# 11. Energy



With skyrocketing gas prices, growing concerns about the impact of fossil fuel emissions on global warming, and turmoil in the Middle East, achieving reductions in both energy consumption and carbon emissions has become the subject of renewed focus. And because so much of the energy in the United States comes from fossil fuels like coal and oil, reducing energy usage and carbon emissions are intimately tied.

Not much attention has been paid to the role of information technology (IT) in reducing carbon emissions; in fact, some people even see IT as contributing to the problem because the IT

infrastructure and devices themselves consume electricity. Yet by transforming all sectors of the economy and society—from e-commerce and just-in-time manufacturing to telecommuting and clean alternative energy technologies—IT is allowing the U.S. economy to become more energy efficient and less carbon intensive. IT is doing that by:

- letting many energy-intensive physical activities be substituted for more energy-efficient digital activities
- enabling individuals and organizations to adopt more energy-efficient practices and processes
- rewriting the rules of electricity production, distribution, and consumption
- reducing energy use in the IT sector itself

The bottom line is that the transformation to a more digital and information-driven economy will be a key factor in reducing energy usage and carbon emissions in the United States and elsewhere.

## Substituting Energy-Efficient Digital Connections for Physical Travel

Travel serves two main purposes: transporting people and goods for physical activities (e.g., driving to mountains to go hiking) and transporting people for information activities (e.g., flying across the nation to attend a meeting). Although IT cannot substitute for the first kind of travel, it can and is substituting for the second. In other words, IT is letting people reduce the number of trips they take primarily to engage in information processing and exchange.

Indeed, IT is at the heart of many solutions that promise to reduce the number of miles traveled in the transportation sector. As discussed below, IT can cut energy usage in the transportation sector by allowing office workers to telecommute or companies to hold virtual meetings or reducing the need to transport some goods by transforming them into bits that can be moved through energy-efficient telecommunications networks. Given that the transportation sector accounts for a significant share of energy use in most nations—for example, 29 percent in the United States in 2007—the opportunities that IT offers to reduce physical travel are very important.[1]

### *Telework*

In the old economy, when most things were on paper, when phones were analog, and when many fewer jobs involved information tasks, it was difficult for most workers to work remotely. Now armed with just a computer, a broadband connection, and a smart Internet protocol phone, home workers can perform all the functions that they would in the typical office environment.

In fact, IT has become such an integral part of the office environment today that physical location is less important than ever before. Home-based workers can keep in touch via e-mail and instant messaging applications. They can connect easily and securely to work servers using virtual private networks. They can collaborate on documents with colleagues with a wide array of software programs, and can attend meetings virtually through teleconferencing or videoconferencing. Smart office phones can automatically route office calls to the home or alert workers by e-mail when they have a voicemail message. And with the proliferation of high-speed broadband, the connection between a home computer and the office is now nearly as fast as the connection between an office computer and the office server.

Much of the evidence on the productivity of telecommuting is anecdotal or from self-reported data at this point, but there are good reasons to believe that telecommuting does let people in many jobs work more productively.[2] First, many people report that they can get more done with fewer interruptions at home. Second, telecommuting allows employees to work when personal or family needs might other-

**One study estimates that in 2007 the telecommuters in the United States saved 840 million gallons of gasoline and reduced carbon emissions by almost 14 million tons.**

wise force them to be absent from the office.[3] Finally, telecommuting frees employees from, on average, almost an hour of commuting each day. If any of this time is put toward working, it translates into greater output.

As a result of such considerations, many organizations are now encouraging their employees to telework. One is the retailer Best Buy. By relying on IT (broadband, mobile e-mail, faxes, etc.), Best Buy was able to give a large share of workers at its corporate headquarters the option of more flexible working hours, including working at home; the workers' output increased by 35 percent. Many of airline Jet Blue's reservation agents also work from home, using a personal computer (PC) and broadband telecommunications connections. And in other organizations, more and more corporate employees are "going Bedouin," with as many as 40 percent of all employees not in the office on any given day.[4]

By 2004, the overall number of workers in the United States who spend any time working from home—including both part-time telecommuters who work at home as little as one day a year and individuals who work at home full time—had grown to 44.4 million.[5] The vast majority of workers in the United States who spend any time working from home engage in part-time telecommuting. At the U.S. Patent and Trademark Office (PTO), for example, a part-time telecommuting program was introduced over 10 years ago. By 2007, there were 220 trademark examiners and 600 patent examiners participating in the program—and plans to add 500 teleworking patent examiners in each of the next five years.[6] In addition to saving commuting time and energy, the PTO's part-time teleworking program saves office space. Participating employees spend approximately one day per week in the PTO office, where a limited number of desks are designated as available for telecommuters. In 2006 and 2007, as a result of its teleworking program, the PTO was able to hire 1,200 new patent examiners without having to lease more office space.[7]

In 2006, thanks to advances in IT, telecommuting and at-home work, about 5.4 million people—3.9 percent of the U.S. workforce—regularly worked from home.[8] The potential of teleworking to expand is tremendous, given that, according to one estimate, about 20 percent of the U.S. workforce engages in work that is eligible for at least part-time telecommuting.[9] Moreover, if some regions of the United States move to implement congestion pricing—IT-enabled automatic tolling systems on roads that are congested, such as those used in London and Stockholm—that, too, would spur the expansion of telecommuting.

The impact of transportation on the environment is substantial. In the United Kingdom, for example, one-quarter of the country's carbon dioxide emissions come from transport.[10] By allowing people to work effectively from a distance and by providing the tools to make transportation more efficient, IT is reducing energy use and carbon emissions in the transportation sector. In fact, one study estimated that in 2007 the telecommuters in the United States saved 840 million gallons of gasoline and reduced carbon emissions by almost 14 million tons.[11] With private vehicles responsible, by one account, for between 30 and 50 percent of greenhouse gas emissions, the potential benefits from widespread telecommuting are dramatic indeed.[12]

In addition, because telecommuters' reduced travel comes largely at peak travel times when traffic congestion is most severe—"rush hour"—the reduced traffic allows the remaining cars on the road to flow more freely, thereby saving additional energy as a result. Fewer cars on the roads means less gridlock, so even the remaining cars pollute less (because each car pollutes more when stuck in traffic).[13] The benefits from reduced congestion are substantial, given that congestion alone wasted 2.9 billion gallons of fuel in 2005 in the United States—an increase of 480 percent from 1982, when congestion accounted for 500 million gallons of fuel.[14] As traffic congestion continues to worsen, telecommuting offers a remedy that few other traffic solutions can match: the prospect of actually taking vehicles off the road by eliminating the need to travel altogether.

In addition to reducing travel, telecommuting saves energy by reducing the amount of office space the economy needs to build and heat and cool. Like the PTO, many corporations have been able to reduce the amount of office space they occupy as more workers either telecommute full time or engage in "office hoteling," in which employees do not have dedicated offices, and instead reserve flexible space when needed. Under Sun Microsystems's Open

Work program, for example, employees can work from almost any location where there is an Internet connection. Currently, 19,000 Sun employees, 56 percent of the total employee population, are participating in the flexible telework program. Fifty percent of Sun's employees telecommute or work from a flexible office part time, and 6 percent do so full time. As a result, Sun has realized office space savings equivalent to $387 million dollars.[15] One study estimates that, if a predicted additional 10 percent of the U.S. workforce takes up telecommuting within the next 10 years, the United States would need 3.3 billion square feet less of office space. Forgoing the construction of this large amount of space would save 28.1 billion tons of greenhouse gas emissions.[16]

Though it might seem fairly straightforward that giving up a commute would naturally result in less driving and diminished pollution as a result, some analysts have argued that the reality is more complex. They note, for example, that some telecommuters may take advantage of their freedom to live in a more remote area than they might otherwise, which requires longer travel for tasks unrelated to work, such as buying groceries, for example. In other words, if telecommuting frees us from the ties of city living, it might actually encourage us to live more energy-intensive lives that actually result in increased pollution. Moreover, the energy savings that result from the construction and operation of less office space as more people work from home may be offset by increased home energy demands caused when home workers use computers and air conditioning that might otherwise remain dormant during the day.

Such arguments seem to be countered by Walls and Safirova's recent review of the literature, which found that telecommuting reduces commuting mileage and does not appear to be associated with a significant increase in the amount of noncommuting mileage traveled. In fact, telecommuting reduced daily vehicle travel by 53 percent to 77 percent.[17] An analysis of the substitution and environmental effects of telework, teleconferencing, and telemedicine in Sweden similarly found that if these three substitutes were used to their utmost potential, overall travel in Sweden could be reduced by one-third.[18]

More research is needed to better understand and compare the energy impact of having people work in a home environment versus having people work in an office. It is plausible that the increase in home energy use is outweighed by the energy savings from the need for less office space, and in turn, less construction and office energy use. With buildings accounting for 39 percent of primary energy use in the United States,[19] the benefits from constructing fewer offices would be substantial.

Sun Microsystems' Open Work program offers an example of the environmental and cost-saving possibilities that can result when firms take advantage of teleworking. A recent report on the program analyzed whether telework reduces Sun's carbon footprint or simply transfers energy costs to employees working at home. By comparing home and work energy use of more than 100 Sun employees, the study concluded that teleworking enables employees to save money, reduce their carbon footprint, and be more efficient employees. Employees working at home 2.5 days a week saved $1,700 per year on gasoline and car repairs. Commuting represented 98 percent of each employee's carbon footprint for work; by working from home 2.5 days a week, employees reduced their energy use by the equivalent of 5,400 kilowatt-hours annually. And by not commuting, employees saved an average of 2.5 work weeks a year, making more efficient use of their time.[20]

With higher gas prices, the widespread deployment of broadband Internet connections, and the advent of next-generation broadband applications like videoconferencing, there can be little doubt that teleworking will continue to grow substantially in the years to come. Given that just over half of the households in the United States have broadband connections at home—though, to be sure, the numbers are higher among office workers—there is certainly room for growth, and with traffic congestion worsening, telework is becoming an ever more attractive option.

### *Videoconferencing*

Beyond making all or some trips to the office obsolete for some workers, IT is helping to make unnecessary many business trips that currently require expensive and energy-intensive air travel. Although companies have long made use of videoconferencing technology, its quality has until recently been relatively poor, with high levels of latency, poor

picture and sometimes sound quality, and limited screen size. Thus, a videoconference was more like a slightly better phone call than a slightly worse in-person meeting. Not surprisingly, business travel has continued to grow, accounting for 25 percent of all domestic trips in the United States.[21]

IT has only recently begun to change this, as broadband connections have become fast enough and computing equipment powerful enough to support more robust virtual videoconferencing technology. Technologies such as those offered by Cisco and HP allow for real-time virtual meetings that begin to create adequate substitutes for real face-to-face interaction, particularly when considering the time and cost savings of not having to hop on a plane and stay in a hotel. These technologies offer high-definition audio and video that even allow participants to communicate with body language, making virtual meetings almost as lifelike as face-to-face meetings.

The potential for energy savings is also significant. One study has estimated that if Europeans substituted videoconferencing for 20 percent of air travel, the European Union could reduce carbon dioxide emissions by 22 million tons annually.[22] Although it is difficult to predict how using telepresence technology and other collaborative and mobile technologies might reduce travel, one estimate by Cisco suggests that it might eventually reduce overall air travel by 10 percent to 25 percent from what it would be otherwise.[23] Right now, the costs for the devices and telecommunications technologies are still relatively high. The costs are expected to decline, though, in which case such technologies will become more affordable for more organizations and applications. Even so, it would be unrealistic to expect videoconferencing to replace the need for business travel altogether because not every important decision on a business trip is made in a meeting room. Nevertheless, it appears that some routine business travel could be eliminated, thereby cutting costs, reducing energy use, and reducing carbon emissions.

### *Dematerialization: Transforming Atoms into Bits*

By allowing the widespread production, transmission, and consumption of virtual products—replacing bits for atoms—IT is paving the way to a more sustainable society. The IT-enabled "dematerialization" of the economy—in which atoms (e.g., letters written on paper) are increasingly replaced with bits (e.g., e-mail)—is leading to energy savings not just from reduced transportation, but also from reduced production of material goods.

**If Europeans substituted videoconferencing for 20 percent of air travel, the European Union could reduce carbon dioxide emissions by 22 million tons annually.**

Take movies and music, for example. For most people, watching a movie at home has traditionally required getting into a car and driving to the movie store. But with the emergence of high-speed broadband networks and much easier-to-use home video network systems, movies are beginning to be offered digitally over the Internet. Likewise, instead of getting in a car to drive to the mall to buy a music compact disc (CD), increasingly consumers are buying their music online and downloading it to a digital music device. This not only eliminates the trip to the store to get the disk, it eliminates shipping from the CD manufacturer to the wholesaler and the retailer, and saves all the energy used in producing the plastic and the disk. Online music sales are growing rapidly, too. Apple's iTunes, the leading online music store, recently became the second most popular music retailer in the United States, behind Wal-Mart, the country's largest retail firm. Apple has sold more than 4 billion songs without shipping a single physical CD (or the accompanying plastic packaging) or erecting a single iTunes retail store.[24] Fuhr and Pociask have estimated that eliminating the production of CDs and their plastic cases in the United States alone could save 42 million gallons of oil per year while reducing greenhouse gas emissions by half a million tons.[25]

But digital movies and music are just one manifestation of the larger phenomenon of dematerialization. Paper is a prime example, as the IT

revolution has digitized many tasks that used to require paper, including letters, newspapers, office work, and even books, with considerable energy savings and environmental benefits. Paper manufacturing is an extremely energy-intensive process, requiring about 3,405 kilowatt-hours of energy to produce 100 tons of paper.[26] Thus, reading the news on a personal digital assistant (PDA) releases 32 times to 140 times less carbon dioxide than reading the news in a newspaper.[27] With the advent of Web-based news, newspaper circulation has declined on average 1.7 percent a year in the United States, and Fuhr and Pociask have estimated that this decline in newspaper circulation has already prevented the release of 7.9 millions tons of greenhouse gases from paper news production processes.[28]

Similarly, instead of relying on paper mail, consumers and businesses have increasingly been turning to the Internet to do their banking, pay bills, file taxes, and generally communicate. As a result, the use of first-class mail in the United States has been on the decline, with the number of first-class mail pieces dropping from 103.5 billion pieces in 2002 to 97.6 billion pieces in 2006, saving 184,000 tons of paper—not to mention saving the energy that would have gone to manufacture all this paper, an estimated 7.4 million British thermal units (BTUs) annually.[29] IT has had a similar impact on the use of paper checks. There is little wonder that banks have embraced the technology, given that processing a check costs banks approximately $1.40 compared to just 8 cents for processing an electronic bill payment. The result has been a dramatic decline in the use of paper checks, and the accompanying energy required for their printing and processing. According to the U.S. Federal Reserve, check-writing in the United States has declined in recent years, going from 49.5 billion checks paid in 1995 to 36.7 billion checks in 2003.[30]

## Enabling More Energy-Efficient Practices and Processes

Business has driven the IT revolution by deploying new technologies strategically in order to reinvent and streamline practices for the sake of productivity gains. IT that drives increased efficiency in business frequently leads to more energy efficiency because waste in business often equates to waste of energy. As a result of the deployment of IT technologies to enable more energy-efficient practices and processes—including more efficient logistics and travel and e-commerce—the American economy has become considerably less energy-intensive over the last 15 years.

**On-board computers that allow managers to better coordinate trucks and loads boost capacity utilization 3.3 percent and save $16 billion annually in the $500 billion trucking industry.**

### *More Efficient Logistics and Travel*

IT-enabled advances in manufacturing and supply chain technologies help firms better track inventory and engage in just-in-time production, thereby eliminating the production of unnecessary inventory, with energy savings at every step of the production and supply chain. The result has been energy savings from less manufacturing and warehouse infrastructure (resulting in less construction), as well as from the decreased need for transportation. The projected monetary savings from eliminating unnecessary inventory run in the hundreds of billions of dollars—between $250 and $350 billion according to one 1999 study.[31] Although no analysis of the energy savings has been conducted, the energy savings from reducing unnecessary inventory are likely to be correspondingly large.

In addition, IT is allowing the transportation sector to be more efficient by increasing capacity. Airlines, for example, use IT to better schedule flights and to raise seat utilization, allowing them to fly fewer flights, saving fuel and money. Now airlines can advertise and sell e-fares online one or two weeks before a flight departs, filling up otherwise underbooked flights with customers willing to fly with flex-

ible schedules and pay lower prices. This capability is particularly important in ensuring that scheduled departures are as full as possible because airlines receive no revenue from empty seats and the increased weight of each additional passenger means little in terms of fuel use. Although we passengers might not like flying in full planes, the end result is that airline fares and energy consumption are lower.

This same phenomenon is occurring in freight movement. Companies are also relying heavily on IT to boost the efficiency of their transportation fleets. United Parcel Service (UPS), for example, uses software that allows the company to optimize its truck delivery routes, resulting in significant fuel savings. In 2006, UPS reduced truck travel by 28.5 million miles with the software.[32] Because of difficulty in predicting demand for hauling, transportation companies' equipment is often underutilized. Trucks, for example, may be fully loaded for delivery but then have to make the return trip partially or completely empty. Indeed, about one-fifth of trucks at any one time are "transporting air."[33]

With global positioning system (GPS) devices, cell phones, and wirelessly connected computers, truck drivers and dispatchers can now more easily find loads to pick up for return deliveries, boosting fleet efficiency and cutting the overall number of trips.[34] By using IT to coordinate schedules, for example, two companies, Fort James Paper and General Mills, were able to give their scheduled runs to a single carrier that dedicated trucks to the business, leading to savings of $731,000 a year.[35] The Internet enables this kind of demand aggregation. Websites like Getloaded.com act as a matching service, preventing excess capacity from going to waste by connecting trailers that would otherwise be traveling empty with loads that need to go to the same destination. One study found on-board computers that allow managers to better coordinate trucks and loads boosted capacity utilization 3.3 percent and saved $16 billion annually in the $500 billion trucking industry.[36]

Beyond making freight travel more efficient, IT is making individual travel more efficient. IT is also making vehicles smarter and more efficient in a number of ways. One everyday example of this phenomenon are the GPS-driven navigation tools that help drivers find the fastest, most efficient route for any given trip. These devices have become increasingly sophisticated, with newer models combining GPS navigation with continuously updated traffic flow information to automatically optimize recommended routes. The European Commission's Intelligent Car Initiative envisions a more fuel efficient car owing to a range of technological innovations that encourage more efficient driving behavior and better vehicle maintenance, including tire pressure monitoring systems (because underinflated tires decrease gas mileage).[37]

### *E-Commerce*

E-commerce, one of the most visible manifestations of the IT revolution, yields significant energy savings. New e-commerce-enabled business practices like Amazon.com's centralized warehousing are actually less damaging to the environment than traditional bricks-and-mortar retail operations even though such practices result in increased shipping. Hendrickson and Matthews, using the U.S. Department of Defense (DOD) as a case study, found that centralizing warehouses greatly reduces environmental impacts; they also found that centralizing all 286 DOD warehouses for spare parts into 19 major warehouses would render a net benefit economically and environmentally even if twice as much trucking and shipping were used as a result of lower warehousing costs.[38]

E-commerce and centralized warehousing result in even greater savings in the retail environment, primarily because most retail shoppers get in the car and drive to a store, using considerable amounts of energy unnecessarily. Instead of driving from store to store, consumers can now compare items and prices with the click of a button. When products and consumers meet virtually rather than face-to-face, the energy savings are considerable. Indeed, in an analysis of online booksellers, Matthews and Hendrickson find that reduced automobile trips are an important factor in giving the environmental and energy edge to e-commerce over traditional retail, despite the increased packaging required, along with the authors' assumption that all e-commerce book orders are shipped at least partly via air freight.[39]

Centralized warehousing is a critical IT-driven innovation, especially in the book industry, given that approximately 35 percent of best-selling books are left

over and returned from retail stores as "remainders"—a practice eliminated altogether in e-commerce. The energy involved in selling $100 of books is 14 times more for a traditional superstore than for an online bookseller.[40] And Romm documents how a 20-mile round trip to the mall to purchase two five- pound products consumes about a gallon of gasoline, while shipping the packages 1,000 miles by truck consumes only 0.1 gallon of gasoline. By allowing for significant changes to the way that we shop, e-commerce is dramatically reducing energy consumption.

## Rewriting the Rules of Electricity Production, Distribution, and Consumption

With coal power plants responsible for nearly 40 percent of electricity production worldwide,[41] electricity generation is responsible for a significant share of global carbon emissions. And the problem is not limited to the most industrialized countries of the world because China is erecting new coal power plants at a pace of one per week.

Fortunately, IT is rewriting the rules of electricity production, distribution, and consumption. In response to growing concerns about global warming and energy independence, energy efficiency and alternative energy sources have become the subject of renewed focus. New energy production technologies, including wind and solar power, rely heavily on IT for their design and operation. IT is also revolutionizing the way that we distribute and consume energy through innovations such as the smart grid, also resulting in considerable energy savings.

### *New Energy Production Technologies*

Renewable energy sources constitute a small, albeit growing, segment of the power- generation sector. Design improvements made possible by IT continue to drive improved performance and efficiency, in the process making renewable energy technologies increasingly competitive with traditional, and dirtier, energy sources. Two such energy sources are wind and solar power.

Wind turbines have come a long way since the days of the simple windmill. Manufacturers like General Electric now design advanced wind turbines that rely on IT to automatically adjust the blade angle (pitch) for optimal efficiency in a variety of conditions and wind speeds.[42] Advanced electronics also manage the flow of electricity between these turbines and the electricity grid, ensuring integration with the grid, even under intermittent wind conditions.[43]

Apart from the computer technology contained in wind turbines, IT also underpins the advanced modeling that has become a critical part of the wind energy industry. Companies like 3Tier use wind modeling to identify the best sites for wind farms, where wind turbines will work most efficiently. Wind energy companies also rely on advanced weather modeling to anticipate future conditions and in turn predict production levels.

IT is no less important to solar power generation, a technology with zero emissions and minimal operating costs. In fact, the photovoltaics used in solar cells generally rely on silicon, and technology manufacturers such as Applied Materials have simply retooled their semiconductor and flat panel display production processes for the manufacture of critical solar power components like thin film panels and solar wafers.[44] Sun Power, a spinoff of Cypress Semiconductor, also uses semiconductor manufacturing equipment to make solar wafers for solar panels in commercial and residential applications. And these recent entrants to the business promise to make waves. With negligible operating costs, the major obstacle to more widespread adoption of solar panels is their high initial cost owing to expensive manufacturing processes. By bringing their standardized and efficient manufacturing processes to bear on solar technology, these companies are likely to help drive down prices and, in the process, make solar energy a more competitive clean alternative energy source.

Harnessing solar energy, once considered an environmentally friendly but expensive and inconvenient power source, is also becoming more efficient with the help of IT. Although solar energy comes from the sun, standalone panels do not always capture the sun's power in the most efficient manner. Newly automated panels, such as those designed by Stirling Energy Systems Inc., use IT to track the sun's rays and respond to clouds and wind. The Stirling system, which can be controlled over the Internet anywhere in the world, even turns its self on and off every morning and night.[45]

### *Distribution and Consumption Technologies*

IT is also revolutionizing the way that we distribute and consume energy. One of the most promising innovations in terms of conserving energy is the so-called "smart grid." In addition, green buildings designed to reduce the overall impact of the built environment are another promising innovation in terms of conserving energy.

**The Smart Grid.** One reason for high electricity costs is that utilities can accommodate demand increases only up to a certain threshold; beyond that threshold, they must fire up more generators—a process that is energy-intensive, costly for the utility, and when fossil fuels are the energy source, highly polluting. Another reason for high electricity costs is that utilities must build and run enough plants to meet some portion of peak load power demands. If the peak load power demands were reduced, utilities could generate less electricity.

Until recently, power companies have known very little about how the energy is consumed across the grid. Similarly, consumers have had no way of knowing whether running an extra load of laundry on a hot summer afternoon contributes to pushing the system over a given threshold; nor has any pricing incentive for consumers to modify their behavior at such times of peak demand been in place. Thanks to IT, that situation is now changing.

The IT-enabled smart grid uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability, and safety of power delivery and use. It also underpins new pricing mechanisms that allow producers and consumers to make better informed decisions about production and consumption according to market incentives, thereby cutting energy consumption and boosting energy efficiency in the process.

The Global e-Sustainability Initiative (GeSI) and the Climate Group forecast that IT can reduce global emissions by 15 percent by 2020, in part, through more energy-efficient transmission and distribution networks. Transmission and distribution losses in India's power sector, for example, could be reduced by as much as 30 percent if more advanced IT and smart-grid technology were used to monitor and manage electricity grids. Yet the energy-saving potential of IT extends far beyond the developing world. Globally, smart-grid technology could reduce $124.6 billion worth of emissions.[46]

The Pacific Northwest National Laboratory (PNNL), as part of the GridWise project, has tested in a demonstration project a system of real-time price monitoring that allows consumers in the state of Washington to control their electricity consumption on the basis of their own preferences. Software is used to maintain a pricing system that updates prices every five minutes to reflect real-time electricity supply and demand. Consumers use a Web interface to set their preferred temperature range; then thermostats and water heaters in individual households communicate wirelessly with the system to respond automatically to these real-time price signals, switching on or off, according to the preformulated household preferences.[47] The PNNL researchers hypothesized that giving consumers better price information about when their energy usage is most expensive, while making the necessary thermostat adjustments an automatic process, would help consumers save both energy and money. Indeed, the study found that, on average, households using the system of real-time price monitoring and automatic responses saved 10 percent on their utility bills. IT-enabled tools such as these can reduce peak load demands on the power grid by up to 15 percent at times of peak demand over an entire year.[48]

**Nissan has found that drivers whose cars are equipped with real-time fuel-efficiency gauges reduce their fuel consumption by 10 percent.**

A number of companies are offering smart-grid systems. Most rely on wireless or satellite technology to alert participating consumers to curtail energy usage at certain peak times, with the incentive that these on-demand saved megawatts ("negawatts") are sold back to the utility. One such company, Con-

sumer PowerLine, sees energy consumption savings of 15 percent among its customers. Another, SCE, is experimenting with wirelessly enabled refrigerator magnets that alert consumers to times of peak demand.[49] Utilities, too, are getting into the game, exploring the possibility of offering consumers real-time pricing along the lines of the PNNL project.

IT-enabled electronic devices also help make consumers more conscious of the environmental impact and cost of their energy use. One device that consumers can plug into a wall outlet, for example, measures the amount of electricity consumed by a particular appliance. Similar devices monitor electricity usage for an entire home. One such product, the Owl, can display total household energy consumption or compute the financial cost or carbon dioxide emissions based on the energy source and price input by the consumer.

Electronic devices that provide feedback on energy consumption or other factors help individuals make more environmentally friendly decisions in a host of areas, not just electricity consumption. Nissan has found, for example, that drivers whose cars are equipped with real-time fuel-efficiency gauges reduce their fuel consumption by 10 percent. By revealing to people the impact of their driving behavior, such as excessive acceleration, such devices cause many drivers modify their habits to save money. By one estimate, widespread implementation of electricity-demand management tools in the United States would obviate the need for construction of 30 large coal power plants over the next 20 years.[50]

Additional ways in which IT can be used to save energy have been demonstrated in other projects that have incorporated IT into household appliances so the appliances can communicate with the power grid and turn off briefly when the grid is under strain. In a study separate from the one just discussed, PNNL researchers examined clothes dryers equipped to turn their heating elements automatically off until the strain on the power grid is alleviated. The researchers found, in the words of program director Robert Pratt, that the impact of using such clothes dryers was dramatic—"the equivalent of turning power stations on."[51] PNNL estimates that similar controllers could be applied to 20 percent of the nation's energy usage.[52] This tremendous benefit comes at small expense to consumers, whose clothes simply may take a few minutes longer to dry. Findings from Japan confirm the benefits of automated load shifting. One study of a home energy management system that automatically controls home appliances while also letting consumers track their energy consumption and costs found that it reduced home electricity and gas use by between 2 percent and 6 percent.[53]

No less important, IT is allowing utilities to monitor their grids remotely, using optical current sensors that yield critical information for pinpointing outages and other problems when they occur. Working with utilities in Denmark, IBM has found that because these monitoring systems track grid performance and capability, utilities no longer have to overbuild their networks so extensively, instead relying on better information to use existing capacity more efficiently, which can result in capital savings of up to 90 percent.[54]

**Green Buildings.** In recent years green buildings have gained attention for their efficient use of natural lighting, recycled materials, and other important construction innovations that save energy and promote sustainable living. With buildings accounting for 36 percent of energy consumption and 30 percent of greenhouse gas emissions in the United States,[55] there is room for significant improvement in energy efficiency to reduce energy use and carbon emissions. IT plays an important role in many green designs, particularly their role in improving energy efficiency. The Global e-Sustainability Initiative (GeSI) and the Climate Group predict that using IT to design, manage and automate buildings in North America could reduce the emissions footprint of buildings in our continent by 15 percent.[56]

Many of the most advanced green building designs rely on remote sensors to monitor resource consumption such as IT-equipped thermostats in individual households to reduce energy usage. One builder of green homes called Living Homes equips its homes with remote sensors that monitor energy and water usage, giving homeowners the opportunity to measure their carbon footprint through an Internet application.[57] Using IT to manage more closely the temperature in buildings can yield significant savings. Coordinated control of supermarket freezers and air conditioners, for example, cuts

maximum power consumption by 40 percent.[58]

In commercial buildings, in particular, IT is supporting important new energy management tools. IT is especially critical to the design of energy-efficient commercial buildings. Using energy simulation software models, architects can calculate the energy impact of material and design choices over the building's entire lifecycle (through so-called "lifecycle analysis"), and select the best design characteristics that maximize efficiency.[59] Moreover, the use of IT is not limited to optimizing the design process. A program under development in California, called Cal-Arch, allows California building owners to enter their building information and energy consumption, so that they can see a graphical comparison of their energy usage with data from other similarly situated buildings in the same zipcode, thereby gauging their relative energy efficiency.[60] Some IT-driven innovations are even simpler, an example being motion sensors in common areas automatically switch off lights when nobody is around.

In sum, IT is revolutionizing the ways we produce and consume electricity—enabling more efficient, emission-free alternative energy sources, boosting the energy efficiency of the existing distribution network, and other changes that promise to reduce dramatically both our energy consumption and costs.

## Reducing Energy Use in the IT Infrastructure Itself

IT has catalyzed a number of important innovations in energy efficiency, but the increasing ubiquity of IT comes with a cost. IT may transform sectors of the U.S. economy, but PCs and the hardware and servers that constitute the backbone of the Internet also use power. As discussed below, however, advances in data center technology and other areas are helping to mitigate the energy impact of the IT infrastructure. For that reason, projections for future IT energy consumption must take into account that much of the continued growth in IT use will be balanced out by improvements in IT energy efficiency.

Before discussing how advances in IT are helping to mitigate the energy impact of the IT infrastructure, however, it should be noted that there has been a considerable amount of misinformation about the

### Box 11-1: E-Paper: The Printed Word in the 21st Century

Though the printing press was a revolutionary technology, a new concept called e-paper —or electronic paper—may soon displace the traditional text-on-paper experience. Generally speaking, e-paper is a family of display technologies that manipulate digital ink to display text. Unlike a computer screen, e-paper does not rely on backlights; instead the digital ink is visible just like regular ink on paper. Because power is required only to change pages and not keep the screen lit, battery life for e-paper is typically at least 10 times greater than for a comparably sized laptop.

One application for e-paper is electronic devices known as e-book readers, which can store hundreds of digital books, magazines, and newspapers. Although an e-book can generically mean any digital display that shows a book in electronic form, products now coming to market as e-book readers all tend to rely on some form of e-paper. Network-capable e-paper devices allow users the opportunity to grab text from the Web and to read at their leisure. Kindle, an e-book reader released by Amazon.com, for example, has built-in wireless Internet access through the Sprint network that empowers users to find, buy, and download new books, newspapers, and blog postings without having to use a computer at all. Though e-book readers have been around for a few years, the market has generally not responded with overwhelming demand. Amazon's Kindle has been the lone exception as it sold out quickly upon its release and continues to be hard to find.[61] The three primary limiting factors have been cost, lack of content, and some consumers' preference for paper—the tactile sensation of holding a book and turning its pages.

That being said, the rise of e-paper as a dominant display technology is inevitable. The price of e-book readers will eventually come down. The long-term expectations are that it will be possible to produce e-paper so cheaply that it will be on cereal boxes. As more devices get into the marketplace and demand increases for e-book content, more titles will come online in digital formats. Ultimately, continuing developments in e-paper will allow for things like color, video, and greater interactivity.

energy usage of the IT sector to date. In 1999, in part to critique the energy policy of the Clinton Administration, Huber and Mills published what unfortunately became a widely cited estimate of IT energy consumption in the United States, claiming that Internet-connected computer equipment accounted for 8 percent of the country's overall electricity use and that computer equipment altogether (including non-Internet-connected computers and chips) accounted for 13 percent.[62] These authors anticipated that IT would consume half of the country's electricity by 2009.

Several more recent and comprehensive analyses have shown that Huber and Mills' estimates of energy consumption due to IT in the United States, as well as their projections, were vastly overstated. In a thorough analysis, Koomey and a team of scientists at the Lawrence Berkeley National Laboratory found that Huber and Mills' study had overestimated energy consumption due to IT by 88 percent.[63] Using 2000 data, Koomey and his colleagues estimated that IT activities accounted for closer to 3 percent of U.S. electricity consumption—much lower than the 13 percent found by Huber and Mills.[64]

Seven years later, as the transformation to a digital economy has proceeded, IT use in the United States has grown, and the economy relies more than ever on IT. The majority of American adults are now online, and the majority of businesses have intensive IT users.[65] A 2008 estimate by the Energy Information Administration of the U.S. Department of Energy was that IT use accounted for 6 percent of the country's overall electricity use— nowhere close to Huber and Mill's estimate of 13 percent back in 1999 and a far cry from their projection that IT would account for 50 percent of the country's overall electricity use in 2009.[66] The Energy Information Administration projects that U.S. electricity consumption due to IT will continue to grow in the coming years, but at a much slower rate, reaching just 9 percent of U.S. electricity consumption by 2030.[67]

IT may be governed by Moore's Law—continuously growing cheaper and more powerful—but IT's demand for electricity is not governed by this law, at least so far. In fact, as processors become faster, more products and services can be delivered with less energy. Stated differently, advances in IT lead to more output per unit of energy. Whereas cars get around 40 percent more miles to the gallon then they did 30 years ago, IT devices get 2.8 million percent more instructions per watt than in 1978.

**Researchers have estimated that for every unit of energy consumed by IT, there is a corresponding savings of 6–14 units of energy.**

### *Improved Efficiency of Data Centers*

To see why projections for future IT energy consumption must take into account that much of the continued growth in IT use will be balanced out by improvements in IT energy efficiency, consider recent efficiency improvements in energy use by data centers, which provide the brains and storage that underpin computer networks and, as a result, are responsible for a growing share of IT energy use. Indeed, one recent analysis calculates server energy demand in 2005 at 1.2 percent of total U.S. electricity consumption—double the amount in 2000. In terms of capacity, this energy use from 2005 is equivalent to the output of five 1,000-megawatt power plants.[68] In fact, data centers have become so power hungry that, according to Cisco, for "every dollar spent on computer hardware, 50 cents are spent on power and cooling."[69]

In response to the growing strain of such energy costs, IT companies are finding ways to lower energy consumption. IBM, for example, is investing $1 billion to improve data center efficiency, with the stated goal of doubling its data center computing capacity over the next couple years without increasing electricity usage.[70] IBM is also promoting mainframe alternatives to the standard data center—its latest z10 mainframe uses 85 percent less energy than a typical collection of servers with a corresponding computing power.[71]

One important innovation for cutting server energy costs is server "virtualization," which allows servers to be more fully utilized by handling multiple applications simultaneously, rather than just one. Because the average server uses only between 5 percent and 15 percent of its capacity,[72] virtualization means that several servers can be combined into one. Fewer servers means lower energy consumption because the electricity usage and cooling demands of a fully utilized server do not differ significantly from one that is running at 15 percent capacity.[73] Cisco estimates that virtualizing servers and storage, combined with optimizing air flow for cooling efficiency and improving server power efficiency could yield operating expenditure savings of 50 percent.[74] According to one estimate, 1.2 million servers have already been virtualized worldwide, resulting in savings of 8.4 billion kilowatt-hours of electricity yearly.[75] Even at the microprocessor level, companies like Intel are working to develop more energy-efficient processors and implement innovative technologies like an open-standard power management protocol to enable control and real-time monitoring of compliant power-conversion products.[76]

By some estimates, between 30 percent and 60 percent of server energy consumption is wasted—and much of the waste is due to inefficient cooling systems.[77] Newer data centers feature more efficiently designed cooling architectures that reduce cooling energy costs from between 15 percent and 40 percent through innovations such as HP's use of three-dimensional modeling called "Thermal Zone Mapping" to cool most efficiently.[78] Indeed, just as with energy-efficiency improvements in other areas, the application of IT forms the basis for achieving energy-efficiency improvements in data centers.

### *Improved Efficiency of Computers*

Data centers are not the only components of the IT infrastructure making significant efficiency improvements. IT and consumer electronics manufacturers are also producing computers and electronics that are more energy efficient.

According to the Climate Savers Computing Initiative, desktop PCs waste approximately half of the energy they consume. Too often computers are left idle when not being used rather than left in power saving mode or turned off altogether. By using power management applications to shut down its computers at night without losing saved information or causing errors, computer manufacturer Dell achieved dramatic results in reducing energy consumption for those computers:[79] The energy consumption of desktop computers at the company dropped from 89 watts per hour to just five watts per hour, and the energy consumption of notebook computers dropped from 15 to 25 watts per hour to merely three watts per hour.[80] Using power management, Dell anticipates reducing its computer-related energy consumption by 40 percent.[81] Dell's newest OptiPlex computers, for example, consume up to 70 percent less energy than previous models through more energy-efficient power settings and better design for more efficient cooling.[82] No less important, computer components are becoming more energy efficient. AMD's "Cool 'n' Quiet" processors, for example, are designed to vary their energy use to match processing needs at a particular time, significantly decreasing overall PC power consumption by as much as 35 watts at a given time.

Aside from the individual efforts of manufacturers, industry members of the Climate Savers Computing Initiative have committed to halving computer energy consumption by 2010 worldwide, saving $5.5 billion in energy costs, and preventing the release of 54 million tons of carbon dioxide yearly.[83] Currently, most people's homes are filled with a multitude of devices that never actually power off; instead, the devices sit in standby when not in use, on average adding more than a hundred dollars annually to the typical energy bill.[84] Although standby mode is important for features consumers want—allowing devices to remember individual settings, for example—some companies, like Nokia, are finding ways to significantly reduce the power draw of their products in standby mode.

Amid the controversy over IT energy consumption that has been brewing since Huber and Mills made their claims in 1999, one fact is clear—namely, that IT infrastructure and hardware will be made more energy efficient. Furthermore, IT is driving and will continue to drive the efficiency improvements that make IT hardware and infrastructure more energy efficient.

## Conclusion: IT's Net Impact in the Energy Realm

Clearly, given all the evidence in support of a strong relationship between IT and energy savings, it would be a mistake to consider IT's energy costs in isolation. Instead, net impact is the proper lens through which to view IT's impact on energy consumption and costs.

Although IT's energy costs are often direct, IT's energy benefits can be less direct—a fact that confounds efforts to estimate IT's net impact in the energy realm accurately. Measuring electricity consumption due to IT is fairly straightforward. Measuring IT's benefits is considerably more challenging. As an example, consider the impact of e-commerce—a behavior with a number of indirect energy benefits aside from the immediate benefit of a forgone trip to the local store. Indeed, with enough people shopping for music online, the local music store might disappear altogether, thereby saving the energy that is no longer required to heat and air condition the store, plow its parking lot, or even build the store. In addition, entire supply chain and manufacturing processes are reworked in a more efficient manner, with ripple effects that touch many sectors of the economy. Such benefits of e-commerce enabled by IT are often not immediately apparent, much less straightforward to quantify.

Nonetheless, studies have shown that IT has been a major driver of economic growth, a fact which complicates analysis somewhat, because more economic activity will often mean more pollution, even if that additional activity is less energy-intensive than it might otherwise be. An examination of recent history suggests that IT has had an appreciable positive effect on energy intensity (energy used per unit of gross domestic product). From 1996 through 1999, the United States experienced an unprecedented 3.2 percent annual reduction in energy intensity (energy used per unit of gross domestic product)—four times the rate of the previous 10 years.[85]

Although several factors may account for this reduction in energy intensity, including the shift in the U.S. economy toward less energy-intensive sectors, the incorporation of IT into business practices appears to be a key source of the improvement.[86] In a recent statistical analysis, Laitner and Ehrhardt-Martinez found, on balance, that for every unit of energy consumed by IT, there is a corresponding savings of 6–14 units of energy.[87] Thus, although IT itself requires energy, albeit less and less, using IT yields a large savings of energy by making activities more energy efficient, with the end result that IT is responsible for significant net energy savings.

In the future, it is reasonable to expect that IT will continue to drive energy-efficiency improvements. A report by McKinsey Global Institute estimates that cost-effective investments in existing technologies and energy productivity techniques could improve energy production by 25 percent over the next 20 years.[88] That report considers a host of proven steps that could be taken, all with a minimum 10 percent rate of return, from more efficient lighting to implementation of more advanced combined cycle power plant technologies. Not all of these benefits can be chalked up to IT, but IT clearly has contributed to many of them, including the development of more efficient home appliances.

Similarly, the Lawrence Berkeley National Laboratory estimates that IT could reduce the growth in projected carbon emissions by one-third over a 10-year period.[89] The lower projections result from the anticipated continued diffusion of IT in a range of areas, including e-commerce, reduced paper and cement consumption, advanced business and supply chain management practices, telecommuting, alternative energy, growth in less energy-intensive IT sectors relative to more energy-intensive sectors, and IT-driven efficiency improvements in a wide range of equipment.

A similar study in Japan estimates that widespread deployment of IT could curtail carbon emissions by over 40 percent by the year 2050.[90] This estimate relies on projected benefits from ubiquitous home energy management systems, vehicle driving support systems, intelligent transportation systems, and supply chain management and also assumes widespread (68 percent) full-time teleworking participation.[91] Though a 40 percent reduction in carbon dioxide emissions is an ambitious target, the study in Japan offers a useful picture of what is possible in a digital society of the future.

Yuji Inoue, CEO of the Telecommunication Technology Committee of Japan, has estimated that Japan could reach 90 percent of its Kyoto targets for

reducing carbon emissions through the application of IT alone.[92] Fuhr and Pociask have estimated that broadband networks, if widely adopted, could result in a net reduction over 10 years of 1 billion tons of greenhouse gas emissions. They calculate that this amounts to the equivalent energy savings of 11 percent of oil imports.[93]

Though there are relatively few authoritative studies on IT's net energy impact, the available evidence—both statistical and anecdotal—strongly suggests that IT is driving energy-efficiency improvements. It is reasonable to expect the trend toward IT-driven improvements in energy efficiency to continue, in no small part because many of the most promising IT-driven innovations in energy savings are still in the early stages of implementation. The net energy impact of IT in the future will heavily depend on how quickly and fully society adopts telecommuting, e-commerce, and other energy-saving practices, and whether we implement policies to spur their adoption. Both our energy future and the future of a warming planet hang in the balance.

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## About the Information Technology and Innovation Foundation

ITIF is a non-profit, non-partisan public policy think tank committed to articulating and advancing a pro-productivity, pro-innovation and pro-technology public policy agenda internationally, in Washington DC and in the states. Recognizing the vital role of technology in ensuring American prosperity, ITIF focuses on innovation, productivity, and digital economy issues.

Technological innovation, particularly in information technology, is at the heart of America's growing economic prosperity. Crafting effective policies that boost innovation and encourage the widespread "digitization" of the economy is critical to ensuring robust economic growth and a higher standard of living. However, as in any new and changing situation, policymakers have varied awareness of what is needed and what will work. In some cases legislators have responded to new and complex technology policy issues with solutions more suited for the old economy. And as the innovation economy has become increasingly important, opposition to it from special interests has grown. Finally, the excitement that the press, pundits and decision makers showed toward the information technology (IT) revolution in the 1990s has all too often been replaced with an attitude of "IT doesn't matter." It is time to set the record straight—IT is still the key driver of productivity and innovation.

As a result, the mission of the Information Technology and Innovation Foundation is to help policymakers at the federal and state levels to better understand the nature of the new innovation economy and the types of public policies needed to drive innovation, productivity and broad-based prosperity for all Americans.

ITIF publishes policy reports, holds forums and policy debates, advises elected officials and their staff, and is an active resource for the media. It develops new and creative policy proposals to advance innovation, analyzes existing policy issues through the lens of advancing innovation and productivity, and opposes policies that hinder digital transformation and innovation.

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