1973 to 1986 (Energy Information Administration, 1999a and 1999b).

The sharp decline in E/GDP in the years 1996 through 1998 has generated strong interest among analysts. Some attribute the majority of the change to weather. Boyd and Laitner (1999), however, suggest structural change as a major influence. A separate analysis by Laitner (1999a) indicates that weather accounts for only 25 percent of the change in the nation's energy intensity. Even with this correction it appears that the last three years show a rate of change similar to that of the 1973-86 period — in the absence of any significant price signal or major energy policy initiatives.

Clearly three years of data are not sufficient to confirm whether the change is a real trend rather than a simple anomaly. Yet, a number of analysts suggest that significant structural change may be real. Such change, in fact, may be driven by recent developments in the information and communication technologies, especially from the economic activity supported by electronic commerce. (Romm, 1999; Koomey, 1999; and Romm, Rosenfeld, and Herrmann, 1999).

[1] **This draft analysis is a preliminary inquiry specifically designed to invite comments from a wide variety of analysts within the economic and energy policy community. Your comments and insights are actively invited.** Please send them to: Skip Laitner, (202) 564-9833, or by email at Laitner.Skip@epa.gov.

[2] The nation's energy intensity is usually measured as the number of Btus of primary per dollar of GDP. The dollar value is denominated in chained 1992 dollars. In 1960, for example, this E/GDP ratio was 19.36 thousand Btus (kBtus) per dollar of GDP. By 1996 the ratio declined to 13.10 kBtus. In 1999 the ratio is estimated to be 11.83 kBtus per dollar.

This paper is a preliminary inquiry that addresses the question of whether the explosive growth of software and information technologies can significantly reduce the nation's energy use (with concomitant reductions in energy-related carbon emissions). More important, are these reduced energy intensities ones that enhance economic well being for the United States?

In 1970 the Internet consisted of just four university campuses connected by a highly limited network. Today it supports $300 billion in electronic commerce revenues (Iwata, 1999). Forrester Research (1999) suggests that by 2003, business to business commerce revenues will grow to $1.3 trillion. Both the Internet and the production of information goods and services are supported by an even larger set of industrial and commercial sectors (Henry, et al, 1999; and OECD, 1999). Yet, we know very little about the potential impact of these goods and services on the nation's rate of energy consumption. Admittedly, there are a number of data problems that limit any first attempt to evaluate that issue. Nonetheless, we can establish a reasonable analytical framework to illustrate or highlight the potential of the information age to increase the nation's energy productivity.

An Analytical Framework

Both Henry, et al (1999) and the OECD (1999) offer working definitions of what might constitute the information and communication technology (ICT) industry. Among the many segments are the production of computers and peripheral equipment, software and programming services, communication services, and electronic commerce involving both the Internet (including the world-wide web) and the many private and public-sector Intranets. Although it is difficult to assign a firm value to the output of these combined sectors, for purposes of this analysis, and loosely following the information from the Department of Commerce (Henry, et al, 1999), the OECD (1999), and Iwata (1999), a working value of about $1.0 trillion will be assigned.

Drawing from the1996 input-output relationships within the U.S. economy, it appears that gross economic output is about $13.4 trillion (about twice the nation's GDP). Hence, the working definition of the ICT sector means that about 7.5 percent of output is generated from the production of information goods and services. Energy expenditures constitute about 4.4 percent of total output. For ICT it appears to be about 0.8 percent (i.e., not very energy intensive).[1]

Drawing from the Annual Energy Outlook 2000 projections (EIA, 1999), the nation's energy use by 2010 is expected to grow by about 13.4 percent over the year 2000 level of consumption. In simplified terms, the increase in energy use is determined by a yearly economic growth rate of 2.32 percent and an average annual change of -1.04 percent in the nation's energy intensity.

[1] Since value-added is approximately 50 percent of total gross output, this implies that energy expenditures are roughly 8 percent of GDP. In addition, OECD suggests that ICT-producing sectors are about 8 percent of U.S. GDP in 1998, contributing about 35 percent of the growth. This implies that the assumption of a $1 trillion gross output for the ICT sector is reasonably in line with the OECD estimate.

Starting with this information we can set up an analytical framework to help us explore the potential energy impact of a sectoral shift in favor of the ICT sectors. For purposes of this analysis, let us examine the following initial conditions that appear to hold for the AEO 2000 reference case: (i) the economy-wide rate of expansion is 2.32 percent per year; (ii) normal efficiency improvements across all sectors will reduce the nation's energy intensity by -0.92 percent per year; (iii) the non-ICT sectors of the economy (with a 92.5 percent market share in the year 2000) will grow at 2.22 percent annually; and (iv) the ICT sectors (with an initial 7.5 percent market share in the year 2000) will grow at 4.00 percent annually.

Illustrating the Growth of the Information and Communication Technology Sectors on the Nation's Overall Energy Use in the Period 2000 through 2010

Average Annual Growth Rate of ICT Sectors	*Average Annual Growth Rate in Nation's E/GDP*	*2010 Energy Consumption (Quads)*
	Assuming a 2.32 percent overall economic growth	
0.040	-0.0104	111.26
0.060	-0.0120	109.46
0.080	-0.0139	107.32
0.100	-0.0163	104.80
0.120	-0.0191	101.83
	Assuming a 2.6 percent overall economic growth	
0.040	-0.0102	114.54
0.060	-0.0117	112.73
0.080	-0.0136	110.60
0.100	-0.0159	108.07
0.120	-0.0186	105.10
	Assuming a 3.0 percent overall economic growth	
0.040	-0.0099	119.42
0.060	-0.0114	117.62
0.080	-0.0132	115.48
0.100	-0.0154	112.96
0.120	-0.0180	109.99

With these parameters established for the reference case, it turns out that structural change combined with normal energy efficiency improvements will induce a slightly faster change in the nation's overall energy intensity. In short, the 4.00 percent growth in the ICT sector — compared to overall economic growth of 2.32 percent — means that the E/GDP ratio will change at an average annual rate of -1.04 percent instead of -0.92 percent annually. Assuming the same 2.32 percent rate of overall economic growth in the years 2000 through 2010, energy consumption would increase by 13.36 percent by the year 2010 (rising to 111.26 quads in 2010 compared to a year 2000 estimate of 98.15 quads).

The table above shows how different levels of growth in the ICT sector might shape a different level of energy consumption than normally predicted. It also highlights the very real prospect that an accelerated ICT-sector growth might drive a more rapid overall economic growth, shown in the table as both a 2.6 percent and a 3.0 percent average annual growth rate.

The first third of the table shows how structural change might affect U.S. energy consumption if we continue to assume the mainstream forecast of an annual 2.32 percent rate of growth in the nation's economy. For example, if the ICT sectors grow at 10 percent annually, and if we assume no other efficiency improvements within the overall economy, then the nation's energy intensity would change by -1.63 percent. The implication here is that energy consumption in the year 2010 would then be only 104.88 quads, about 5.7 percent below the forecasted level for year 2010 but still 6.9 percent about the anticipated level for the year 2000 (or 98.15 quads).

On the other hand, the last third of the table shows how structural change might affect U.S. energy consumption if we assume an annual 3.0 percent rate of growth in the nation's economy. Presumably, this higher level of growth would be driven by the growth in the ICT-sectors of the economy. Again, the analysis holds constant the change attributable to energy efficiency gains at -0.92 percent per year. In this case, if the ICT sectors grow at 8.00 percent annually, the average annual growth in E/GDP will be -1.32 percent. Energy use would be expected to jump to 115.48 quads by 2010. But if the ICT sectors were to grow at a 12.00 percent annual rate, and if we again assume no other efficiency improvements within the overall economy, then the nation's energy use would increase to only 109.99 quads 2010. Here the structural change would drive the nation's energy intensity to change by -1.80 percent per year.

Regardless of assumptions about overall economic growth, it is clear that structural change driven by growth of ICT products and services will be an important force in determining the nation's overall energy use.

Further Comments

In the period 1990 through 1997, the rate of growth in the nation's economy averaged 2.6 percent per year. In contrast, the ICT-sectors — not including Internet and electronic commerce sales — grew at an average rate of 13.5 percent (Henry, et al, 1999). The OECD (1999) indicates that ICT-producing industries experienced a robust 10.4 percent average annual growth in a similar period of time. Estimates for electronic commerce also reflect double digit growth rates (Iwata, 1999; OECD, 1999). Hence, it appears that structural change may account for a significantly larger fraction of improvement in the nation's energy intensity.

At the same time, it appears that the nation's overall economic growth may surpass recent EIA estimates for precisely that same reason. If we assume an economic growth rate of 2.6 percent over the period 2000 through 2010 for the economy as a whole, and a 10 percent increase in the ICT sectors, then E/GDP might be expected to decline by 1.59 percent. This, in turn, would lead to an expected only 108.07 quads of energy use by 2010. This is a 3.19 quad reduction compared to the AEO 2000 reference case forecast.

Yet, electronic commerce may increase the normal rate of energy efficiency improvements as indicated by Romm, Rosenfeld, and Herrmann (1999). What might happen should these benefits increase the energy efficiency improvements such that E/GDP declines by an average annual rate of -1.25 percent rather than -0.92 percent? In that case, the 10 percent growth rate in the ICT sectors, coupled with the larger gains in energy efficiency just described, implies that E/GDP will decline an average of -1.91 percent per year.[1]

In energy terms, the difference between these two scenarios is significant. In the EIA reference case energy consumption is projected to be 111.26 quads in 2010. Assuming both a higher GDP, a slightly higher rate of efficiency improvement, and greater structural change as described above (as a result of the growth in the ICT-sectors), energy use would be only 104.57 quads. This is a 6.69 quad difference between the two projections. Assuming a carbon/energy ratio of 16 million metric tonnes (MtC) per quad, this implies a carbon emissions projection that is about 107 MtC lower by 2010.

From a policy perspective, a 6.54 percent growth (in the years between 2000 and 2010) is more manageable with respect to encouraging policies that support greenhouse gas reductions. For example, if the nation supports policies and programs that encourage a change of, say, a -1.75 percent rather than the projected -0.92 percent growth rate, and assuming 10 percent growth in the ICT sectors, energy use in the year 2010 would be only 1.26 percent above the year 2000 level. Yet, this analysis and many others raise more questions than they provide answers. Among the shortcomings, in no particular order, are the following issues:

(1) The analysis addresses the potential benefits from large-scale structural change, but it does not reflect any significant substitution effects. For example, if households order more groceries, books, clothing and other consumer goods through the growing electronic commerce channels, can we expect their own energy expenditures also be reduced when compared to their previous purchasing patterns?

(2) Would a better definition and measurement of the ICT-sectors, from both an economic and an energy perspective, either weaken or improve the supposed benefits that are described in the scenario analysis above?

[1] There is at least one analysis suggesting that the internet economy would actually increase the nation's energy consumption. However, at EPA's request, researchers at the Lawrence Berkeley National Laboratory (LBNL) evaluated the assumptions behind such a conclusion. The LBNL review found that the analysis overestimated the energy intensity of the internet by a factor of eight. See Koomey, 1999b.

(3) What are reasonable estimates of the anticipated ICT-sector growth rates, especially at the sub-sector level of the economy? How will these growth rates influence economic activity in other sectors of the economy?

(4) How will competition and innovation within the ICT-sectors affect productivity gains throughout the nation's economy? How will they impact other inflationary pressures?

(5) Is there a rebound effect that might be expected to diminish the energy savings benefit of the ICT-driven structural change? Studies on this issue suggest a small but important impact that might offset gross energy savings by perhaps 2-3 percent (Laitner, 1999b).

(6) Are there other tradeoffs not anticipated by the transition to an information-age economy, including a change in distributional benefits, a change in consumer or producer surpluses, the increased reliance on imported or critical materials, and other environmental and economic impacts?

(7) Will the resources devoted to ICT-infrastructure improvements reduce the opportunities for improvement in other sectors of the economy?

Conclusions

By 2006, nearly half of the U.S. labor force will be employed by industries that are either major producers or intensive users of information technologies and services (OECD, 1999). This implies a significant opportunity to encourage significant structural change in a way that enhances both economic output and climate benefits.

Notwithstanding the analytical weaknesses of a "first approximation," several conclusions seem to emerge. First, given the accelerated growth in the ICT-sectors of the economy, overall economic activity may increase significantly faster than typically is assumed by mainstream forecasts. This will have the tendency to increase expected levels of energy consumption and, therefore, greenhouse gas emissions. Second, the explosive growth in the ICT-producing sectors of the economy may prompt large structural changes that can reduce overall energy consumption. It appears that the latter influence may provide a net beneficial impact on the economy than is otherwise suggested within the literature. Based upon this "first approximation" this difference may be on the order of 5 quads and 80 MtC for the year 2010. However, a large number of analytical issues must be addressed before any confidence interval level can be assigned to the anticipated net benefits for both the economy and climate change.

References

[Boyd and Laitner, 1999] Boyd, Gale, and John A. "Skip" Laitner, "Recent Trends in the U.S. Energy Intensity (1977-1998): An Index Number Analysis, EPA Office of Atmospheric Programs, Washington, DC, January 2000 (forthcoming).

[DeCanio, 1999] DeCanio, Stephen J. Personal communication, October 1999.

[EIA, 1999a] Energy Information Administration, *Annual Energy Review 1998*, DOE/EIA-0384(98), U.S. Department of Energy, Washington, DC, July 1999.

[EIA, 1999b] Energy Information Administration, *Short Term Energy Outlook*, U.S. Department of Energy, Washington, DC, January 2000.

[EIA, 1999c] Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(00), U.S. Department of Energy, Washington, DC, December 1999.

[Forrester, 1999] Forrester Research, Inc., 1999

[Henry, et al, 1999] Henry, David, Sandra Cooke, Patricia Buckley, Jess Dumagan, Gurmukh Gill, Dennis Pastore, and Susan LaPorte, *The Emerging Digital Economy II*, U.S. Department of Commerce, Economics And Statistics Administration, Office of Policy Development, Washington, DC, June 1999.

[Iwata, 1999] Iwata, Edward, "Online Revolution Here to Stay: Venture Capitalists Say Internet is Under-Hyped," *San Francisco Examiner*, June 10, 1999.

[Koomey, 1999] Koomey, Jonathan G., personal communication, November 1999.

[Koomey, 1999b] Koomey, Jonathan, Kaoru Kawamoto, Bruce Nordman, Mary Ann Piette, and Richard E. Brown, "Initial comments on 'The Internet Begins with Coal,' A memo from Lawrence Berkeley National Laboratory to EPA's Skip Laitner, December 9, 1999. Available for downloading at http://enduse.lbl.gov/projects/infotech.html.

[Laitner, 1999a] Laitner, John A. "Skip", unpublished analysis on the impact of weather on changes in the nation's energy intensity, EPA Office of Atmospheric Programs, Washington, DC, October 1999.

[Laitner, 1999b] Laitner, John A. "Skip", "Energy efficiency: rebounding to a sound analytical perspective," *Energy Policy* (forthcoming), 1999.

[IMPLAN, 1998] Minnesota IMPLAN Group, Stillwater, MN, 1998.

[OECD, 1999] *The Economic and Social Impact of Electronic Commerce*, Paris, France, February 1999.

[Romm, 1999] Romm, Joseph, personal communication, November 1999.

[Romm, Rosenfeld, and Herrmann, 1999] Romm, Joseph, Arthur Rosenfeld, and Susan Herrmann, *The Internet Economy and Global Warming: A Scenario of the Impact of E-Commerce on Energy and the Environment,* The Center for Energy and Climate Solutions, The Global Environment and Technology Foundation, Arlington, VA, December 1999. Available for downloading at http://www.cool-companies.org.

ONE HUNDRED SIXTH CONGRESS

Congress of the United States

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February 9, 2000

Via Facsimile
Mr. Joseph Romm
Executive Director
Center for Energy and Climate Solutions
2727 29th Street, NW - 218
Washington, DC 20008
FAX: (202) 483-1062

Dear Mr. Romm:

Thank you for testifying at the Subcommittee's hearing on the Kyoto Protocol and the Internet. I was very interested in your testimony and am sorry I was unable to stay for the question and answer period.

As discussed at the hearing, I would like to ask you a few questions for the record. Please answer the following questions:

1) You testified about the phenomenon that arose in the last few years when the economy grew quickly while energy use did not. You testified that this could be evidence of a trend towards a more energy efficient economy. Have any other countries indicated that they can sustain economic growth without an increase in energy use or is this phenomenon limited to the United States?

2) If this trend continues, would it make it easier and cheaper for us to reach the goal of greenhouse gas emission reductions set out in the Kyoto Protocol?

3) Mr. Hakes testified that utility deregulation may lead to declining electricity prices, and if so, increased energy use. Given the status of utility deregulation efforts in many states, and pending federal deregulation legislation, what is your analysis of the effect of deregulation on future energy demand and greenhouse gas trends?

4) You mentioned that the Internet could lead to gains in energy efficiency. Could you give us some examples of how the Internet could make us more efficient?

5) Are there any other comments that you would like to add?

Thank you, in advance, for your assistance in this matter.

Sincerely,

Dennis J. Kucinich

Dennis Kucinich
Ranking Member
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs

cc Members of the Subcommittee

February 26, 2000

TO: ELIZABETH MUNDINGER
FROM: JOSEPH ROMM

RE: ANSWERS TO QUESTIONS

Sorry for the delay, but I've been traveling. I hope these aren't too late.

1. A number of other countries have reduced greenhouse gas emissions in recent years even as their economy has kept growing. For instance, from 1996 to 1998, China's emissions of carbon dioxide from fossil fuels dropped 7% while their GDP grew by some 16%. Over the same period, Germany's emissions dropped 5%, while GDP grew 4%, and the United Kingdom's emissions dropped 7.5% while GDP grew 5.5%. This is very suggestive that many different types of countries can have economic growth without a comparable rise in emissions.

2. If the trend continues of the Internet driving a more efficient economy and slower greenhouse gas growth, it will be easier to reach our reduction targets set out in the Kyoto Protocol. The key point is that if our growth in emissions has slowed compared to traditional forecasts, then less effort will be required to meet our targets, since less overall reduction will be required. It seems likely based simply on flaws in their modeling that EIA has overestimated the cost of carbon dioxide permits by the same margin they overestimated the cost of sulfur permits a few years ago—a factor of 4. If they have also overestimated the growth in greenhouse gas emissions over the next 10 years, however, then the cost of carbon permits may be lower still.

3. In the short-term, deregulation has not been good for energy efficiency, because it has led to the dramatic reduction of utility demand side management (DSM) programs, which were very successful in promoting energy efficiency. Over the next several years, however, I believe that deregulation will prove to have a powerfully beneficial effect on energy efficiency, that will more than compensate for the decline in DSM programs and the impact of declining electricity prices on energy demand.

Because of deregulation, a new trend has emerged that is revolutionizing corporate energy efficiency investments. Companies are starting to outsource their power needs altogether. In 1999, Ocean Spray announced a $100 million deal with the energy services division of Enron, an energy 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. Owens Corning, the fiberglass insulation manufacturer, later 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.

The potential impact of this trend is enormous. Companies like Ocean Spray, Owens Corning, and Ultramar 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, and PG&E, 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. I 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. If this scenario comes to pass, then energy outsourcing—and hence utility deregulation—will have a major impact on improving the nation's energy intensity in this decade.

4. One way the Internet Economy may be contributing to increased energy productivity is that the Information Technology sector, which includes computer manufacturing and software, is not very energy intensive (compared to sectors such as the paper industry and construction). If the IT sector continues to generate a large fraction of our economic growth, EPA projects that this alone will reduce energy consumption in 2010 by 5% compared to current forecasts.

Another big impact probably comes from business-to-business e-commerce. As more companies put their supply chain on the Internet, and reduce inventories, overproduction, unnecessary capital purchases, and mistaken orders, they achieve greater output with less energy consumption. Fed 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.*"

Compared to traditional companies, internet firms require less square footage and, we calculate, under one-tenth of the building energy consumption per dollar of sales. Mark Borsuk wrote recently in the *Industry Standard* that Wall Street will "demand that retailers curtail new store growth, reduce the number of locations, and shrink store size." Firms like IBM and AT&T are reducing office square footage for their mobile workers because of the Internet. We believe the Internet Economy could ultimately render unnecessary as much as 5% of U.S. commercial floor space, saving considerable energy used for construction, heating, cooling, and lighting.

The Internet can foster what we call "e-materialization," as newspapers, catalogues, and CDs are being partly replaced by websites and downloadable files. Online B-to-B auction sites can make the economy run more efficiently (for instance, the National Transportation Exchange is now auctioning off empty space on cargo trucks).

5. My two main theses were that EIA is overestimating the growth of greenhouse gas emissions and that the Internet is making the economy more efficient in its use of energy, not less. In December 1999, EIA predicted (in its *Annual Energy Outlook 2000*) that U.S. carbon dioxide emissions would rise 2.3% in 1999. EIA's most recent data (from its *Monthly Energy Review* for February 2000) suggest that growth rate is high by a factor of 2.

In the February 23, 2000 issue of the *Wall Street Journal Interactive* edition, Mark Mills wrote "Aircraft and truck fleets have gained fuel savings from intelligent routing and dispatch. We are only at the beginning of a world of smart imbedded and networked chips in practically everything from refrigerators to machine tools. The collective effect of such efficiency is to build in more resilience to energy commodity price swings." The Internet Economy and IT lead to more efficient use of energy.

ONE HUNDRED SIXTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON GOVERNMENT REFORM
2157 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6143

MAJORITY (202) 225–5074
MINORITY (202) 225–5051
TTY (202) 225–6852

February 9, 2000

Via Facsimile
Mark P. Mills
President
Mills-McCarthy & Associates
8319 Kerry Road
Chevy Chase, MD 20815
FAX: (301) 718-7806

Dear Mr. Mills:

Thank you for testifying at the Subcommittee's hearing on the Kyoto Protocol and the Internet. I was very interested in your testimony and am sorry I was unable to stay for the question and answer period.

As discussed at the hearing, I would like to ask you a few questions for the record. Please answer the following questions:

1) You performed your analysis of the energy implications of the Internet for the Greening Earth Society. What is the Greening Earth Society?

2) Was the Greening Earth Society created by the Western Fuels Association?

3) Who are members of the Western Fuels Association?

4) Are any of the members coal utilities?

Thank you, in advance, for your assistance in this matter.

Sincerely,

Dennis J. Kucinich

Dennis Kucinich
Ranking Member
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs

cc Members of the Subcommittee

MILLS • McCARTHY & Associates

8319 Kerry Road, Chevy Chase MD 20815
301 718-9600 (Fax 301 718-7806)

February 15, 2000

VIA FACSIMILE

Honorable Dennis Kucinich
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs
U.S. House of Representatives
2157 Rayburn House Office Building
Washington DC 20515-6143

Dear Mr. Kucinich:

It was a pleasure to testify before the Subcommittee. I too regret that you were unable to stay longer to engage the discussion of the issues.

Regarding the four questions in our letter of February 9, 2000, I should first note for the record that my analysis of these issue has been, and continues to be for a broad variety of clients. The Greening Earth Society commissioned one specific document ("The Internet Begins with Coal") that encompasses some, but far from all, of the aspects of my work in this field.

With respect to the organizational questions about the Greening Earth Society and Western Fuels Association; I have no special knowledge about these organizations. For the information you seek about these organizations, I recommend your staff visit the relevant sites on the World Wide Web. If additional information or clarification is required, I strongly suspect that a phone call to Fred Palmer, the head of both those organizations, would elicit an eagerness to provide the information you seek.

Respectfully,

Mark P. Mills
President, Mills McCarthy & Associates Inc.

cc. Members of the Subcommittee

WESTERN FUELS ASSOCIATION INC.
The National Fuel Supply Cooperative

Fredrick D. Palmer
General Manager and Chief Executive Officer

February 15, 2000

The Honorable Dennis Kucinich
Ranking Member
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs
U.S. House of Representatives
2157 Rayburn House Office Building
Washington, DC 20515-6143

Dear Mr. Kucinich:

Mark Mills, President of Mills McCarthy & Associates, Inc., has provided me a copy of your February 9, 2000, letter requesting from him a written response to four questions. They concern his relationship with Greening Earth Society, Greening Earth Society's relationship to Western Fuels, our membership, and the nature of our members' business. I want to take this opportunity to respond. I request that my response be made a part of the Subcommittee's hearing record on the Kyoto Protocol and the Internet.

Greening Earth Society was created by Western Fuels Association on Earth Day (April 22nd) 1998. In the press announcement, on the GES website (*www.greeningearthsociety.org*), and in all of Greening Earth Society's display advertising it is clearly stated, "GES is the creation of Western Fuels Association, Inc., a not-for-profit fuel supply cooperative comprised of consumer-owned utilities." GES also enjoys individual members and has attracted support from a number of consumer-owned utilities.

As the former mayor of Cleveland, Ohio, you among all of your peers can no doubt appreciate the significance of our relationship to consumer-owned utilities because of your role in defending your local, consumer-owned, municipal utility against encroachment by investor-owned utilities.

Western Fuels operates on a not-for-profit basis to supply coal to our member/owners' power plants for the generation of electricity. We were createc as a direct consequence of the policies and programs of the Carter Administration in the mid-1970s that encouraged consumer-owned utility investment in coal-fired generation as a principled and good faith response to Project Energy Independence.

PO Box 33424 ▪ Denver, CO 80233-3424 ▪ Telephone 303/450-9976 ▪ Fax 303/450-1042 ▪ E-mail wfalakewood@pcisys.net
4301 Wilson Boulevard, Suite #805 ▪ Arlington, VA 22203-4193 ▪ Telephone 703/907-6160 ▪ Fax 703/907-6161 ▪ E-mail wfa@westernfuels.org

As a consequence, rural electric cooperatives today rely upon coal-fired electricity to supply more than 80% of their electricity. That's compared with a national average reliance on coal of 52%. Publicly-owned systems (municipals) are not so heavily dependent on coal for their total energy supply due, in large measure, to their reliance upon the hydroelectric capabilities of the large State, regional and federal power authorities; the nuclear capability of the Tennessee Valley Authority; and the hydroelectric capacity owned by several of the municipal, public utility districts and state authorities in the West and Northwest. Together, these sources provide more than half of the energy used by municipal electric systems. Yet, even though municipal electric systems receive better than half of their power from such non-fossil sources, of the remainder nearly 90% comes from burning coal.

I recite this background so that you can appreciate why Western Fuels conducts its advocacy programs in defense of coal-fired electricity, especially in the context of the climate change issue and in dealing with a Clinton/Gore Administration dedicated, in their own words, to *dialing out* the coal option. Dialing-out coal dials out public power's $26 billion investment in utilization of our nation's most abundant and cheapest source of energy.

Western Fuels' membership encompasses municipal and rural electric systems across America's heartland. Collectively, our cooperative business is the single-largest purchaser of coal from the Federal leases in Wyoming and Montana's Powder River Basin, the nation's most prolific coalfield and source of the low sulfur coal mandated by the Clean Air Act.

I am enclosing a copy of our most recent annual report. It will provide you additional detail about our business and our motivation.

Congressman Kucinich, I would be honored to answer any further inquiry from you. I admired your fighting spirit in behalf of consumer-owned utilities and the electric consumers who own them during your time as Mayor of Cleveland. My own advocacy work in behalf of public power is in large part modeled on your own.

Sincerely yours,

Fredrick D. Palmer

cc: Subcommittee Members
WFA Board & Membership
GES Board & Membership
Misc. NRECA & APPA Members

Greening Earth Society is a not for profit grassroots organization created by Western Fuels Association to promote the viewpoint that humankind is a part of nature, rather than apart from nature.

Greening Earth Society believes that humankind's industrial evolution is good, and using fossil fuels to enable our economic activity is as natural as breathing.

We promote the benign effects of carbon dioxide (CO2) on the earth's biosphere and humankind. Our message is that CO2 is required for life on earth and that the earth is actually getting greener thanks to increasing CO2 levels.

Greening Earth Society provides sound information about CO2 and fossil fuels to educators, students, business and media representatives, community leaders and policymakers. Information is provided to the public through the biweekly *World Climate Report*, the annual *State of the Climate Report*, the video "The Greening of Planet Earth" and "The Greening of Planet Earth Continues" and this Web site.

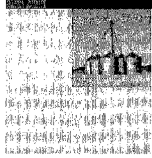
By doing this, we enable our citizens to make decisions that benefit both humankind and the planet.

Our Symbol: The Bristle Cone Pine

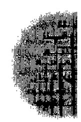
The symbol of the Greening Earth Society is the Bristle cone pine--the world's oldest living plant. Why? Because it's been nurtured for thousands of years with CO_2.

Some Bristle cone pines are 3,000 years old. Tests on these old trees show that they've grown best during times of higher CO_2 concentrations. We believe the Bristle cone pine proves our point--that nature and CO_2 can grow together!

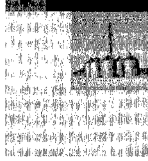
WESTERN FUELS



Western Fuels Association, Inc., operates on a not-for-profit basis to provide coal for the generation of electricity by consumer-owned utilities throughout the Great Plains, Rocky Mountain, and Southwest states, and in Louisiana. We are a cooperative. Our 22 member/owners are rural electric generation & transmission cooperatives, municipal utilities, and other public power bodies.



WESTERN FUELS HOME



PROFILE
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THE ROAD TO POWER GENERATION

THE WESTERN FUELS COOPERATIVE

Western Fuels Association's membership is divided among utilities for whom we have a contract for coal supply (Class A & Class B members) and those who simply choose to affiliate with us and utilize our fuel supply expertise on an as-needed, at-cost basis (Class C members). In addition, all of our members work with us on policy issues that affect coal utilization.

CLASS A & B MEMBERS

BASIN ELECTRIC POWER COOPERATIVE

Headquarters: Bismarck, North Dakota

Basin Electric is a consumer-owned, regional cooperative responsible for supplying wholesale electric power to more than 100 rural electric systems in Colorado, Iowa, Minnesota, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. Basin's member systems distribute electricity to about 1.5 million consumers.

Basin Electric operates four power plants with a total generating capacity of 3.3 million kW. They include the Laramie River Station (1.65 million kW, coal-fired), the Antelope Valley Station (900,00 kW, lignite-fired), the Leland Olds Station (650,000 kW, lignite-fired), and the Spirit Mound Station (104,000 kW, oil-fired). About 2400 miles of high-voltage transmission lines are associated with these power plants.

Western Fuels is the coal supplier at the Laramie River Station.

Website URL: http://www.basinelectric.com

CAJUN ELECTRIC POWER COOPERATIVE, INC.

Headquarters: Baton Rouge, Louisiana

Cajun Electric provides wholesale power over 80% of Louisiana's land area to more than 1.5 million consumers through 12 rural electric distribution cooperatives.

Cajun's generating resources include Big Cajun No. 1 Station consisting of 2 110-mW gas-fired units and Big Cajun No. 2 Station, a 1730-mW coal-fired power plant. Cajun also receives a 91 mW allocation of peaking power from the Southwestern Power Administration.

Cajun owns 848 rotary-dump railcars in service between Gillette, Wyoming, and St. Louis, Missouri, which move approximately 6 million tons of Powder River Basin coal each year. Western Fuels Association supplies coal for Big Cajun No. 2.

KANSAS CITY, KANSAS, BOARD OF PUBLIC UTILITIES

The Kansas City, Kansas, Board of Public Utilities (KCBPU) serves 65,740 electric meters in Kansas City, Kansas, and operates two coal-fired power plants for that purpose: Nearman Creek Station (235 mW) and the Quindaro Station (208 mW). Western Fuels Association and its affiliated companies supply coal for operation of the power plants.

KCBPU has long-term contracts for sale of a portion of the capacity from Nearman Creek to Columbia, Missouri and the Kansas Municipal Energy Agency.

PLAINS ELECTRIC GENERATION & TRANSMISSION COOPERATIVE, INC.

Headquarters: Albuquerque, New Mexico

Plains Electric has 13 member distribution cooperatives providing electric service to approximately 250,000 consumers in New Mexico and Arizona.

Plains owns two generating stations: the coal-fired Plains Escalante Generating Station at Prewitt (260-mW) and the oil/gas-fired Algodones Power Plant (46.5-mW), which is on "cold standby." Additional requirements are met by purchases from the Western Area Power Administration.

Western Fuels Association supplies coal to the Plains Escalante Generating Station and operates the Escalante-Western Railway connecting the coalmine and power plant.

Website URL: http://www.plainsgt.org

BOARD OF MUNICIPAL UTILITIES

Sikeston, Missouri

The Board of Municipal Utilities of Sikeston, Missouri was created in 1931 for the purpose of manufacturing and distributing electric power to the city's residents. Sikeston is located in the southeast corner of Missouri and has a population of approximately 19,000.

The Sikeston Electric System consists of a 13.8 kV distribution system extending throughout the city corporate limits and serving almost 8900 customers. The 235-mW coal-fired Sikeston Power Station is its main source of power. Designed to meet Sikeston's future power needs, excess power and energy is currently sold to other municipalities and power entities through interconnections with the Southwestern Power Administration, Associated Electric Cooperative, and Ameren (UE).

The Sikeston Power Station utilizes more than a million tons of Powder River Basin coal per year, supplied by Western Fuels Association.

Website URL: http://www.sikestonbmu.org

SOUTHERN MINNESOTA MUNICIPAL POWER AGENCY

Headquarters: Rochester, Minnesota

Southern Minnesota Municipal Power Agency (SMMPA) was founded in 1977 as a joint-action municipal power agency supplying electricity and related services to 18 municipally-owned utilities mostly in southeastern and south-central Minnesota. SMMPA's members serve the needs of approximately 350,000 people.

SMMPA's main source of energy is its 41% share in the 874-mW Sherco 3 generating unit near Becker, Minnesota. The plant burns low-sulfur, western coal supplied by Western Fuels Association and is the largest such unit in the state. Member city generation provides approximately 240 mW of baseload and diesel peaking capacity to SMMPA's energy mix.

SMMPA is an active marketer of wholesale energy to buyers outside its service area. The Agency is strengthened in this effort by an alliance with the international diversified energy firm PacifiCorp of Portland, Oregon.

SUNFLOWER ELECTRIC POWER CORPORATION

Headquarters: Hays, Kansas

Sunflower Electric is a Touchstone Energy[SM] generation and transmission power supplier for six rural electric cooperatives and several municipalities serving 150,000 people living throughout the western one-third of Kansas.

Sunflower's system is comprised of five generating units located in or near Garden City, Kansas. Its newest plant is Holcomb Station, a 360-mW coal-fired unit, which went into commercial service in 1983 and receives its coal supply through Western Fuels Association. Other generating units include three gas-fired turbines and a steam turbine that can produce 215 mW, for a total system generating capacity of 575 mW.

Sunflower's transmission system includes 238 miles of 345 kV line and 797 miles of 115 kV line for a total of 1,035 miles in service. Other transmission system components include 25 substations, 14 microwave sites, and 52 Supervisory Control and Data Acquisition (SCADA) terminals.

Website URL: http://www.sunflower.net

TRI-STATE GENERATION & TRANSMISSION ASSOCIATION, INC.

Headquarters: Westminster, Colorado

Tri-State Generation & Transmission Association's 32 member distribution systems provide electric service to 700,000 rural customers in a 150,000 square mile area covering significant portions of Colorado, much of Wyoming, and western Nebraska.

Tri-State supplies electricity through ownership of a 408-mW unit and a 24% share in two additional 428-mW units of the Craig Station in northwestern Colorado. Tri-State is the power plant operator. Tri-State also owns and operates the 100-mW Nucla Station in southwestern Colorado and has a 24.14% share in output of the Laramie River Station in southeastern

Wyoming. In total, Tri-State has 1,152 mW of coal-fired baseload generating capacity plus 100 mW of reserve capacity in an oil-fired generating station in eastern Colorado.

Western Fuels Association supplies coal for the Nucla Station and Laramie River Station, and manages the coal supply contract for the Craig Station.

Website URL: http://www.tristategt.org

CLASS C MEMBERS

ARIZONA ELECTRIC POWER COOPERATIVE, INC.

Headquarters: Benson, Arizona

Arizona Electric Power Cooperative (AEPCO) has six member distribution cooperatives providing electric service to approximately 101,000 meters in Arizona, and portions of southern California and western New Mexico.

AEPCO owns and operates Apache generating Station, a 520-mW facility located near Cochise, Arizona. The station has two 175-mW units that can be fueled by either coal or natural gas; one natural gas-fired combined-cycle steam unit, and two combustion turbines used for peaking energy. Additional power requirements are met by purchases from federal hydroelectric facilities and contracts with other utilities.

Website URL: http://www.aepnet.com

ARKANSAS ELECTRIC COOPERATIVE CORPORATION

Headquarters: Little Rock, Arkansas

Arkansas Electric Cooperative Corporation (AECC) is a generation and transmission cooperative and is the wholesale power supplier for rural electric distribution cooperatives in Arkansas. AECC's members serve more than 375,000 homes, farms, businesses and industries in Arkansas and some neighboring states.

AECC has a generating capacity of 1,970 mW and energy sales of more than six million megaWatt-hours.

Website URL: http://www.aecc.com

ASSOCIATED ELECTRIC COOPERATIVE, INC.

Headquarters: Springfield, Missouri

Associated Electric is owned by, and provides wholesale power to, six regional and 51 local cooperative systems in Missouri, Oklahoma, and southeast Iowa. AECI's system serves 680,000 homes and businesses, representing 1.8 million individual consumers.

AECI owns and operates two coal-fired power plants with 2353 mW of capacity and two 22.5 mW oil-fired turbine generators, and has a long-term contract with the Southwestern Power Administration for 519 mW of hydroelectric peaking power. AECI is jointly developing a new 250-mW, combined-cycle electric generation plant with Duke Energy Corporation and also has two simple-cycle, gas-fired combustion turbine generation projects in development.

AECI and the Missouri electric cooperatives own an extensive high-voltage integrated transmission network.

Website URL: http://www.aeci.org

BLACK DIAMOND ENERGY, INC.

(A wholly-owned subsidiary of Oglethorpe Power Corporation)

Headquarters: Tucker, Georgia

Oglethorpe Power Corporation is a generation and transmission cooperative providing wholesale electric power to 39 of Georgia's 42 customer-owned Electric Membership Corporations which more than 2.6 million Georgians in about two-thirds of the state's land area.

Oglethorpe Power System owns, leases, or has under contract approximately 5000 mW of generating capacity. The system currently has ownership in six generating facilities including two coal-fired power plants (37.7% of the energy supply mix), two nuclear power plants (36.9%), and two hydroelectric facilities (2.4%), one of which is a pumped-storage plant. The balance is from purchased power (23%).

Website URL: http://www.opc.com

DEPARTMENT OF UTILITIES

Fremont, Nebraska

The Fremont Department of Utilities is the third largest (and one of the oldest) municipal utilities in Nebraska. It is a multi-service municipal agency consisting of water, wastewater, electric, and natural gas distribution systems. The Department serves a population of approximately 26,000 in an electric service area encompassing 60 square miles and including greater Fremont and the surrounding rural area. The gas distribution system serves the greater Fremont area and Cedar Bluffs.

Fremont's facility for electricity generation is the 136 mW, coal-fired Lon D. Wright Power Plant. It also operates facilities for electricity transmission and distribution; a water wellfield with storage and treatment facilities, and a distribution system; a wastewater collection system and treatment facilities; and a natural gas, peak shaving and distribution system.

HEARTLAND CONSUMERS POWER DISTRICT

Headquarters: Madison, South Dakota

Heartland Consumers Power District is a public corporation and political subdivision of the State of South Dakota supplying supplemental electric power to 15 municipal electric systems in South Dakota, two in western Minnesota, and one in northwestern Iowa. Heartland also supplies electric service to three South Dakota institutions and a portion of the service area of a member rural electric cooperative.

Heartland is a part owner of the Missouri Basin Power Project's Laramie River Station at Wheatland, Wyoming. Western Fuels Association supplies coal to that power plant.

Website URL: http://www.hcpd.com

LINCOLN, NEBRASKA, ELECTRIC SYSTEM

The City of Lincoln, Nebraska, has been in the electric power business since the turn of the century. The Lincoln Electric System (LES) is a publicly-owned electric utility serving all residential, commercial, and industrial customers within a 190 square-mile area in Lancaster County, Nebraska. It includes the communities of Lincoln, Waverly, Prairie Home, Walton, Cheney, and Emerald. LES provides electricity to over 105,000 customers (meters) in its service area.

LES owns 11% of the Missouri Basin Power Project's Laramie River Station. Additionally, LES is a participant in three Nebraska Public Power District projects. LES supplied its customers 2,948,499 megaWatt hours of electricity during 1997.

Website URL: http://www.les.lincoln.ne.us

MISSOURI RIVER ENERGY SERVICES

Headquarters: Sioux Falls, South Dakota

Missouri River Energy Services was formed in the 1960s as the Missouri Basin Municipal Power Agency to help municipalities operating their own electric systems to work together in planning for future power supply needs and solving other mutual problems. It supplies electricity to 56 municipalities in Iowa, South Dakota, Minnesota, and North Dakota which, in turn, serve 200,000 customers. Its average member community has a population of about 5000.

Missouri River Energy Services supplements hydroelectric power from the Western Area Power Administration through participation in the Missouri Basin Power Project's coal-fired Laramie River Station. The Agency also owns 60 mW of oil-fired peaking capacity and is a member of the Mid-Continent Area Power Pool.

Website URL: http://www.mbmpa.org

NEBRASKA PUBLIC POWER DISTRICT

Headquarters: Columbus, Nebraska

Nebraska Public Power District (NPPD) is Nebraska's largest electric utility serving approximately one million Nebraskans in all or parts of 91 of Nebraska's 93 counties. NPPD is a public corporation and political subdivision of the State of Nebraska.

NPPD uses a mix of generating resources to meet the needs of its customers. This includes a nuclear power plant, two steam plants, nine hydroelectric facilities, nine diesel plants, and three peaking units. NPPD also purchases power from the

Western Area Power Administration. Its typical fuel supply mix is 60 percent coal-fired, 20 percent nuclear, 20 percent hydro, and 0.1 percent natural gas or oil.

Website URL: http://www.nppd.com

SILICON VALLEY POWER

Santa Clara, California

Silicon Valley Power is a municipal electric utility serving the City of Santa Clara, California. Founded in 1896, this consumer-owned utility serves more than 45,974 electric customers.

Silicon Valley Power owns, operates and participates in more than 380 megawatts of electric generating resources serving a peak load of 411 mW. As a charter member of the Northern California Power Agency, Santa Clara is the lead partner in the 110 mW NCPA Geothermal Project, the first municipally-owned and operated geothermal power plant in the United States.

Website URL: http://www.alphais.com/santa_clara

CITY UTILITIES OF SPRINGFIELD, MISSOURI

City Utilities of Springfield, Missouri provides electric, natural gas and bus transportation services in the greater Springfield area. There are 91,000 meters on the CU electric distribution system.

CU's power production capacity consists of 450 mW of coal-fired steam generators and 250 mW of combustion turbine generators. CU has an electricity supply contract with the Grand River Dam Authority of Oklahoma for 60 mW and another for 50 mW with Southwestern Area Power Administration.

Website URL: http://www.cityutil.com

TURLOCK IRRIGATION DISTRICT

Headquarters: Turlock, California

Turlock Irrigation District, formed in 1887, was the first among 65 California irrigation districts. Since 1923, the District has provided all electric service within its 425 square-mile service area and today serves 64,877 electric customers.

The District's electric system includes generation, transmission, and distribution facilities. Its generation resources include 150.7 mW of hydroelectric capacity, two 24.5-mW gas-fired combustion turbines, and 49.9 mW of combined-cycle, steam-injected gas turbine capacity. Its power purchases include coal, hydroelectric, geothermal, and system resources.

Website URL: http://www.tid.org

Jonathan G. Koomey, Staff Scientist
Energy Analysis Department
1 Cyclotron Road, MS 90-4000 Berkeley, California 94720
Tel: 510/486-5974 Fax: 510/486- 4247 e-mail: JGKoomey@lbl.gov

MEMORANDUM (LBNL-44698)

December 9, 1999

To: Skip Laitner, EPA Office of Atmospheric Programs
From: Jonathan Koomey, Kaoru Kawamoto, Bruce Nordman, Mary Ann Piette, and Richard E. Brown
RE: Initial comments on "The Internet Begins with Coal"
cc: Mark P. Mills, Rob Bradley, Amory Lovins, Joe Romm, Alan Meier, Alan Sanstad, and Erik Brynjolfsson
Download this memo and related data at: http://enduse.lbl.gov/projects/infotech.html

Short summary

This memo explores the assumptions in Mark P. Mills' report titled *The Internet Begins with Coal* that relate to current electricity use "associated with the Internet". We find that Mills has significantly overestimated electricity use, in some cases by more than an order of magnitude. We adjust his estimates to reflect measured data and more accurate assumptions, which reduces Mills' overall estimate of total Internet-related electricity use by about a factor of eight.

Introduction

At your request, we have begun to explore some of the assumptions in Mark P. Mills' report titled *The Internet Begins with Coal* (Mills 1999). In this memo, we restrict our comments to a few key assumptions in Part 7 of Mills' report, where he estimated total current electricity demand associated with the Internet. We do not address in this memo any of Mills' assertions about future growth of Internet electricity use, nor do we address any comments he made about the types of electricity supply technologies that would support any such increases in electricity demand. As more data become available, we expect refine the estimates in this memo, which must at this time be treated as preliminary.

The existence of the Mills report highlights the critical need for comprehensive data on electricity used by office equipment and associated network related-hardware. The last time such a comprehensive report was done (Koomey et al. 1995) was prior to the Internet becoming such an important force in the U.S. economy. That report did not address energy used by network hardware, but it did deal explicitly with stocks, energy use per unit, and operating hours to estimate total electricity used by commercial sector office equipment in the U.S. It compiled measured data on many of these parameters, which guided the creation of the scenarios generated in that report. This kind of comprehensive analysis, updated to reflect recent market developments and encompassing a broader scope, would resolve many lingering questions on this issue.

From a methodological perspective, it is problematic to assess only one portion (e.g., the Internet portion) of electricity used by office equipment in the U.S. In the absence of a complete accounting for all office equipment (as found in the Koomey et al. report), the accuracy of the calculations cannot rely on the checks and balances that such a complete accounting would enforce. For example, the total number of personal computers (PCs) is known with much more precision than the number of PCs associated with the Internet, so trying to estimate the latter without first estimating the former will yield a much less certain result.

There are difficult boundary issues in this assessment as well.[1] Mills chose to estimate the electricity used by the Internet and associated equipment, but he did not attempt to assess the effects of *structural changes* in the economy that are enabled by the existence of the Internet. These structural changes will almost certainly affect electricity and energy use. Without assessing the effect of these changes, the *net* effect of the Internet cannot be calculated, yet that is really what we care about. Given the large productivity benefits induced by computer hardware when properly used, it is plausible to speculate that these changes will be large enough to matter.

Mills also makes the assumption that all usage associated with the Internet is incremental. Instead it is actually more likely that at least some of this usage is *substituting* for other energy consuming functions that preceded the Internet (the Internet is expanding uses for the PC at the expense of other energy-using devices). Private computer networks and fax machines, for example, are increasingly being displaced by the Internet. Computer use is substituting for other forms of entertainment, like TV. Even voice communications (formerly the province of the telephone network) are being carried over the net. Such displacement effects represent another difficult boundary issue not treated in Mills' analysis.

In addition, the definition of which hardware is "associated with the Internet" is at best an imprecise one. Is a home computer "associated with the Internet"? People might use it for writing, for doing calculations, for analyzing personal finances, for creating party invitations, or for accessing the net. Does that mean that ALL of its energy use can be attributed to the Internet, or just a part? If just a portion, how much should be allocated to Internet use? Many of the reasons for owning a computer are independent of the

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1 The ISO 14000 standards documents (particularly ISO 14040 and 14041) deal with the methodological issues surrounding such boundary issues. See http://www.iso.ch.

Internet, and taken together justify the purchase of a computer. The same conclusion holds even more strongly for PCs in offices, since there are many reasons beyond Internet access for companies to invest in PCs. This kind of arbitrary allocation makes for calculations that are at best limited in usefulness.

In some sense, Mills is asking the wrong question by focusing on the Internet-related portion of electricity use by office equipment. Future studies should analyze total electricity used by this equipment, and not focus on what is Internet related, because these boundary issues are so difficult to resolve.

We turn now to specific assumptions that Mills made in his analysis. There are only a small number of assumptions that drive his results. Table 1 shows that of the 295 TWh that Mills calculates for Internet-related electricity use, more than half is in just three categories: Mainframe computers that serve "Major dot com company" web sites, Web sites using smaller servers, and telephone central offices. An additional 25% of Mills' total energy use is associated with use of PCs in offices and homes, and another 8% of Mills' total energy use is associated with routers. The rest (10%) is associated with the embodied energy to manufacture the equipment. We treat each of these categories in turn.

Table 1: Summary of Mills' estimates of current electricity use associated with the Internet circa 1998

	# of units Millions	*Elect. Used TWh/year*	*% of total*	*Cumulative %*
1) Major dot-com companies	0.033	72	24%	24%
2) Web sites	4	52	18%	42%
3) Telephone central offices	0.01	43	15%	57%
4) PCs in offices for all purposes	40	44	15%	71%
5) PCs at home for all purposes	41	31	10%	82%
6) Routers on Internet	2	16	5%	87%
7) Routers in LANS and WANs	1	8	3%	90%
8) Energy to manufacture equipment	19.5	29	10%	100%
Total		295	100%	

1) Mainframe computers for 'Major dot com companies'

Mills takes the number of mainframe computers in the U.S. from the ITI data book, which is the industry source for such numbers. He assumes that 10% of all mainframe computers in companies other than the major Internet companies are devoted solely to serving web sites. We have no way to judge the plausibility of this assumption, but we note that many such computers serve multiple functions (it is their multitasking abilities that make them so useful). Mills' choice to add the 10% of total mainframe installations to the number of mainframes/web farms in "Major dot-com" companies is an arbitrary one, but one with which we do not have the data to quibble.

Definitions of mainframe computers are not well established, and it appears that Mills did not use the same definitions for his stock and power estimates. The stock estimates rely on the ITI data book numbers, which count any computer costing more than $350,000 as a mainframe. The power estimates he used appear to be inconsistent with this definition.

Mills assumes that each mainframe uses 250 kW, 8760 hours per year. Half of this is assumed to be direct electricity used by the computer, and half for cooling. If the computer's direct consumption is 125 kW, this would place it in the ballpark of LBNL's Phase I supercomputer, installed in July 1999, which draws 150 kW (actual, not rated). It has about 600 processors, and is one of the most powerful in the world. The LBNL supercomputer cost tens of millions of dollars, but such supercomputers number only in the hundreds in the U.S. The bulk of mainframe installations are nowhere near the computing power of a supercomputer, yet that is the power use Mills chose for the typical mainframe.

For LBNL's Phase I supercomputer, the actual power use is about 0.25 kW per CPU.[2] If we use this consumption per CPU, the 125 kW Mills assumes is equivalent to a supercomputer with 520 processors. This represents far more processing power than a typical mainframe computer.

The IBM S/390 Enterprise server, which Mills' report cites as an example of the latest mainframe technology, has a rated (maximum) power of up to 6.4 kVA (roughly equivalent to 6.4 kW), depending on the number of processors. For the reasons described in Nordman (1999), the *actual* power use of almost all types of electronic equipment is typically one-half to one-third of the rated power (the rated power is the maximum power that the power supply will consume under fully loaded, worst case conditions). If the actual power is half of the rated power, this machine would use 3.2 kW for typical installations. Of course, IBM's server is relatively new and it relies on CMOS technology to reduce power use, so it probably uses less power than an older mainframe. The rated power may also not include peripheral equipment that would be included in a typical mainframe installation.

It is clear that 125 kW is a much larger power number than has been used in such analyses in the past. The Koomey et al. (1995) report estimates power used by older (1985-1990) mainframes at 25 kW, declining to 10 kW by 1999 (an estimate for 1999 which is validated by the S/390 data described in the previous paragraph). The recent Swiss study by Meyer and Schaltegger (1999) used 30 kW for the average power of each of the roughly 1000 mainframes in Switzerland.

We checked the price of the S/390 on the IBM web site and found that its cost is well above ITI's $350k cutoff for mainframes (S/390s cost millions of dollars). We believe, as Mills also does, that this machine is representative of mainframe computers now being

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2 Note that the LBNL Phase II Supercomputer, now under construction, will use about 0.1 kW per CPU. Source: Howard Walter at LBNL, who is designing the power systems for the new LBNL NERSC building. He generously provided numbers on the power requirements of supercomputers and their associated cooling loads.

installed. If we accept the 3.2 kW direct power use of the S/390 and quadruple it to account for peripheral equipment, that still leaves our estimate of power used per mainframe (12.8 kW) at about one tenth of what Mills assumes.

Cooling is at most 50% of direct power consumption, not 100% as Mills assumes. This result follows from the compressor-based cooling technologies commonly used in commercial buildings and computer rooms, which have Coefficients Of Performance (COPs) of 2.0 or better. A COP of 2.0 implies that 1 unit of electricity is consumed to move 2 units of heat out of the conditioned space. We consulted with the supercomputer team at LBNL, who use 50% additional power for cooling as their best guess for maximum cooling loads when designing a new supercomputer (although in actual practice, 30% is more typical in the Bay Area).

Using our 12.8 kW direct power use estimate, combined with a 50% multiplier for cooling energy, leaves us at 19.2 kW per mainframe. If we replace Mills' assumption of 250 kW with this new estimate, total electricity used by the Major dot-com companies becomes 5.5 TWh, a reduction of 66.5 TWh or about a factor of thirteen. By itself, this correction reduces Mills' estimate of electricity used by the Internet by 22%.

2) Web servers

Mills refers to an article titled "WWW Hosts 5 Million Web Sites" (http://www.nua.ie/surveys) to justify his assumption of the number of web servers. He takes 70% of 5 million, which rounds to 4 million servers. The problem is that the article to which Mills refers talks about web sites NOT servers. One server can host dozens of web sites (a fact that Mills acknowledges in his report), so the number of servers is much lower than the number of sites. We assume, for purposes of these calculations, that each server hosts 5 sites (although that is likely to be an underestimate). In practice, some servers will have just one site, and others will have many. This correction factor alone reduces Mills' estimate of electricity use for this component by 80%.

The power used by mini-computers and workstations is assumed by Mills to equal 1.5 kW, 1 kW of which is direct power used by the computer, and 0.5 kW is from peripherals, "especially data backup". Data backup only runs once a day, and services many CPUs. It is unlikely that 0.5 kW per CPU is a reasonable estimate for this service.

Based on the discussion of PC power use below, we reduce Mills' 1.5 kW estimate by a factor of 5, to 0.3 kW. With both corrections (for number of units and power per unit), total power used by U.S. web servers is reduced by a factor of 25, to 2.1 TWh.

3) Telephone central offices

Telephone central offices are the next most important item in Mills' list, but much more information and documentation is needed to justify the calculations, particularly the number of such offices and the power use per office.

Mills' estimates that central offices each use 500 kW. His table indicates that there are 25,000 such central offices in the U.S. In fact, most of these central offices are significantly smaller than Mills' assumes (between 30 and 50 kW). We are working on getting an accurate distribution of such central offices by power level, but in the absence of those data, we took another tack.

Our contact at a major phone company reports that a central office uses about 3.3 kWh per thousand minutes of so called "dial equipment minutes" or DEQ (a standard measure of phone connect time). FCC (1999) reports total DEQ for the U.S. of 3,612 billion minutes in 1997. These two numbers together imply electricity used by all central offices of 12 TWh/year. To make this number comparable to Mills' estimate, we multiply this figure by 40%, to get 4.8 TWh/year.

With this revised estimate, power used by central offices is reduced by 37 TWh, or about a factor of nine.

4) Office PCs

The power used by most personal computers is assumed by Mills to equal 1 kW. This estimate is assumed to include all peripheral equipment associated with PCs, as well as some unspecified other equipment. Without a detailed accounting of his assumptions about this equipment, it is difficult to determine what he assumed. However, there is a large body of literature on actual power used by such equipment. A recent power measurement of a 500 MHz Pentium III PC that had no power management showed average power over the course of a day of about 40 W for the CPU.[3] A typical 17" monitor uses about 90 W in active mode.

Of course, most PCs and monitors now are capable of power management (which neither of the above measurements include), so that over the course of a day, these power numbers would be reduced. ENERGY STAR PCs power down to less than 30 W, and typical ENERGY STAR monitors power down to less than 10 W. Whether power management is enabled in many cases is an open question (recent surveys found roughly a third of PCs and monitors had power management correctly enabled in offices), but for the sake of argument, we ignore it.

Peripheral equipment is often shared. In our office, 20 people share a workgroup printer (HP 8000 DN). We metered this printer, and it draws about 163 W in active mode (when printing), and about 120 W in standby mode. In sleep mode it draws about 30 W, and on average, including sleep modes and printing, it uses about 50 W. Even ignoring the power management of the printer, and assuming it is constantly printing, it would add only 8 W per CPU to our estimate of average PC power. For home PCs, most printers will be inkjets, which typically draw less than 30W even in active mode.

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3 Personal communication with Bruce Nordman, LBNL, November 1999.

It is not clear what other equipment Mills is referring to in his 1 kW estimate, but we feel it is unlikely to push the average power used by PCs and peripherals to greater than 200 W (and with power management, we feel strongly that 200 W average power is an overestimate). For purposes of these calculations, we use 200 W instead of Mills' 1 kW estimate, and recalculate electricity used by PCs to reflect this revised estimate. If he believes that other "behind-the-wall" components account for a significant amount of power use (800 W/CPU in this case), he needs to specify, item by item, the number and power use of all these components. We examined the "behind the wall" components of the LBNL computer network, but we were unable to figure out how these components, most of which serve multiple CPUs, could possibly add up to 800 W per CPU (tens of watts per CPU over and above router power use is more like it. See Nordman 1999 for details).

The power used by high end personal computers is assumed by Mills to equal 2 kW. We reduce this estimate also by a factor of five, to 400 W, even though this is almost certainly an overestimate (doubling the CPU power for the 500 MHz Pentium III above and assuming a 21 inch monitor at about 120 Watts only leads to actual power use of 200 Watts, without considering power management).

For usage of PCs at the office, Mills assumes twelve hours per week, which is the same as that assumed for home PCs (see point 5, below). It is important to note the inherent arbitrariness of attempting to calculate what part of office PC use is "associated with the Internet". We have no data for what portion of office computer use is "associated with the Internet". The only adjustment we make to Mills' usage numbers in this category is to reduce usage for typical office PCs to seven hours per week from 12 hours per week, to reflect our revision in the home PC usage number below (this adjustment preserves consistency between our methodology and that of Mills). We do not change usage assumptions for PCs at offices behind a firewall or PCs used in commercial Internet services.

With these corrections, PCs in offices use about 7.2 TWh, a reduction of 84% from Mills' estimate.

5) PCs at home

Mills' assumption of 1 kW power draw for home PCs is subject to the same issues examined under point 4, and hence we reduce his 1 kW by a factor of 5, to 0.2 kW. Even though peripheral equipment in a home is associated typically with one PC instead of many in a work environment, that equipment is not always on when the computer is on, and it is likely to be lower power versions of that equipment (e.g. ink jets instead of laser printers, low end scanners, etc.).

We now turn to usage of home PCs. Mills assumes twelve hours per week of usage for these computers, based on an Intelliquest study of home users, but he acknowledges that "other surveys show lower averages". He cites the Neilson/NetRatings March 1999 survey at seven hours per month (less than two hours per week). Another quite recent study (7 December 1999) shows usage of five to eight hours per month, which is also about two hours per week (http://www.nua.ie/surveys/?f=VS&art_id=905355453&rel=true). With this great a range in estimates of usage, it is important to be cautious in drawing conclusions. We were unable to locate any studies that indicated that average U.S. Internet users were logged on more than 12 hours per week, so we feel justified in treating this as an upper bound, with the likely average possibly as low as two hours per week. Even choosing seven hours per week (the midrange between those two estimates) would reduce Mills' estimates for electricity associated with home Internet use substantially.

Mills claims he is being conservative by assuming that

> every single PC and all its relevant peripherals accessing the Net is physically turned on and operating only the 12 hours per week from the Forrester Research (IntelliQuest) survey, and otherwise completely off. As a practical matter many (possibly most) are on at least 50 hours per week, many 24 by 7. A 'realistic' weekly 'on' time of 50 hours yields about the same rough kWh for a 200-300 W duty-cycle compensated PC as the conservative 12 hour/wk duty cycle does for a 1,000 peak W device (footnote 53, in Mills 1999).

The claim of conservatism is spurious. People use their computers for many other things besides Internet access, which is why at least some people have their computers on for 50 hours per week or more (though we doubt many home users do). According to the surveys cited below, the Internet-related component of home PC use is between two and 12 hours per week. That some people keep their home PCs on for more hours than that is irrelevant to Mills stated purpose, that of calculating electricity use "associated with the Internet".

Based on the surveys cited above, we choose usage of seven hours per week for typical home PC users, instead of 12 hours per week. We do not change hours of usage for PC power users or PCs in home offices.

With these corrections for power and usage, PCs in homes use about 5 TWh, a reduction of 84% from Mills' estimate.

6) Routers on The Internet

Mills' assessment of the number of routers seems inconsistent with our review of the market for these products. It is not clear why there would be twice as many high end routers as low end ones, when in fact the low end ones must be more numerous in any network with central nodes feeding dispersed nodes. We did not correct for this observation, but simply note it for future research. It is also not clear if Mills' stock estimates include switches and routers together, or just routers alone. This issue also must await further research.

Cisco's very highest-end router, which is used in the highest throughput applications, has a rated power of 1.5 to 2 kW. The actual power used for this device will then be 0.75 to

1 kW, because rated power is typically two times the actual power (see text under item 1 above). Unfortunately for Mills' argument, there are very few of these large routers sold every year. Based on a review of the high-end routers sold by Cisco systems, we find that more typical high end routers have rated power of 0.3 to 0.8 kW in typical use (actual power of 0.15 to 0.4 kW). We therefore reduce power use to 0.3 kW, from 1 kW.

Once we correct the power use, routers on the Internet show total consumption of 4.8 TWh, a reduction of 70% from Mills' estimate.

7) Routers on LANs and WANs

Routers on Local Area Networks and Wide Area networks (LANs and WANs) use much less power than Mills assumes. In the text of his report, he states that he uses 0.5 kW for the smaller routers, and 1 kW for the larger (Internet) routers. The total TWh calculations do not support this assertion--they imply that the 1 kW assumption was also used for the LAN and WAN routers (divide 8 TWh by 1 million routers, and then by 8760 hours, and you get just under 1 kW).

Mills therefore assumes 1 kW average power draw for all routers. Cisco's typical lower end routers (which account for the majority of all routers) range in rated power from 0.04 to 0.2 kW. We therefore reduce Mills' estimate by a factor of twenty, to reflect a rated power of 0.1 kW and an actual average low-end router power of 0.05 kW (this last factor of two correction from rated power to actual is the same as that used under points 1 and 6 above).

Once we correct the power use, routers on LANs and WANs show total consumption of 0.4 TWh, a reduction of 95% from Mills' estimate.

8) Manufacturing energy

Manufacturing energy for computers on the Internet is the most difficult of these categories to analyze, because of the lack of data. The life-cycle assessment needed to calculate embodied electricity use of electronic equipment is a complicated exercise, and one that has only rarely been carried out. The most recent data we examined come from NEC, the largest computer manufacturer in Japan (Tekawa 1997).

NEC estimates total greenhouse gas emissions from manufacturing a desktop PC to be 128 kg/CO_2 equivalent (unfortunately, we don't at this time have much detail on the components of this calculation). Some of these emissions are non-CO_2 greenhouse gases, and some are from non-electricity related fuel use. Nevertheless, we can get an estimate for the upper bound to electricity used for manufacturing all parts of the PC by assuming all of these emissions come from electricity (electricity is more carbon intensive per unit of energy consumed than direct use of fuels). The average emissions factor for Japanese electricity production is about 0.42 kg CO_2 per kWh (115 g C per kWh). This factor implies total electricity use of about 300 kWh per desktop PC, which is an upper bound, as described above. NEC states that the electricity used to assemble their PCs is about

120 kWh per unit,[4] so total electricity use is between 120 kWh and 300 kWh per PC. We chose 300 kWh per PC, which is one fifth of Mills' estimate. This is an absolute upper bound. The true number is almost certainly lower than this.

With this factor of five correction, Mills estimate of 29 TWh for manufacturing energy is reduced to 6 TWh.

Conclusions

Table 2 shows Mills' estimates corrected as described above. In every category, his estimates must be reduced substantially (by factors of 3 to 25) to reflect more accurate assumptions. For all categories taken as a whole, Mills' estimates are reduced by 88%.

Mills' report does not contain enough detailed documentation to assess the reasonableness of many assumptions, but it is clear from the review of assumptions conducted above that he has vastly overestimated electricity use associated with the Internet. In addition, the value of such estimates is questionable, given the difficult boundary and allocation issues described above. It would be more useful to estimate total electricity used for all office equipment and associated network equipment, because that number is inherently more reliable than deriving what fraction of such devices are "associated with the Internet".

Finally, the structural and substitution effects alluded to above are almost certainly large enough to matter. Future estimates of the impacts of the information technology revolution (which are larger in scope than those of just the Internet) should explicitly account for these effects.

Table 2: Corrected estimates of current electricity use associated with the Internet

	# of units Millions	*Elect. Used TWh/year*	*% of total*	*Cumulative %*
1) Major dot-com companies	0.033	5.5	15%	15%
2) Web sites	0.8	2.1	6%	21%
3) Telephone central offices	0.01	4.8	13%	35%
4) PCs in offices for all purposes	40	7.2	20%	55%
5) PCs at home for all purposes	41	5.0	14%	69%
6) Routers on Internet	2	4.8	13%	82%
7) Routers in LANS and WANs	1	0.4	1%	83%
8) Energy to manufacture equipment	19.5	6.0	17%	100%
Total		36	100%	

References

FCC, Federal Communications Commission. 1999. *Trends in Telephone Service*.

4 Both Compaq and Dell appear to use significantly less electricity than NEC to assemble their PCs, and we are investigating this difference.

Washington, DC: Industry Analysis Division, Common Carrier Bureau. September. Found at http://www.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/trends.html

Huber, Peter, and Mark P. Mills. 1999. "Dig more coal—the PCs are coming." In *Forbes*. May 31, 1999. Read online at http://forbes.com/forbes/99/0531/6311070a.htm.

Koomey, Jonathan G., Mike Cramer, Mary Ann Piette, and Joe Eto. 1995. *Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties*. Lawrence Berkeley Laboratory. LBL-37383. December. http://enduse.lbl.gov/Info/37383-abstract.html. Also published in 1996 in *Energy Policy*. vol. 24, no. 12. December. pp. 1101-1110.

Meyer & Schaltegger AG. 1999. *Bestimmung des Energieverbrauchs von Unterhaltungselektronikgeräten, Bürogeräten und Automaten in der Schweiz*. St. Gallen, Switzerland: Bundesamts für Energie. March.

Mills, Mark P. 1999. *The Internet Begins with Coal: A Preliminary Exploration of the Impact of the Internet on Electricity Consumption*. Arlington, VA: The Greening Earth Society. May. http://www.fossilfuels.org.

Nordman, Bruce. 1999. Memo to Jonathan Koomey on Electricity requirements for LBNL's Networking Hardware. December 9. Lawrence Berkeley National Laboratory.

Tekawa, Masafumi, Shigeyuki Miyamoto, and Atsushi Inaba. 1997. *Life Cycle Assessment: An Approach to Environmentally Friendly PCs*. Proceedings of the IEEE International Symposium on Electronics and the Environment. pp. 125-130.

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The Honorable David M. McIntosh
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Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs
Room B-377
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Washington, DC 20515

February 13, 2000

Re: Kyoto and the Internet: the Energy Implications of the Digital Economy

Dear Chairman McIntosh:

Estimates of changes in energy usage from computers, peripherals, and the Internet (information technology or IT) go beyond the direct use of energy in manufacturing and powering such equipment (the *direct effect*) and the associated energy savings from more efficient production and sale of goods (the *efficiency effect*). There are four other areas of IT-related energy effects that were not considered by the panelists at your February 2nd hearing. *Each of these four linkages works to increase energy demand.* They should be added to direct IT energy use before netting the effect of lower energy use through direct IT efficiencies.

These four new factors are:

1) **Increased production and sales of energy-using goods from IT-derived efficiencies**. Reduced costs and prices, the flip side of the efficiency effect (above), create a *market expansion effect* that has the same effect as any new technology that cheapens the production process to expand output for consumption. In terms of equilibrium analysis, the supply curve is shifted to the right to increase the quantity sold, while the demand curve remains unchanged. In the case of wholly new energy goods created by IT, a supply curve and consumption is created where there was none before. Both the production and usage of these additional units create incremental energy usage.

2) **Increased production and sales of energy-using equipment from the incremental wealth created by the IT economy**. In equilibrium analysis the *wealth effect* shifts the demand curve to the right to increase the quantity sold at any given level of supply. In macroeconomic parlance, the consumption function is increased and the marginal propensity to

consume rises.[1] This incremental consumption indirectly increases energy usage, and the wealth effect directly increases energy consumption from increased affordability.

3) **Lower costs and prices from Internet transactions that increase the demand for and supply of energy goods and increase the demand for and supply of energy itself.** The *on-line price effect* results from increased price transparency lowering transaction costs and reducing sales margins. This effect is just beginning as Internet transactions take hold throughout the structure of production for inputs and outputs. Lower prices for energy goods and energy itself from on-line price economies enhance energy demand.

4) **Increased hydrocarbon energy supplies from applied IT mining techniques and innovations.** The *supply effect* creates incremental energy supplies that increase energy consumption since "supply creates its own demand" either now or in the future.

All six of the above effects are at work in a mature IT economy. The *direction* of these factors is quantitatively known: five increase energy demand and one decreases energy demand. The difficulty is estimating the separate and overall effect on final energy consumption given that laboratory conditions are not present to isolate and measure cause and effect. The net effect could mean higher overall energy usage (the five positive energy effects are greater than the one energy savings effect), lower overall energy usage (the negative effect swamps the other five effects), or neutral energy usage (the one negative and five positive effects cancel each other out).

While direct IT energy consumption reflects physical laws and can be estimated through bottom-up estimation analysis, anecdotes and case studies are needed to surmise the efficiency effect. The Mills-Koomey-Romm debate surrounds these two areas. The four other effects introduced here can be supported by anecdotal evidence,[2] beginning with the fact that the IT economy has dramatically improved productivity and has created great economic wealth in the process.

A Case Study: Motor Vehicles

Business reports in 1999 and 2000 to date indicate several linkages between IT and record sales of new automobiles. The following quotations indicate how new motor

[1] Paul Samuelson and William Nordhaus, *Economics* (New York: Irwin MCGraw-Hill, 1998), pp. 415-17, 421.

[2] A methodological observation from a study for the Organization for Economic Cooperation and Development quoted by Joseph Romm is relevant here, "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." Quoted in Joseph Romm, *The Internet Economy and Global Warming* (The Center for Energy and Climate Solutions, December 1999), p. 68, fn. 2. He also brings attention (ibid., fn. 5) to "the data problems involved in tracking the Internet economy."

vehicles are becoming more plentiful (market expansion effect) and affordable (wealth effect; on-line pricing effect) in the IT era to increase the total vehicle population and increase related energy usage.

> "The New Economy is driven by a powerful ethos, a conviction that new technology can eliminate traditional drains on efficiency. . . . Navistar International Corp. can now produce 300,000 diesel engines a year with 1,800 workers, compared with 100,000 engines with 1,200 workers in 1994. . . . Ford Motor Co., the auto icon that perfected the assembly line early in the century, is saving tens of millions of dollars a year by simulating many of the cumbersome and costly car design processes on powerful supercomputers."
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> - Mark Leibovich, "Life in the Fast Lane: Rapid Changes in Technology Have Transformed American Business," *The Washington Post National Weekly Edition*, December 6, 1999, p. 7.
>
> "Automobile affordability in the U.S. hit a 191/2-year high in the third quarter. . . . Vehicle affordability has been a major factor in the auto industry's booming sales this year. Industry experts estimate that total sales of new vehicles this year will hit a record 17.5 million units."
>
> - Staff Report, "New-Vehicle Affordability Reaches a 191/2-Year High," *Wall Street Journal*, November 15, 1999, p. B13F.
>
> "The U.S. auto market roared to a record high of 17 million vehicles sold last year, creating a boom not only for the manufacturers but also for all levels of the supplier chain. Look for continuing strong demand this year to keep capacity and production at high levels."
>
> - "Industry BUZZ," *Forbes*, January 10, 2000, p. 120.
>
> "Has the U.S. auto market suddenly become a lot bigger—permanently? . . . This year's surprise boom in vehicle sales is demolishing a 13-year record. . . . The consensus: 'Normal' is now thought to be somewhere between 15.7 million and 16.2 million sales of cars and trucks a year. . . . That's as much as a million vehicles a year more than most economists and industry executives previously thought. It amounts to a huge conceptual change that could affect future investment decisions in a sector that accounts for 4% of the U.S. economy. . . . Auto makers are already betting billions on a bigger market."
>
> - Robert Simison, "U.S. Auto Market May Be Bigger Than Detroit Thought," *Wall Street Journal*, December 1, 1999, p. B4.
>
> "Even in the most economically advanced countries . . . transportation energy consumption per capita continues to increase over the projection period, as rising

per capita incomes are accompanied by purchases of larger personal vehicles and by increased travel for business and vacations."

- U.S. Energy Information Administration, *International Energy Outlook 1999* (Washington: Government Printing Office, 1999), p. 6.

"Riding the economic boom, U.S. automakers boosted January sales 10% from a year earlier. . . . Big luxury sedans and full-sized SUVs such as Expeditions are selling as well as they did last year even though gas prices have risen 30 cents [a gallon] in the last 18 months. 'The economy is strong and I think people can afford to pay for gas.'"

- Joseph White, "U.S. Auto Sales in January Set Several Records," *Wall Street Journal*, February 2, 2000, p. A4.

"Autobytel.com Inc. . . . is expected to announce that the company will offer a 'click and buy' option so consumers can purchase a car immediately at a fixed price. That's a dramatic shift from Autobytel's old model, which left it up to dealers to respond with an e-mail price quote then haggle on the showroom floor."

- Fara Warner, "Racing for Slice of a $350 Billion Pie, Online Auto-Sales Sites Retool," *Wall Street Journal*, January 24, 2000, p. B1.

"Major auto makers are weighting whether to ditch longtime pricing practices to follow the herd of online car-retailing services by posting invoice prices or 'street' prices—what a car actually sells for—on their Web sites. . . . 'Because of the Internet, there will be an increase in cost-plus pricing, rather than going through arduous negotiations' down from manufacturer's list prices, said James C. Schroer, Ford's vice president for global marketing."

- Joseph White and Fara Warner, "Car Makers May Try to Alter Pricing Practices," *The Wall Street Journal*, January 24, 2000, p. A4.

IT Energy Supply Effect

Hydrocarbon energies, considered "depletable," are not depleting but becoming more abundant despite record consumption. As I have written elsewhere:

"World oil reserves today are more than 15 times greater than they were when record keeping began in 1948; world natural gas reserves are almost four times greater than they were 30 years ago; world coal reserves have risen 75% in the last 20 years."

- Robert L. Bradley, Jr., "The Increasing Sustainability of Conventional Energy," in John Moroney, ed., *Advances in the Economics of Energy and Natural Resources* (New York: JAI Press, 1999), p. 64.

Whether or not hydrocarbons are depleting resources (the Thomas Gold hypothesis on the origins of hydrocarbons believes they are abiogenic rather than biogenic[3]), IT technology is increasing supply by improving the drilling success rate and lowered finding costs in general.

> "Doomsayers to the contrary, the world contains far more recoverable oil than was believed even 20 years ago. Between 1976 and 1996, estimated global oil reserves grew 72%, to 1.04 trillion barrels. Much of that growth came in the past 10 years, with the introduction of computers to the oil patch, which made drilling for oil more predictable."
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> - Christopher Cooper, "It's No Crude Joke: This Oil Field Grows Even as It's Tapped," *Wall Street Journal*, April 16, 1999, p. A1.
>
> "The oil industry has been undergoing its own revolution. . . . Assessing the seismic data, which once took 10 or 15 people, now takes one or two. Development planning times that took months or years now takes weeks. 'The visualization technology will allow our crop yields to go up and reduce our risk,' says Michael Zeitlin, a pioneer of the technology. 'It's going to keep the cost of oil relatively flat and help us maintain oil prices at a level that is competitive with other energy sources.'"
>
> \- Steve Liesman, "The Price of Oil Has Doubled This Year; So, Where's the Recession? *Wall Street Journal*, December 15, 1999, p. A10.
>
> "The cost of finding new oil and gas wells has declined significantly since 1977 when EIA began collecting these data. A new barrel of oil or gas reserves that cost about $15 in 1997 (inflation-adjusted price) costs less than $5 to find today. Reserve cost reductions occurred primarily because of significant improvements in exploration and development technology."
>
> - U.S. Department of Energy, Energy Information Administration, *25th Anniversary of the 1973 Oil Embargo: Energy Trends Since the First Major U.S. Energy Crisis*, August 1998, p. 10.

Energy Demand

Electricity demand in the U.S. has been surging in recent years. The intuition is that new electrical devices, prominently including IT applications, are driving the growth.

> "Booming electricity demand along with utility deregulation are remaking the U.S. electric industry. . . . 'Millions of electrical devices that didn't exist 10 years ago or even five years ago are here now,' said Joe Petta, a spokesman for Consolidated Edison Co. in New York. 'The whole landscape of power usage is being transformed by this new technology.'"

[3] See, generally, Thomas Gold, *The Deep Hot Biosphere* (New York: Copernicus, 1999).

- Erik Ahlberg and Eileen O'Grady, "Blackouts Shed Light on the Pressures Facing Utilities as Demand Escalates," *Wall Street Journal*, August 3, 1999, p. B11A.

"Power demand is rising faster than the system's ability to generate and deliver it, driven by a booming economy and the proliferation of computers, fax machines, air conditioners and the other amenities of an affluent, wired society."

- Richard Perez-Pena, "Power System Uses Pressing Limits in New York Area," *New York Times*, July 9, 1999, p. .

Both increased "miscellaneous" uses of electricity and hotter-than-normal summers increasing peak demand have created a boom in power generation construction as well.

"Already this year, the state has shattered last summer's power-consumption records—something utilities did not expect, because this summer hasn't been as hot as last year's record scorcher . . . . To meet this growing demand, utilities and so-called merchant power companies—those that supply the wholesale markets on a spot basis—are rushing to build generating plants. The 18,000 megawatts of capacity on their drawing boards is to be completed in the next three years."

- Eileen O'Grady, "Power Suppliers Scramble to Improve Transmission," *Wall Street Journal*, August 25, 1999, p. T1.

"Power markets around the world—and particularly the U.S. power market—are becoming investment hotbeds. . . . Over the next 10 years, an estimated $500 billion will be spent worldwide on new independent power plants and generation and distribution divestitures, according to consultants Hagler Bailly Inc. As a part of the worldwide picture, a disproportionate amount of money will be spent in the United States."

- Jeff Gosmano, "Global Boom in Power Generation Strains Supply of Gas Turbines," *Natural Gas Week*, July 19, 1999, p. 4.

"More than half of the overall [U.S.] energy growth of the last 25 years—about 11 quadrillion Btu—has occurred during the last 6 years [1992-97]."

- U.S. Energy Information Administration, *25th Anniversary of the 1973 Oil Embargo: Energy Trends Since the First Major U.S. Energy Crisis*, August 1998, p. 19.

Conclusion

The U.S. economy is rapidly entering into the IT age. Some of its energy-demand effects have become obvious, and other effects are just emerging. While more and better aggregate statistics will help answer the question of the net effect of IT on energy usage in the years ahead, understanding the qualitative factors is an important first step in the process. Five of the six factors linking IT to energy usage suggest increasing energy consumption, not less.

Sincerely,

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President
Institute for Energy Research
(delivered by e:mail)