The Information and Communication Technology Revolution: Can It Be Good for Both the Economy and the Climate?

Discussion Draft

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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.

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The deepest innovations, the ones that are most transforming of our condition, are the ones that are least anticipated or predicted. Turing began to imagine computers in the 1930s (Babbage was too far ahead of his time), but even as the first ones were being built during WWII, no one imagined their potential civilian applications. When the first mainframes were built, no one imagined the PC or the ubiquitous chip. Even in the 1980s when PCs came out for the wider market, few imagined the Internet. Yet that progression of innovations is probably 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).[3]

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.

Starting with this information we can set up an analytical framework to help us explore the

[3] 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.

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.[4]

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?

(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

[4] 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.

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 Hermann, *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.