Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities Within Households

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Foreword

Tackling climate change is not only a huge challenge for the world—it is also a significant opportunity. Evidence shows that the information and communication technology (ICT) sector plays a key role in addressing climate change and facilitating efficient and low carbon development.

In 2008, the Global e-Sustainability Initiative's (GeSI's) report SMART 2020: Enabling a Low-Carbon Economy in the Information Age demonstrated how ICT is making the world's energy infrastructure more efficient and concluded that smart grids, buildings and transport along with travel substitution could reduce global carbon emissions by 15 percent and save up to €600 billion by 2020.

This report marks another milestone in GeSI's role of bringing together leading ICT companies and non-governmental organizations to raise awareness of the contribution innovative technology can make to sustainability. Commissioned by GeSI and its members BT, Deutsche Telekom, Ericsson and Verizon, the study contributes to the growing body of evidence that proves how ICT and broadband-enabled services are delivering energy savings.

The report focuses on the micro-level and identifies energy efficiency associated with increased adoption of ICT and broadband services at the residential level. It examines eight consumer activities enabled by the development of broadband technology:

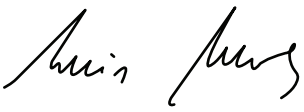
- Telecommuting
- Use of the Internet as a primary news source
- Downloading video/music
- Online banking
- Online auctions/purchases
- Online education
- Use of digital photography
- Use of e-mail

The findings are encouraging. Under ideal circumstances, and assuming an upper end of reasonable adoption of all eight activities, the U.S. could generate an annual net energy savings of about 336 million barrels of oil, equivalent to 2 percent of total U.S. energy consumption. France, Germany, Italy, Spain and the U.K. could generate an annual net energy savings of 164 million barrels of oil, equivalent to 2 percent of total energy consumption in those countries.

As global policymakers convene for the Rio+20 United Nations Conference on Sustainable Development, the report is timely in reinforcing the role that ICT can continue to play in facilitating the transition to a low-carbon economy. The findings emphasize that in order to reach the full energy efficiency potential of ICT, global policymakers need to continue creating a policy environment that encourages investment in and use of broadband services across economies. Once countries ramp up usage of broadband-enabled services across whole communities or entire cities, countries can achieve the scale required to reap the energy efficiency benefits highlighted in this report.

GeSI is convinced that innovative ICT is an important component in fostering a low-carbon, sustainable society. GeSI will remain a thought leader by continuing to produce credible primary research on the role of ICT and broadband in promoting energy efficiency.

I urge you to review this report and focus your efforts on improving energy efficiency wherever possible, and to collaborate with us in driving the sustainability agenda and creating an environment that is conducive to the rollout of ICT solutions for climate change.



Luis Neves

GeSI Chairman

About GeSI

The Global e-Sustainability Initiative (GeSI) is a strategic partnership of the Information and Communication Technology (ICT) sector and organisations committed to creating and promoting technologies and practices that foster economic, environmental and social sustainability. Formed in 2001, GeSI's vision is a sustainable world through responsible, ICT-enabled transformation. GeSI fosters global and open cooperation, informs the public of its members' voluntary actions to improve their sustainability performance, and promotes technologies that foster sustainable development. GeSI has 31 members representing leading companies and associations from the ICT sector. GeSI also partners with two UN organizations - the United Nations Environment Program (UNEP) and the International Telecommunications Union (ITU) - as well as a range of international stakeholders committed to ICT sustainability objectives. These partnerships help shape GeSI's global vision regarding the evolution of the ICT sector, and how it can best meet the challenges of sustainable development. For more information, see www.gesi.org.

Executive Summary

Recent studies have shown that broadband technologies can help shift the global market to a more energy-productive and low-carbon economy. Indeed, a detailed 2008 study by the Global e-Sustainability Initiative (GeSI) found evidence that large-scale, systems-enabled broadband and information and communication technologies (ICT) could deliver a 15 percent reduction in global greenhouse gas emissions and save up to €600 billion ($946.5 billion) by 2020. Against that backdrop, GeSI wanted to identify the key areas where the ICT sector can make the biggest contribution to sustainability within normal household activities. GeSI and several of its member companies—including BT, Deutsche Telekom, Ericsson and Verizon—contracted with Yankee Group and the American Council for an Energy-Efficient Economy (ACEEE) to explore the potential net energy reduction that might follow from additional broadband usage within U.S. and European households.

The study looked specifically at eight household-level activities or behaviors that are enabled or enhanced by the use of broadband Internet access, and that might also replace a more energy-intensive set of conventional activities. These activities were telecommuting, using the Internet as a primary news source, online banking, e-commerce, downloading and/or streaming media (music and video), e-education, digital photography and e-mail.

The study looked at the level of engagement of those activities across six countries: France, Germany, Italy, Spain and the U.K. (referenced as the EU-5) and the U.S. With a projected population of 318 million in 2012, the EU-5 shows a per capita gross domestic product (GDP) of about $40,000. The U.S., on the other hand, has a slightly smaller current population of 314 million but a larger per capita GDP of $48,000.

Using the Monte Carlo simulation technique and data that was drawn from multiple sources including consumer surveys conducted across the six markets, the study provides reasonable estimates of net energy savings that might be generated should further adoption of ICT and broadband services be made.[1] Exhibit 1 summarizes the typical energy savings that might be expected given current trends and market assumptions. The values are expressed in million barrels of oil equivalent.[2]

Exhibit 1: Summary of Typical Energy Savings for Eight ICT-Related Activities in the EU-5 and the US (in Million Barrels of Oil Equivalent)
Source: ACEEE and Yankee Group, 2012

Region	Online News	Music Streaming	Online Banking	Telecommuting	Online Shopping	Online Education	Digital Photos	E-Mail	Total
Typical savings EU-5	0.2	2.1	5.1	102.0	5.2	1.1	5.2	1.8	122.9
Typical savings U.S.	0.2	1.8	7.8	214.6	8.6	2.0	11.3	3.4	249.7

1 More details on the use of the Monte Carlo simulation technique can be found in Appendix I of this report.

2 One million barrels of oil is roughly the energy equivalent of 5.8 trillion Btus or 6.1 petajoules. One million barrels of oil is also sufficient energy to power about 5 million 100-watt incandescent light bulbs for about one year of use, or about 20 million of the more efficient compact fluorescent lamps in the U.S. Assuming a more energy-efficient electricity generation system in the EU, 1 million barrels of oil is enough energy to power 7 million and 31 million incandescents and compact fluorescents, respectively.

Telecommuting provided the largest energy benefit across the EU-5 and U.S., generating about 83 to 86 percent of net energy savings respectively. Telecommuting practices may also have a significantly greater level of market benefit compared to other activities because additional benefits such as reduced driving time and more time with family and friends may accelerate market penetration to a greater degree than other ICT-related activities. The areas of least savings were online news and e-education. In these cases, consumers are likely to continue old practices, such as reading a newspaper, while adopting new broadband-enabled activities.

Across all eight activities, we find the average savings for the EU-5 is the equivalent of 123 million barrels of oil per year, with a high-end achievable net energy savings of 164 million barrels of oil annually. For the U.S. the savings are somewhat larger at about 250 million barrels of oil on average or 336 million barrels at the upper end. As expressed in barrels of oil equivalent, these suggested energy savings imply an annual reduction of carbon dioxide emissions on the order of 39 and 79 million metric tons for the EU-5 and the U.S., respectively. While the economies are comparable in size, the EU appears to be more energy-efficient than the U.S. as a whole. Hence, the EU-5 shows a significant but smaller magnitude of net energy savings from ICT-related activities.

If all energy forms, whether the use of electricity or natural gas, were expressed in corresponding units of oil, these savings would total about 2 percent of total U.S. energy consumption. In the EU-5, though the savings appear smaller in barrels of oil equivalent, the countries' lower overall energy usage means the savings would total about 2 percent of their total energy consumption.

Key findings:

- The total savings in this report at first might seem small, but that is only because the eight activities we studied are a relatively small part of their respective economies. Even at this scale, these relatively small activities may generate a larger benefit than the 1.3 percent total carbon dioxide emissions impacts that result from the services provided by the entire ICT and electronic media industries.
- And even larger savings may come from large-scale energy and infrastructure systems and feedback mechanisms enabled and coordinated through broadband technologies. For example, increasingly popular home area networks (HANs) are being extended to bring "smart home" and a variety of home energy services quickly to market. Studies document the connection between feedback and awareness as they motivate reduced energy use in the home.
- This study affirms the net positive energy savings potential associated with the use of ICT and broadband technologies. But it also highlights the need for enabling a policy environment that encourages the investment and the use of broadband services throughout the entire economy. Many of the services that may seem individually small—for example, reading the daily paper or doing online banking—could generate a more compelling level of energy savings if the activities were actively scaled up to whole communities or entire cities as part of a rebuilding of an economy's infrastructure.

We urge policymakers to:

- **Gather and analyze more impactful data.** While the opportunity to generate new levels of cost-effective energy savings appears to be significant, the current level of data that is now collected does not allow for a fully meaningful assessment of potential large-scale impacts. Hence, there is a critical need to gather ICT-related data that encourages a more productive assessment of the emerging potential.
- **At a national level, encourage and reward companies that adopt and enforce flexible work policies that encourage the use of broadband capabilities to reduce travel.** These measures should include tax incentives and credits that promote greater adoption of telecommuting.
- **At a local/municipal level, investigate public/private partnership models that bring broadband connectivity to all residents.** Given the cost of extending broadband to those that are unserved or underserved and the challenging business models, it is highly advantageous for municipal governments to consider the energy savings generated by broadband adoption as part of the equation for extended deployment of the technology.
- **National/local governments should actively encourage both innovation and collaboration that can lead to dematerialization of existing products/services within all sectors and industries of the economy, and not merely to residential ICT services.** As both the U.S. and the EU more broadly step up efforts to find productivity-led reductions in greenhouse gas emissions, ICT services should be seen as among the fundamental building blocks to manage national climate strategies and targets.

In this case, and entirely consistent with the 2008 GeSI study, the deployment of ICT-enabled practices and improvements can become a critical step toward a much more energy-productive and low-carbon economy.

Introduction

The Global e-Sustainability Initiative (GeSI) was founded in 2001 to identify the key areas in which the information and communication technologies (ICT) sectors can provide the biggest contribution to global sustainability. As part of this effort the GeSI organization brings together over 30 of the world's leading telecommunications service providers, vendors and associations that have undertaken a number of studies to measure the impact of ICT on energy consumption and the subsequent carbon footprint. A 2008 study by GeSI found evidence that large-scale, systems-enabled broadband and ICT could deliver a 15 percent reduction in global greenhouse gas emissions and save up to €600 billion ($946.5 billion) by 2020 (GeSI 2008). Against that backdrop GeSI wanted to identify the key areas where the ICT sector can make the biggest contribution to sustainability within normal household activities. Both GeSI and several of its member companies—including BT, Deutsche Telekom, Ericsson and Verizon—contracted with Yankee Group and the American Council for an Energy-Efficient Economy (ACEEE) to explore the potential net energy reduction that might follow from additional broadband usage within U.S. and European households.

The ICT-related activities explored in this report are (in no particular order): telecommuting, using the Internet as a primary news source, online banking, e-commerce, downloading and/or streaming media (music and video), e-education, digital photography and e-mail. Based on the available survey and other market data, we characterize these eight activities as they might impact net energy savings in both the U.S. and five European countries: France, Germany, Italy, Spain and the U.K. (the EU-5). As part of the assessment, we designed and completed two simulation models to determine the magnitude of net energy savings that might accrue from these eight activities—one assessment each for the U.S. and the EU-5, respectively.

Yankee Group and other market assessment firms have generated solid survey data among end-users of these ICT-related services. As such, they provide a set of reliable indicators on the magnitude of the larger use patterns for these various services. These data, in turn, provide a useful cornerstone for estimating the net energy impacts that might be associated with the deployment of ICT systems as they displace older and generally more energy-intensive communication alternatives. The survey data can be coupled with the kind of discrete energy savings analyses that have been generated in such recent calculations as Weber et al. (2009), which examines the impact of downloading music rather than buying CDs, and Malmodin, Lundén and Lövehagen (2010a), which examined CO_2 emissions from the communication networks in Sweden and explored the effects of introducing smart work or telework solutions in that nation. These have provided useful exercises in generating what we might think of as "one-off" or discrete assessments for very specific reviews of energy use patterns. However, the detailed end-user data necessary to provide an accurate impact assessment are largely missing and are not generally collected. Moreover, many surveys that focus on specific end-user activities rely on a self-reporting methodology. And in some cases, such as with German respondents in our survey around media usage, we find differences between private-sector survey results and other sources such as the federal government reports.

Recognizing these data limitations, we have adapted the use of the Monte Carlo simulation technique, which provides an analytical framework for a probability assessment to help fill in the data gaps and expand energy savings assessments to the ICT-related activities reviewed here. In the report that follows, we first provide a brief historical background on past assessments (for more background on the history of Fermi problems and the Monte Carlo algorithm that underpins the assessment characterized here, see Appendix I). From that point, and generally following the methodology described in Appendix II, we provide an overview of the GeSI methodology. We then characterize the data-gathering methodology and findings from surveys undertaken by Yankee Group and used by ACEEE to develop and calibrate the two ICT net energy savings models mentioned earlier. From there we further characterize the findings and draw conclusions based on the work and the simulation exercises undertaken for this project.

Background

With the explosive growth in the use of the Internet there is also growing interest and concern about the potential impact on energy demands arising from related new activities. Indeed, the studies and working memos popular in the late 1990s and early 2000s echoed a misleading study that incorrectly estimated the growth of the information economy would require huge amounts of new energy resources (Huber and Mills, 1999). A working memo by Koomey et al. (1999) corrected the misleading assumptions in the Huber-Mills study, indicating that only a relatively small amount of energy was required to power the U.S. economy's digital information needs at that time—about 3 percent of the expected total electricity consumption. Laitner et al. (2001) provided one of the first adjustments to the standard macroeconomic forecasts by using updated assumptions about the emerging information economy. In that analysis, the authors were able to identify a 6 percent reduction in the forecasted 2010 economy-wide CO_2 emissions.

In a more open-ended inquiry, Laitner (2003) noted that the complexity and connectivity of the information economy yielded a deep uncertainty about the eventual long-term impact on energy consumption. The evidence, he noted, points to continuing technical changes and the growing substitution of knowledge for material resources in ways that would likely generate small decreases in energy intensity. This would be expected, in turn, to reduce subsequent environmental impacts relative to many baseline energy forecasts and projections. Despite those trends, he also posed a number of questions that needed to be addressed before any solid long-term conclusions might be forthcoming. Some of those questions are beginning to be answered, but depending on the actual end-user behaviors assumed, there may be a tendency toward net energy increases from some activities if consumers continue to rely on older forms of information services (e.g., reading a newspaper or receiving traditional banking statements) and merely use ICT-activities as a complement to rather than a full substitute for those traditional services. In effect, there may be some consumers who do both, continuing to read newspapers, for example, while supplementing their reading with online activities.

At the same time a number of studies began to explore specific instances and technologies to determine potential net impact. In addition to the Weber et al., Malmodin, Lundén and Lövehagen (2010a), and Malmodin et al. (2010b) works previously described, Hendrickson et al. (2006) outlined a methodology that used a life cycle assessment of goods and services, including ICT-related activities. In its 2008 assessment previously referenced, GeSI determined that the ICT sector has "both a profitable opportunity and a critical role to play with other sectors to design and deploy solutions needed to create a low carbon society." The report, SMART 2020: Enabling a Low-Carbon Economy in the Information Age, undertaken on GeSI's behalf by the Boston Consulting Group, illustrated for the first time "the scale of the opportunity for ICT to drive efficiency across the economy." Its economy-wide estimate found the potential for ICT to deliver emission savings of 15 percent of global business-as-usual (BAU) emissions in 2020—7.8 billion tons (gross tons) of carbon dioxide equivalent (CO_2e). Although not specifically calculated in the 2008 study, this is roughly the equivalent of about 25 billion barrels of oil saved per year.[3]

We draw on this emerging literature to explore the impact of detailed economy-wide net energy savings from the eight ICT-related services for the U.S. as a whole and for five of the larger countries within the EU. Interestingly, France, German, Italy, Spain and the U.K. have roughly the same estimated 2012 population (318 million) as the U.S. as a whole (314 million). At the same time, the EU-5 nations show a per capita gross domestic product (GDP) of about $40,000 while the U.S. reports a larger per capita GDP of $48,000.

3 One barrel of oil is the equivalent of about 0.317 metric tons of CO_2.

In generating this current assessment we again note the lack of specific data collected down to these highly detailed end-use levels. For example, in evaluating the net energy savings impact of music streaming activity, Weber et al. (2009) isolated the purchase of a single music CD and compared it to the download of a comparable number of songs from an Internet-based service. In reality we simply do not know whether (a) users download only their favorite one or two songs from a given music album; (b) users download many more songs than are on a single CD given the apparent ease and lesser cost of downloads; or (c) they spend more time browsing the Internet to learn about the musical background of the artists and the album, or even download the full set of lyrics for one or all of the songs in ways that might require further search time. Nor do we know whether a one-time download per week or per month is applied to all music, or just occasional albums; whether those songs are burned onto one or more personal CDs; or if the combination of CDs and music files are played only on the computer, on home systems or on an iPod or iPhone—or perhaps shared with others. What is more, we should question whether this form of musical entertainment (i.e., downloads) gives way to "musical radio" programs such as Pandora, Spotify or iTunes so users stream music but no longer download. Or are there now three services that users begin to employ: (i) the traditional purchase of CDs, (ii) musical downloads, and (iii) real-time streaming of music and other entertainment?[4] Finally, we do not understand nor do we routinely collect the kind of data to determine how best to allocate the use of computers and their varied services to the ICT-related activities characterized here as they might compare to other normal uses of that same equipment. In short, there is much more we don't know, and there is a significant amount of data we don't have to neatly allow us to take survey information and link it to discrete energy use patterns, and subsequently to the release of CO_2 emissions to the atmosphere (or other environmental impacts, for that matter).

4 Adding to this list of unknowns we might further inquire whether personal downloads are also representative of household patterns, and if users purchase a CD, do they walk, drive or bike to a nearby store or do they use some form of electronic commerce to purchase the disc? And how does the purchase of CDs and books compare to other e-commerce, which is a separate activity evaluated in this mix? The reader can anticipate many other questions that are likely to follow as well.

Assessment Methodology and Data Gathering

The assessment that underpins this report derives from four key elements. The first builds on the GeSI Assessment Methodology (2010) to assess the energy and carbon impacts of a variety of ICT-related activities. The second is drawn from detailed consumer survey data gathered through Yankee Group's normal market research activities. The third incorporates a variety of publicly available energy and economic statistics. The last element is the use of proxy data from one country or business sector that enable us to make reasonable assumptions when there is incomplete data elsewhere in the analysis. For example, if we take estimates of detailed energy use in the newsprint industry within the U.S., we can use a series of other price and quantity data to attribute estimates to the same end use within the EU-5 nations.

The GeSI Methodology

The methodology developed for GeSI in 2010 consists of three major steps to evaluate the energy savings impact of ICT and broadband usage patterns: (1) Define the goal and scope of the study, (2) limit the life cycle processes to relevant and significant components identified in the first step, and (3) assess and interpret the net enabling effect. These steps are described briefly below with a discussion of how they were utilized in this particular assessment.

Step 1: Define the Goal and Scope of the Individual Analysis

There are two aspects shaping both the overall goal and the scope of the analysis that follows. The first is to provide context so that we might better understand the scale of potential changes and their impact on energy consumption. The second is to determine the current usage patterns for each of the eight separate activities to then provide a working estimate of how those patterns might be extended over a two- to three-year period.

Even though we are dealing with relatively large economies, with each region of analysis having populations in excess of 300 million people, the overall scale of economic activity that might be impacted by the eight ICT-related activities is fairly small. We can get a sense of that scale using the most recent data published by the Organisation for Economic Co-operation and Development (OECD), as shown in Exhibit 2.

Exhibit 2: Market Share of ICT-Proxy Sectors as Percent of Total Economic Activity
Source: OECD.Stat Extracts, 2010

Region	Pulp, paper, paper products, printing and publishing	Post and telecommunications	Education	Electricity, gas and water supply
EU-5	1.8%	2.2%	3.1%	2.5%
U.S.	2.3%	3.0%	0.8%	1.8%

As in the U.S., the OECD does not publish sector-specific data that easily matches or conforms to specific ICT-related activities. However, we can adapt economic output data for the EU-5 and the U.S. to compare what we might call proxy statistics for sectors that might serve as surrogate indicators of common economic activity. One of the impacts of ICT-related services, as an example, will be to reduce paper consumption. So we might look to the sector data that the OECD refers to as "pulp, paper, paper products, printing and publishing." As shown in the table, the revenues for that set of goods and services are only 1.8 and 2.3 percent of the total economic activity for the EU-5 and the U.S., respectively.

The combined set of postal services and telecommunications represent only 2.2 and 3.0 percent of total economic activity. Finally, education in the EU-5 is 3.1 percent while a surprisingly smaller 0.8 percent in the U.S. And together, the sales of electricity, gas and water are only 2.5 and 1.8 percent of total economic output for the two regions. This suggests, for example, that if the EU-5 were to adopt a variety of ICT-enabled smart practices that reduced electricity, natural gas and water consumption by 40 percent in all three of the ICT proxy sectors, the reduction in utility services from that set of activities would amount to less than a tenth of a percent economy-wide. One can easily imagine, therefore, that the changes in energy use brought about by expanded ICT practices would also be relatively small.

With that sense of scale anchored for the moment, we now explore the current ICT usage patterns to see how changes in broadband practices might impact energy requirements. As explained further below, here we generally examined the 2011 base year and explored how changed usage patterns in that year might induce further reductions in necessary energy. For example, the U.S. now has a paid newspaper circulation of about 48 million subscribers among its population of 300 million while Germany has 22 million subscribers among its 82 million people. Based on Yankee Group survey data, we might anticipate that of these subscribers, anywhere from 25 to 70 percent might become new readers of online newspapers, and 45 to 90 percent of those households might drop their delivered circulation and rely entirely on the Internet for their news. In the next steps we can then explore, given the range of uncertainties, the potential net reduction in energy consumption from this changed pattern of reading newspapers. The same logic is applied to each of the other seven broadband activities included in this assessment.

The GeSI methodology typically includes consideration of all potential energy effects (together with the related CO_2 emissions) of ICT implementation. This includes the relevant set of primary and secondary enabling and rebound effects impacted by the individual broadband activity. As we noted above, however, we found the impacts of the individual activities in this analysis to be sufficiently small both in scale and scope that we needed to limit consideration of some aspects of this analysis. To that extent, then, we made a working estimate of the energy embodied in the production of displaced paper products such as newspapers, bank statements, and mail; we also included estimates of embodied energy associated with the transfer of data through the variety of Internet services. However, we did not attempt any estimates of embodied energy associated with the production of vehicles since it was unclear what broadband services might imply for the near-term mix or size of existing vehicle stock. Finally, because we were unable, through this exercise, to pull in the relevant price and income data associated with the delivery of these ICT services, we were unable to evaluate a rebound effect that might be implied in the changed usage patterns. As suggested by Ehrhardt-Martinez and Laitner (2010), however, the effects would likely be less than 30 percent—especially as consumers continue to show concern for things such as energy security and climate change. If the rebound effect is as high as 30 percent of a potential 4 percent savings in the EU-5, for instance, the overall change would imply a net savings on the order of 3 percent.

Step 2: Limit Assessment of Less Significant Impacts

The BAU reference case provides a preliminary look at the year 2011 for both the U.S. and the EU-5 nations. In many cases the last historical values are for earlier years. However, using the standard economic projections made available by the Energy Information Administration (2011) and the International Energy Agency (2011) we were able to extrapolate the historical data to generate a working profile of likely impacts in the year 2011. Because of the scale of the eight activities, and without evaluating significant changes in prices or policies, we held our assessment to examine the likely impacts that might occur over the next two to three years as if they also took place in the year 2011. Finally, because the potential net savings of this specific set of ICT activities are likely to have a relatively small global impact (unlike the scale of impacts characterized by the GeSI 2008 assessment[5]), we omitted any estimation of either price or quantity changes that might follow additional ICT-enabled energy savings. This is true whether we imagine possible increases in the sale of laptops or iPhones or anticipated changes in the cost of energy. Two other aspects should also be referenced here. The primary focus in this analysis is the change in or savings of primary energy requirements. With the many varied units to estimate energy consumption—ranging from British thermal units (Btus) and joules to kilowatt-hours and tons of oil—in this assessment, our primary metric of change is millions of barrels of oil equivalent. Given the limited scope of our analysis, and the wide range of greenhouse gas intensities associated with the many different forms of fossil fuels, here we apply an average coefficient of CO_2 emissions per metric ton of oil. That enables us to provide a working estimate of CO_2 per total end use of energy savings.

Step 3: Assess and Interpret

As we suggest throughout this report, there is a high level of uncertainty associated with both the data and the ranges of responses that might be expected from an expanded use of ICT services within U.S. and EU-5 households. With that uncertainty we make an effort to place the results in context, suggesting that, in the aggregate and on average, the net energy savings are likely to be significantly positive. This appears to hold even if several of the individual activities (e.g., online news and banking services) show a very small increase in energy consumption. In many ways, however, the results we describe here provide what we might think of as a reverse complement of the GeSI 2008 study, which clearly documented significant energy savings and greenhouse gas emission reductions when done at scale. Here we explore eight individual ICT-related services that (besides telecommuting) have a relatively small economic footprint, while the 2008 GeSI study examined large-scale, economy-wide shifts in systems and infrastructure. Unsurprisingly, the clear message that emerges from this analysis is that to realize the full benefits of ICT-led energy productivity improvements we cannot think in increments of change. To generate large-scale benefits from ICT investments and practices, policymakers will need to think big about this rapidly emerging market.

5 The total energy savings for this set of ICT-related activities in the U.S. and the EU-5 might amount to about 2 percent of current energy consumption. The combined populations are just over 600 million people, or about 9 percent of the more than 7 billion persons worldwide. Nine percent times 4 percent is about 0.4 percent savings, compared to the 15 percent reductions in greenhouse gas emissions highlighted in the 2008 GeSI study.

Generating and Integrating the Data

This study builds on two primary sources of information. The first is drawn from detailed consumer survey data from the years 2003 through 2010 that were gathered through Yankee Group's normal market research on connectivity and how consumers currently use technology. While the later years are more immediately relevant, historical data from the early years provide useful insights about the adoption trends of ICT practices. Additionally, we conducted an online survey in July 2011 asking 6,000 American, British, German, Italian, French and Spanish consumers about their behaviors online and the choices they have made in replacing other related activities. We examined an array of broadband applications as they might affect traditional consumer banking practices, the purchase of music and commuting to work. It's important to note that while we asked most questions to 1,000 consumers in each country, follow-up questions often were only asked to a smaller sub-set. For example, we asked everyone their employment status, but we only asked those who were employed full-time or part-time whether they had the option of telecommuting.

The second source of information is an array of discrete data that enabled us to assess the net energy savings that might be possible from an expanded use of consumer broadband activities. This data included number of households and number of persons per household, average energy consumption per household, typical fuel economy of cars and trucks, and estimates of typical newspaper subscriptions and other common services. It also included estimates of the energy use associated with displaced paper products and the energy required to power ICT and broadband activities. As we further detail below, there appears to be a significant potential to further increase net energy savings in both the U.S. and the EU.[6]

6 While these data points provide a useful benchmark to estimate energy savings, they are collected for different purposes and with different measurement perspectives. It is fair to say that many data were never intended as a basis to evaluate net energy savings from ICT-related activities—especially in ways that compare across regions or sectors. For example, the International Energy Agency (2011) may report U.S. energy consumption as about 92 quads of total energy in 2011 (as this is converted from millions of tons of oil equivalent reported by the IEA), but the U.S. Energy Information Administration (2011) reports total energy use that is about 98 quads. And the latest OECD (2010) economic input-output tables used to generate proxy data for key ICT-related sectors for both the U.S. and the EU-5 have baselines that are reported as the "mid-2000s." Nor do they report discrete ICT-related sectors; rather, they are averaged into other sectors so that it is difficult to isolate specific energy or economic relationships.

Based on the findings of this study, the single biggest opportunity to reduce energy consumption through increased energy efficiency is in the expanded use of telecommuting or work shifting. At the same time, however, it is important to emphasize that telecommuting or work shifting emerged as the greatest opportunity for net energy savings only among the discrete activities examined as part of this study. Other implementations of ICT are likely to have greater impact on net energy savings. These could include applications such as smart grids and other ICT-enabled applications that impact all users as opposed to only those with flexible employment options. Laitner (2010), for example, highlighted the potential for a 27 percent electricity savings by 2030 as the result of an economy-wide investment in semiconductor and ICT-enabled technologies. In effect, the activities examined here turn out to be a small subset of the larger opportunities that will likely unfold as further investments in such technologies are encouraged.

Survey Results and Summary of Findings

To generate a snapshot of the current level of consumer broadband-related activities in the home, we conducted an online survey across six national markets. Using a third-party fulfillment house, we posed 30 questions to more than 1,000 consumers over the age of 16 in France, Germany, Italy, Spain, the U.K. and the U.S. As stated previously, we strove to achieve a balance among survey respondents so that they reflected the general population of the country being surveyed. The survey objective was to gather sufficient user profile data that, in combination with estimates of households and their current energy practices, would facilitate our evaluation of the potential energy savings benefits associated with changing consumer behaviors as enabled by broadband services.

Respondents were asked specific questions about eight activities we believe are enabled or enhanced by broadband connectivity and/or that provide a substitute for another activity and contribute to a reduction in carbon footprint as a result of a net savings in the overall demand for energy. The logic behind this assumption is based on the link between all eight activities as replacements for other consumer services that require more energy consumption. The eight activities and the respective consumers that are being replaced are summarized in Exhibit 3.

Exhibit 3: List of Broadband Activities as Replacements for Specific Consumer Services
Source: ACEEE and Yankee Group, 2012

Broadband-enabled/enhanced activity	Replacement for…
Telecommuting	Commuting to/from an office
Using the Internet as a primary news source	Purchasing a printed newspaper/magazine
Online banking	Traveling to/from a bank branch
E-commerce	Purchasing retail products in a store
Downloading/streaming media (music and video)	Purchasing physical media for music, video and books
E-education	Commuting to/from class on campus
Digital photography	Purchasing/processing physical prints
E-mail	Sending personal correspondence via postal service

In addition, we supplemented the survey data with other questions that focused on usage of mobile devices, participation in social networking sites such as Facebook and Twitter, and demographic information around age, income, household makeup and population density of primary towns of residence to develop profiles of certain types of consumers.

With consumer profiles and activities established, we then developed an array of end-use data to convert these activities into a range of estimates of potential net energy savings that might be enabled through expanded use of these broadband activities. As one example, we used the average work commute of 18.76 kilometers for Spanish employees (see Exhibit 4 in the Telecommuting section) together with estimates of typical fuel economy for commuter vehicles driven in Europe to see what level of petrol or gasoline consumption might be displaced by allowing more of the labor force to work from their own homes.

The sections that follow lay out the U.S. and EU-5 survey results for each of the eight ICT activities. As we explain the results of our survey, we also provide comparisons with other data sources to show trends among all eight activities.

Telecommuting

The evidence suggests that telecommuting should contribute to a net decline in total energy use by dramatically reducing an individual's transportation energy consumption. The biggest impact comes from removing the energy required to commute between the residence and the place of employment. There are also other benefits including a reduction in energy required in commercial facilities that support employees on premise. Additionally, numerous other studies have shown that there are benefits to employers that encourage and allow employees to telecommute on a regular basis (see, for example, TIAX 2007). It's important to note here that we also recognize a rebound effect where consumers who work from home are consuming more energy to power traditional office equipment in the home, thus our estimates focus on net energy savings.

In our 2011 survey, we found that 27 percent of those employed full-time work for companies that allow telecommuting. The U.S., where many of the largest employers have actively promoted telecommuting as a benefit to employees, had the highest response rate at 34 percent, while France and Italy had the lowest at 19 percent and 23 percent, respectively. While policies that encourage telecommuting certainly play a part in the incidence of companies allowing it, we suspect cultural legacies also likely play a significant role particularly in some European markets.[7] Additionally, for telecommuting to be widely accepted there must be buy-in and active encouragement of the practice from top management. Without such support, middle management often fails to fully utilize the option of telecommuting, thereby muting the impact it has on net energy reduction.

We also recognize there are certain jobs, including most in the manufacturing sector, that simply do not lend themselves to working from home. The average one-way commute reported in the survey was 22.42 kilometers (km), with the U.S. showing a longer distance of 25.58 km and Spain showing the shortest distance of 18.76 km (see Exhibit 4).

Exhibit 4: Over a Quarter of US and EU-5 Respondents Telecommute
Source: Yankee Group, 2012

Does your job allow you to telecommute (work from home instead of physically going into a company facility)?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	3,761	657	701	635	550	633	585
Yes	27%	31%	23%	19%	30%	27%	34%
No	73%	69%	77%	81%	70%	73%	66%
Mean Commute (in km)	22.42	23.27	20.25	27.13	19.55	18.76	25.58

7 Although not a major focus of this report, for a useful discussion in this regard, see Rosenthal (2009).

Among those that worked for companies that allowed telecommuting, we again found wide variations among countries—though on average 31 percent of employees whose companies and jobs allow for telecommuting take advantage of the option on a daily basis (see Exhibit 5). Paradoxically, French respondents were the least likely to work for employers that allowed telecommuting but took advantage of the option more often than similar respondents in other countries.

Exhibit 5: Most Who Telecommute Do So Daily
Source: Yankee Group, 2012

About how often do you telecommute rather than going into a company facility?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	1,021	205	158	120	164	173	201
Every day	31%	30%	25%	39%	34%	27%	31%
Two to four days per week	24%	28%	25%	18%	23%	25%	24%
One day per week	18%	14%	21%	18%	18%	22%	18%
One day every two weeks	6%	7%	7%	9%	5%	4%	6%
One day per month	5%	5%	7%	3%	5%	6%	5%
Less than one day per month	15%	15%	15%	14%	15%	15%	14%

The increase in telecommuting is measureable when we look at prior Yankee Group surveys dating back to 2003-2004, which is roughly when a critical mass of companies began encouraging employees to work from home. It also is approximately the time when broadband connectivity moved into a mass market product in the countries we examined for this study.

In 2003, for example, Yankee Group's Small/Medium and Large Business surveys found that 9.9 percent of U.S. employees were described as regular telecommuters. By 2009, that percentage had risen to 15.9 percent. We saw a similar rise in European markets. In Yankee Group's 2004 Transatlantic Wireless Business Survey, 28 percent of respondents said that at least 50 percent of their employees were mobile workers (which we defined as spending at least 20 percent of their time outside the office). By 2006, that number had risen to 37 percent.

Using the Internet as a Primary News Source

Using the Internet as a primary source of news decreases energy output by reducing the number of printed copies of newspapers and magazines, thereby lowering the energy required to both produce and deliver such physical media. We also could consider the reduced number of trips for consumers to purchase such media, but tracking the means of transportation (walking vs. driving vs. public transit) would require additional survey work.

What we can track with a high degree of confidence is the rise in consumers using the Internet as a source of news and the corresponding decline in circulation of printed media. In our survey we find, not surprisingly, that printed newspapers and magazines rank third or fourth on the list of primary news sources depending on the particular market and that TV is the predominant format for news consumption in all but one of our studied markets (see Exhibit 6).

Exhibit 6: TV and Internet Sites Are Top News Sources
Source: Yankee Group, 2012

	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
Printed newspapers/ magazines	12%	19%	9%	8%	17%	9%	11%
TV	45%	42%	41%	50%	46%	48%	43%
Radio	10%	15%	6%	13%	9%	12%	4%
Internet sites	33%	24%	44%	30%	28%	30%	40%
Other	1%	1%	1%	1%	0%	0%	1%

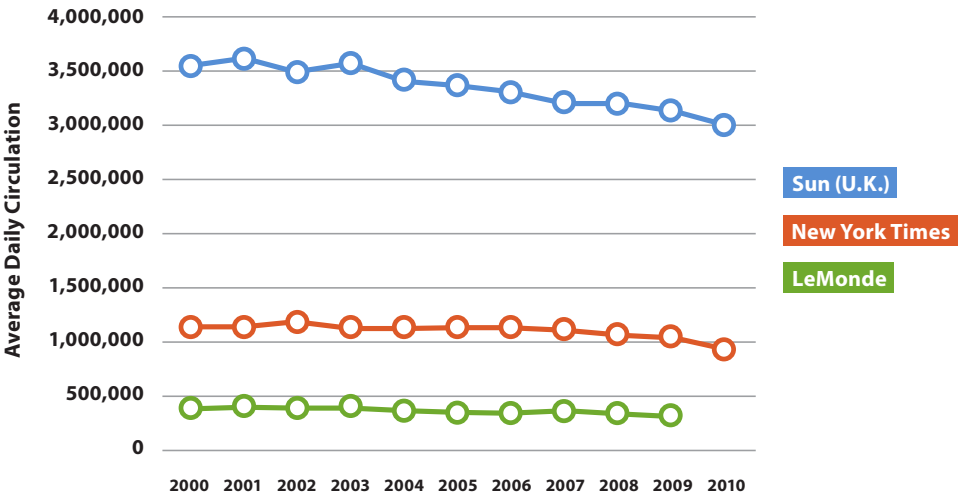
While TV and Internet sites are the most common primary news sources, we haven't found that this has necessarily meant the death of printed media. While we certainly can point to a rapid decline of newspaper and magazine circulation as one consequence of the Internet becoming more important in the news consumption cycle, we find that a majority of consumers still continue purchasing printed material at least once a month. Only in France, where 44 percent of respondents said they rely on the Internet as a primary news source, do we find almost 50 percent of consumers saying they no longer purchase printed newspapers and/or magazines (see Exhibit 7).

Exhibit 7: Many Respondents Still Purchase Printed News Media
Source: Yankee Group, 2012

Do you still purchase printed media or have them delivered?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	5,245	803	908	919	827	907	881
Yes, I still buy a printed newspaper and/or magazine every day	13%	18%	13%	9%	13%	10%	19%
Yes, I still buy a printed newspaper and/or magazine at least once a week	28%	28%	28%	25%	31%	29%	28%
Yes, I still buy a printed newspaper and/or magazine at least once a month	19%	18%	26%	19%	17%	18%	14%
No, I do not buy printed newspapers and/ or magazines	40%	36%	33%	48%	40%	43%	40%

We find a significant amount of secondary data as well as evidence in prior Yankee Group surveys that support the assumption that Internet and TV have been replacing printed newspapers and magazines. Looking at average circulation of a sample of three large daily newspapers, we see a general trend of decline. The New York Times' average daily circulation has declined from 1.15 million in 2000 to 951,000 in 2010, a 17.3 percent decline, while the U.K.'s largest circulation daily The Sun fell 15.5 percent during the same period (see Exhibit 8).

Exhibit 8: Printed Newspaper Circulation Is Declining
Source: Company reports and Yankee Group, 2012



Similarly, we also see rapid declines in the average time spent reading both newspapers and magazines as the Internet and TV become more prominent for news consumption. In Yankee Group's 2005 Technically Advanced Family Survey, respondents reported spending an average of 42 minutes per day reading the newspaper and 30 minutes reading magazines. By the 2009 survey, time spent had dropped to 14 and 11 minutes, respectively.

Online Banking

The use of online banking has increased steadily as consumers have become more comfortable with the idea that their transactions are secured and as banks have made greater use of Internet-based architectures to provide new consumer services. The corresponding reduction in energy output can be seen in fewer trips made to physical bank branches and reduction of energy required to build banking facilities. There are potential additional savings with adoption of mobile banking if consumers reduce their dependence on cash for transactions. In this scenario, there not only is a reduction in the number of trips taken but also a potential energy savings through the reduction of ATM builds. However, for purposes of this study we only measure online transactions as a substitute for physical visits to a bank branch.

In our survey, we find a high usage of Internet banking services (see Exhibit 9). We believe this is likely being driven by simple transactions such as checking account balances, with the high percentage of employees that are now paid via direct deposit having a direct correlation to this activity.

Exhibit 9: Eighty Percent of Respondents Use Online Banking
Source: Yankee Group, 2012

Do you check your bank balances or conduct any kind of banking transactions over the Internet?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
Yes	80%	79%	75%	84%	82%	77%	81%
No	20%	21%	25%	16%	18%	24%	19%

It is interesting to note that among all activities we examined for this study, online banking showed the least variability between respondents in different countries. This is not necessarily historically true, however. In Yankee Group's European Connected Consumer Surveys we find that the percentage of respondents who had conducted an online banking transaction within the prior month ranges from 79 percent in Germany to 50 percent in Spain. In the U.S. at the same time, 46.5 percent said they had conducted a banking transaction online in the last month. However, due to variations in the wording, we can't make a direct comparison between the two samples.

Like the previous activity of consumers using the Internet as a primary source of news, online banking has not completely replaced consumer trips to physical bank branch locations. Indeed, the percentage of consumers who have not visited a bank office in the last 12 months is very small (see Exhibit 10). We believe there are likely a number of reasons for this, including a lack of methods for consumers to deposit funds without going to a bank office.

Exhibit 10: Consumers Are Still Visiting Physical Banks
Source: Yankee Group, 2012

How many times in the last 12 months have you physically gone into a bank office?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
Never	6%	5%	12%	6%	7%	2%	7%
Once or twice	27%	21%	37%	32%	31%	16%	24%
Three to 12 times	43%	43%	36%	47%	44%	46%	44%
More than 13 times	22%	29%	14%	14%	17%	36%	25%
Unsure/don't know	1%	2%	2%	1%	2%	2%	1%

E-Commerce

The impact of the Internet on commerce has been well documented. The rise and fall of companies throughout the dot-com era largely revolved around the singular activity of consumers purchasing products over the Internet. Regardless of the fortunes of those behind the scenes, there is no question that the volume of e-commerce has seen a slow but spectacular rise over the last decade. We believe this leads to lower energy consumption and thus carbon footprint by reducing trips consumers would otherwise be making to retail outlets to purchase products. However, we must be cognizant of numerous other factors when measuring the impact of e-commerce on carbon footprint. While consumers will likely make fewer trips to retail outlets, there is also a large rebound effect in place for this activity due to greater energy consumption by PCs and other devices used to make purchases. Additionally, physical products must still be delivered and therefore energy expended.

In our survey for this study, we find a high level of participation in e-commerce (specifically excluding music and videos, which we deal with separately) across all six markets examined, with 72 percent having purchased at least one item over the Internet in the last year. U.K. respondents were by far the most active participants with 11 percent falling into the highly active category, purchasing more than 30 items over the last 12 months (see Exhibit 11).

Exhibit 11: Almost Three-Quarters of Respondents Have Used E-Commerce in the Past Year
Source: Yankee Group, 2012

In the past 12 months, how many physical products (excluding music CDs or video DVDs) have you purchased off the Internet or in an online auction?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
None	28%	38%	32%	27%	14%	36%	23%
One or two products	20%	17%	23%	28%	16%	22%	15%
Three to 10 products	32%	29%	31%	32%	37%	30%	35%
11 to 30 products	13%	10%	10%	8%	22%	8%	18%
More than 30 products	6%	6%	4%	5%	11%	3%	9%

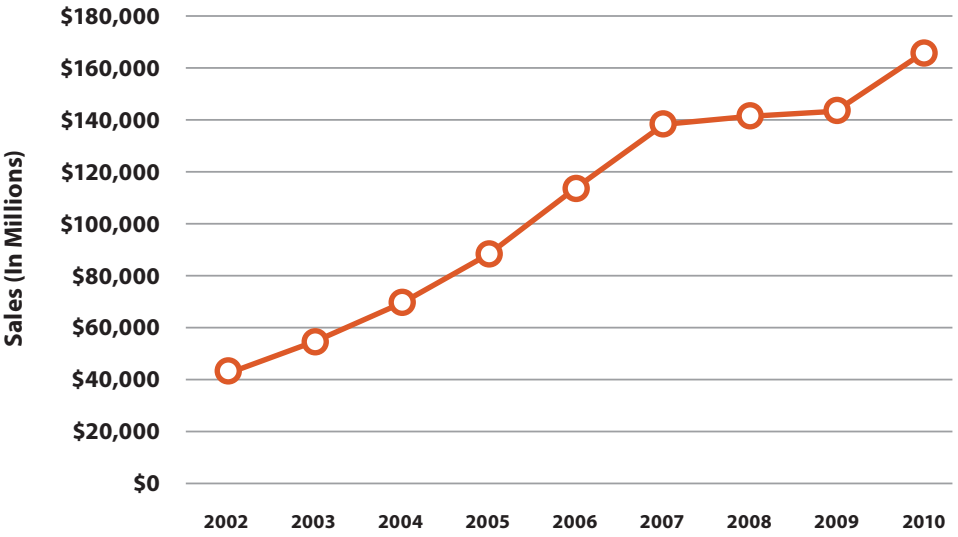
Whether e-commerce replaces trips to physical store locations is difficult to discern without further research. However, we can say with confidence that products being purchased via e-commerce are likely replacing products being bought at physical retail outlets. When comparing the impact of e-commerce on physical store purchases across markets, it's again U.K. respondents who appear most likely to opt for the former (see Exhibit 12).

Exhibit 12: E-Commerce Is Replacing Physical Retail in Many Cases
Source: Yankee Group, 2012

Among those products you purchased, approximately how many of them were available to you in a physical store?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	4,303	625	678	729	860	637	774
None	6%	5%	8%	4%	6%	5%	9%
One or two products	31%	30%	36%	38%	22%	37%	25%
Three to 10 products	42%	46%	40%	41%	43%	44%	42%
11 to 30 products	15%	13%	12%	11%	23%	10%	18%
More than 30 products	6%	6%	4%	6%	7%	4%	6%

Using prior Yankee Group surveys and secondary data we also show a rapid rise in both frequency of e-commerce transactions and value of products being purchased. In Yankee Group's 2004 Technically Advanced Families Survey, 55.5 percent of respondents said they had conducted at least one e-commerce transaction in the prior 30 days. By 2008, that number had risen to 61.6 percent. More stark and perhaps more telling of the level of activity of e-commerce are figures from the U.S. Census Bureau, which has tracked the value of e-commerce sales since 1998. The data for 2002-2010 are shown in Exhibit 13.[8]

Exhibit 13: US E-Commerce Quadrupled From 2002-2010
Source: U.S. Census Bureau



8 While Exhibit 13 shows roughly a quadrupling of e-commerce sales from 2002 through 2010, the total sales volume in 2010 remains a very small 0.6 percent of total economic activity in that year.

Downloading/Streaming Media (Music and Video)

Of all activities examined for this study, the downloading and streaming of music and video show the strongest correlation with the activities they replace. In the case of downloading media, the activity being replaced is purchasing physical media such as CDs and DVDs. There also is likely to be a strong connection between increased download/streaming activity and reduced energy expenditure and therefore carbon footprint as the reduction in physical media diminishes the energy required to produce and ship such product.

As noted in the introduction to this section, we find significant differences between countries in responses to questions about how consumers acquire music, movies, TV shows and episodes and books (see Exhibits 14 and 15). Paradoxically, in opposition to the activity of e-commerce, U.K. respondents showed the highest propensity to purchase physical media, while Italian respondents were more likely than others to say they purchase digital media only. Spanish respondents, who also were least likely to name printed products as their main source of news, said they purchase neither physical nor digital media. There are numerous outside influences that are almost certainly impacting this, with the availability of local content in various formats playing a large role.

Exhibit 14: Preference for Digital vs. Physical Music Varies Across US and EU-5
Source: Yankee Group, 2012

How do you currently acquire music?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
I buy physical media only	23%	21%	17%	28%	30%	21%	22%
I buy digital media only	15%	16%	18%	13%	12%	12%	18%
I buy both physical and digital media	25%	25%	27%	21%	31%	19%	29%
I buy neither physical nor digital media	37%	38%	38%	39%	28%	49%	32%

Exhibit 15: Preference for Digital vs. Physical Movies Varies Across US and EU-5
Source: Yankee Group, 2012

How do you currently acquire movies?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
I buy physical media only	25%	22%	16%	25%	37%	16%	33%
I buy digital media only	10%	11%	16%	9%	8%	10%	7%
I buy both physical and digital media	18%	17%	20%	16%	19%	13%	26%
I buy neither physical nor digital media	47%	50%	49%	51%	37%	62%	35%

This differentiation between countries has remained consistent from prior Yankee Group surveys. From 2003 through 2006, we find that Spanish consumers are least likely to have streamed or downloaded music to a PC within the prior month.

We also find a relatively easily explained anomaly in this activity when it comes to both TV series and TV episodes. In both cases and across all countries, a majority of consumers purchase neither physical nor digital versions of such content. While this appears to be unusual in the pattern of other media, there are several logical reasons for this including the availability of TV series in either format and the high usage of digital video recorders obviating the need to purchase such content.

The impact of downloading/streaming on sales of physical media is best illustrated by showing the increased activity level with the declining sales of music. If we look at total music sales in terms of millions of physical units across the six markets studied we can see a rapid decline as broadband penetration levels increase (see Exhibit 16).

Exhibit 16: Physical Music Sales Decrease as Broadband Penetration Increases
Source: Recording Industry of Japan Yearbooks 2005-2010

Total Music Sales in Six Studied Markets (in Millions of US Dollars)	
2002	1,309.5
2003	1,216.8
2004	1,219.5
2005	1,107.7
2006	987.7
2007	836.2
2008	679.07
2009	559.32

Within this activity we also find two specific user profiles that provide an interesting divergence—families and respondents who participate in online social networks such as Facebook and/or Twitter. When segregating respondents with children under the age of 18 in the household we find that consumption—particularly of physical media—increases almost across all content forms (see Exhibit 17).

Exhibit 17: Households With Children Consume More Movies, Both Physical and Digital
Source: Yankee Group, 2012

How do you currently acquire movies?		
	Household with children	Household without children
Sample size	2,237	3,763
I buy physical media only	25%	24%
I buy digital media only	11%	10%
I buy both physical and digital media	23%	15%
I buy neither physical nor digital media	41%	51%

The result is not particularly surprising to anyone with children. Given the sheer volume of children's programming available on DVD and the relatively low cost of players, the DVD represents an inexpensive form of entertainment.

Within the social networking segment, which by our definition includes people who use the Internet to access social networking sites such as Facebook and/or Twitter, we also find overall purchasing of media higher across all forms, but it is particularly pronounced with movies (see Exhibit 18).

Exhibit 18: Social Networkers Purchase More Movies
Source: Yankee Group, 2012

How do you currently acquire movies?		
	Social networker	Non-social networker
Sample size	4,135	1,865
I buy physical media only	25%	24%
I buy digital media only	11%	8%
I buy both physical and digital media	22%	10%
I buy neither physical nor digital media	42%	58%
More than 30 products	6%	6%

E-Education

Among all activities analyzed we found the lowest level of participation with e-education. Indeed in all markets studied we found only one—Spain—in which more than 20 percent of respondents said they had taken an online class within the prior 12 months (see Exhibit 19).

Exhibit 19: E-Education Shows Low Adoption Levels Among Respondents
Source: Yankee Group, 2012

How many times in the last 12 months have you taken an online class?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
None	86%	91%	84%	90%	91%	76%	84%
One or two classes	10%	8%	13%	6%	7%	18%	11%
Three to five classes	2%	1%	3%	2%	2%	4%	3%
More than five classes	1%	1%	0%	3%	1%	1%	2%

The connection between e-education and reduced energy usage comes in the form of reduced trips to physical classrooms (see Exhibit 20). The 86 percent of respondents who have not yet taken an online class can be interpreted as a future market potential for expanding e-education.

Exhibit 20: E-Education Reduces Trips to Physical Classrooms
Source: Yankee Group, 2012

Among those classes you took, how many of them could you have taken in a local classroom?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	844	93	160	105	93	236	157
None	39%	46%	33%	45%	42%	36%	38%
One or two	47%	47%	57%	42%	42%	50%	41%
Three to five	9%	3%	8%	5%	12%	10%	13%
More than five	5%	3%	3%	9%	4%	4%	8%

That we find the lowest level of participation within this segment is not particularly surprising. For e-education to function, it requires not only activity on the student end but also a significant investment on the part of the educational institution. This can mean resources dedicated to equipment (e.g., PCs, cameras, microphones) but also physical facility improvement (e.g., rewiring classrooms to handle the equipment) and training for teachers who may not be accustomed to teaching students in this setting.

Digital Photography

The rapid uptake of digital photography has clearly had a direct and negative impact on the sale and processing of traditional film. According to the Photo Marketing Association, slightly more than 800 million rolls of film were sold in the U.S. in 1999. That number in 2011 is estimated to be only 20 million rolls.

Intuitively, we can theorize that there is a reduction in end-user energy consumption with this transition through the reduction of the photographic film manufacturing process, the reduction of photo processing and the reduced number of trips consumers are taking to drop off and pick up film and photo prints.

In prior Yankee Group surveys we found a high percentage of digital camera ownership across all markets. However, ownership of a digital camera does not necessarily show a reduction in energy output. It's also important to take into account the proliferation of cameras on mobile handsets. Flickr, for example, announced in 2011 that the iPhone 4 had surpassed the Nikon D90 as the most popular "camera" used by members of the photo sharing site.

To determine impact on energy output, we are more concerned with how consumers view and share the finished product. In this particular activity we look at the number of times consumers have had photographic prints processed by an online service and the impact that has on the number of trips they make to a retail outlet for the same service.

Unlike many of the other activities examined, we don't find significant differences between countries with the one exception of Italy, where respondents appear to use online photo services at a greater rate than those in other markets (see Exhibit 21).

Exhibit 21: More Than a Quarter of Respondents Use Online Photo Sharing Sites
Source: Yankee Group, 2012

How often in the last 12 months have you used Internet-based photo sites (e.g., Flickr, Snapfish) to upload photos or have prints created?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
None	66%	69%	59%	69%	67%	67%	62%
One or two times	20%	20%	25%	20%	19%	18%	18%
Three to 10 times	10%	9%	11%	9%	10%	10%	12%
11 to 30 times	3%	2%	3%	1%	3%	3%	5%
More than 30 times	2%	1%	3%	1%	2%	2%	3%

Regardless of country, respondents in general also have reduced or eliminated their trips to stores for photo processing. Perhaps most surprising is that even with the rise in use of online photo sites, in all markets except France, more than 12 percent of respondents actually go to a retail store more often for photo services (see Exhibit 22).

Exhibit 22: Online Photo Sharing Has Decreased Physical Photo Processing
Source: Yankee Group, 2012

How have these services impacted the number of times you go to a store for photo processing?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	2,063	307	415	306	329	327	379
I go to a store for the service about the same number of times	16%	20%	19%	9%	13%	19%	18%
I go to a store for the service more often	9%	9%	10%	9%	9%	9%	8%
I go to a store for the service less often	33%	32%	36%	28%	28%	34%	38%
I never go to a store for the service	36%	29%	31%	50%	42%	36%	32%
Unsure/don't know	5%	9%	4%	4%	7%	3%	3%

Looking back specifically at the U.S. market, we can see a steady rise in the use of online photo sites. In Yankee Group's prior surveys we find that visits to online photo sites in the prior 30 days have risen almost five times from 12.3 percent of respondents in 2003 to 59.5 percent in 2009, with the most significant jump being from 2008 to 2009 (see Exhibit 23).

Exhibit 23: Online Photo Site Usage Has Increased Steadily in the US
Source: Yankee Group, 2012

Internet Activities Used In Last Month: Photo Sharing	
2003	12.3%
2004	26.8%
2005	27.2%
2006	30.7%
2007	32.9%
2008	31.5%
2009	59.5%

Using E-Mail for Personal Correspondence

Among all activities, we found e-mail to have the highest incidence rates among survey respondents. Given that it is often the first regularly used application even in the pre-broadband era, this is not a surprise. We also believe we can show a correlation between the high usage of e-mail and the decline in mail volumes.

To show a relationship between e-mail usage and a reduction in energy output we chose to specifically look at the frequency of consumers using e-mail for personal correspondence and how that impacts their usage of postal services for the same activity. We believe the reduction of energy output and corresponding carbon footprint comes from the lighter volume of mail and the energy required to process and deliver such correspondence.

In our survey of consumers across the six markets analyzed, we found consistent and high usage of e-mail for personal correspondence. In Spain and Italy in particular we find more than 80 percent of respondents using e-mail for personal correspondence on a daily basis (see Exhibit 24).

Exhibit 24: Almost All Respondents Use E-Mail at Least Once a Month
Source: Yankee Group, 2012

Approximately how often do you use e-mail for personal correspondence?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
Never	2%	2%	3%	2%	2%	1%	3%
Every day	73%	64%	81%	68%	64%	87%	73%
Two to four times per week	15%	20%	12%	17%	21%	9%	14%
Once a week	4%	7%	3%	6%	5%	2%	4%
Once every two weeks	2%	3%	2%	3%	3%	1%	3%
Once a month	3%	5%	1%	4%	6%	0%	4%

Not surprisingly, these same countries also showed the lowest usage of postal services for personal correspondence with more than 30 percent of respondents in both countries saying they never use their respective postal service (see Exhibit 25). At the same time, Spain also shows a bit of an anomaly with a quarter of respondents saying they use the postal service for personal correspondence on a daily basis.

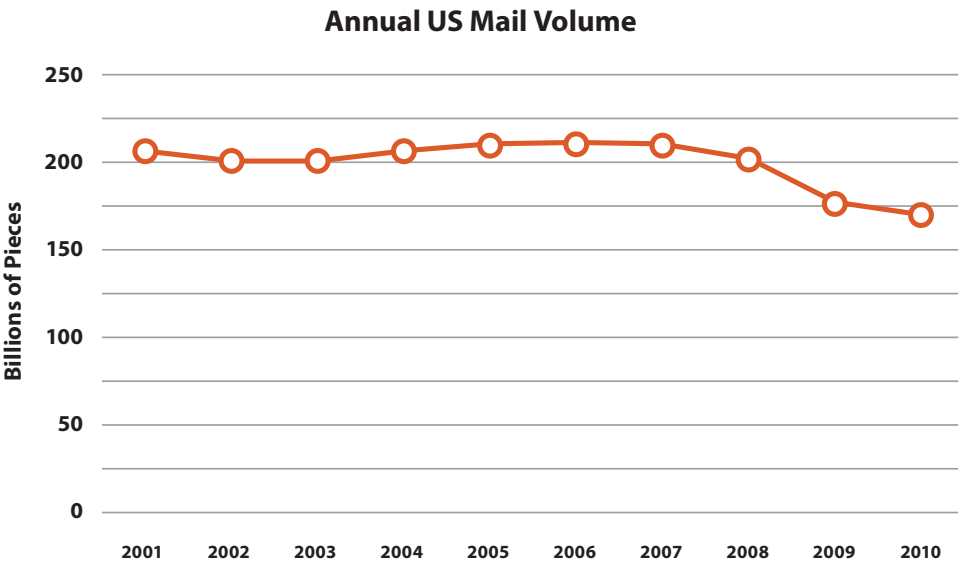
Exhibit 25: A Fifth of Respondents Never Use the Postal Service for Personal Correspondence
Source: Yankee Group, 2012

Approximately how often do you use the postal service for personal correspondence?							
	Total	Germany	Italy	France	U.K.	Spain	U.S.
Sample size	6,000	1,000	1,000	1,000	1,000	1,000	1,000
Never	21%	17%	34%	11%	15%	31%	18%
Every day	12%	10%	14%	12%	4%	25%	5%
Two to four times per week	9%	7%	8%	12%	9%	7%	11%
Once a week	10%	11%	6%	16%	12%	4%	12%
Once every two weeks	12%	13%	6%	17%	14%	3%	15%
Once a month	37%	41%	33%	32%	46%	31%	39%

In prior Yankee Group surveys we also can show high usage of e-mail. In fact in no consumer survey that Yankee Group has conducted since 2004 have we found any less than 80 percent of respondents saying they have used e-mail within the prior 30 days. Not coincidentally, we can see the correlation between the frequency of e-mail and the decline of mail volumes.

Looking at the U.S. Postal Service as an example, we can see historically that mail volumes have tended to rise and fall with economic cycles but have generally showed an upward trend. However, in 2006, we see a peak of 212 billion pieces of mail followed by a rapid decline through 2010 that the Postal Service does not anticipate recovering any time soon (see Exhibit 26).

Exhibit 26: Volume of Physical Mail Is Declining in the US
Source: U.S. Postal Service



Household and Consumer Profiles

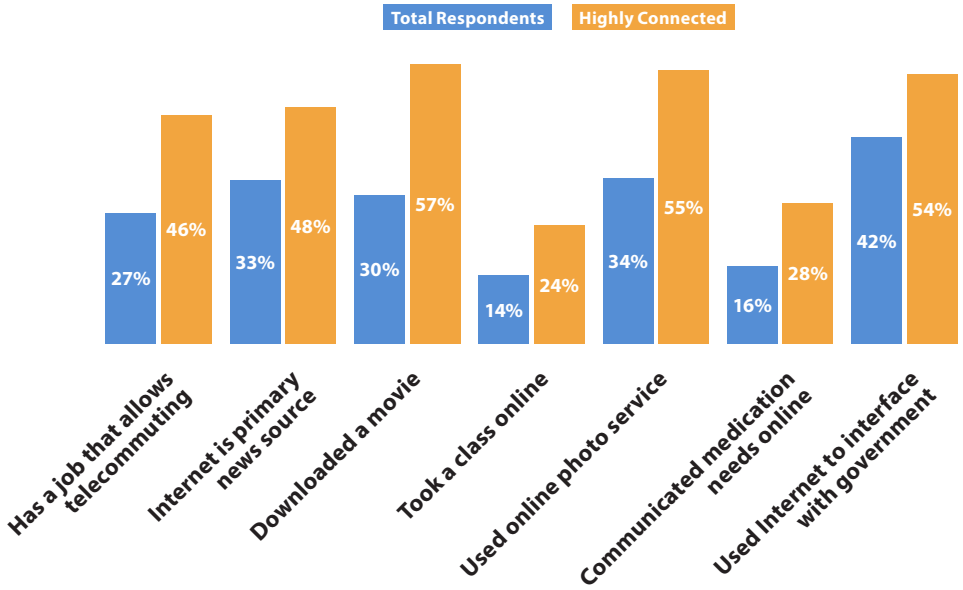
Simply laying out differences between respondents doesn't necessarily give us a complete picture of how broadband connectivity impacts activities we believe lead to energy reduction. Instead we believe it's important to look at profiles of types of users across the markets who have commonalities in their level of connectedness. In the following section we illustrate how levels of connectedness impacts activities.

Highly Connected

Characteristics: Highly Connected individuals use a mobile device to access the Internet, have an advertised home broadband connection of at least 24 Mbps and spend at least three hours per day connected to the Internet.

A total of 265 of our 6,000 respondents fall into the Highly Connected category. Not surprisingly, those respondents almost always show greater incidence of engaging in the activities examined, with the most significant differences coming in the percentage of those that have downloaded or streamed a movie in the last 12 months and the percentage that have used online photo services. At the same time, this group of respondents also tended to be in jobs that allowed for telecommuting (see Exhibit 27 on the next page).

Exhibit 27: Characteristics of Highly Connected Respondents
Source: Yankee Group, 2012



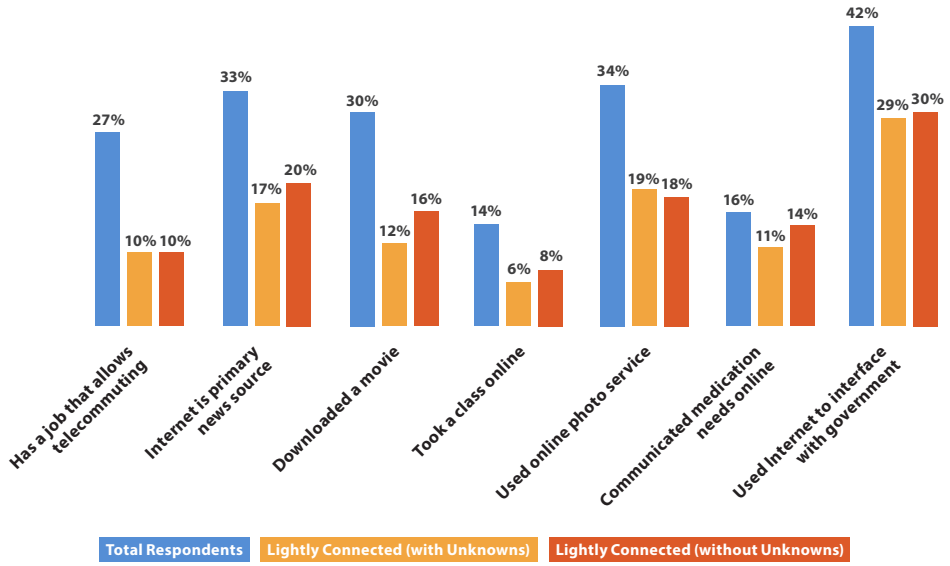
Lightly Connected

Characteristics: Lightly Connected individuals don't use a mobile device to access the Internet, have an advertised home broadband connection of less than 5 Mbps and spend no more than two hours per day connected to the Internet.

The total number of respondents that fall into this category is 159. Lightly Connected respondents almost always show lesser incidence of engaging in the activities examined than the total population of respondents. The most dramatic difference appears in the area of telecommuting; only 1 in 10 respondents we classify as Lightly Connected holds a job that allows for remote working.

Acknowledging that this group represents a somewhat small sample of the total respondent base and is likely under-represented, we also include respondents in the survey that did not know the advertised speed of their primary broadband connection. Including this group in the Lightly Connected segment raises our total sample to 556. However, it doesn't dramatically alter the participation levels in any particular activity measured. For comparison's sake, we present both in Exhibit 28 on the next page.

Exhibit 28: Characteristics of Lightly Connected Respondents
Source: Yankee Group, 2012

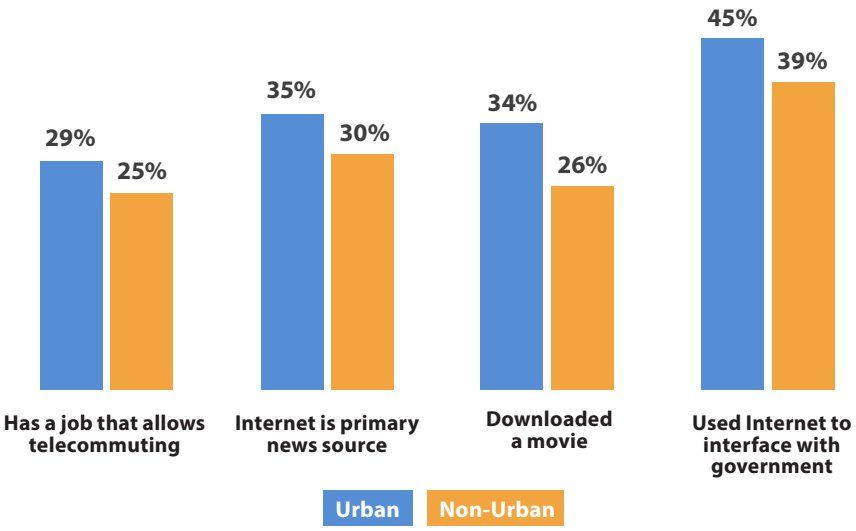


Urban vs. Non-Urban Residents

Characteristics: Of our 6,000 respondents, the largest block (1,811) live in cities with more than 100,000 residents. However, for purposes of this analysis we divided up survey respondents into two groups: the "urban" group, which lives in cities with roughly 100,000 residents or more, and the "non-urban" group, which lives in cities with less than 100,000. This gave us an almost equal number of 3,068 and 2,932 respectively.

Somewhat surprisingly, respondents did not show widely varying responses to any of our questions when divided into urban vs. rural groups. Indeed, one of the areas where there was a somewhat large difference was in the questions of downloading/streaming entertainment. We found that urban residents tend to be slightly further into the digital market, though not by massive margins (see Exhibit 29).

Exhibit 29: Urban Respondents Are Slightly More Likely to Use Online Resources
Source: Yankee Group, 2012

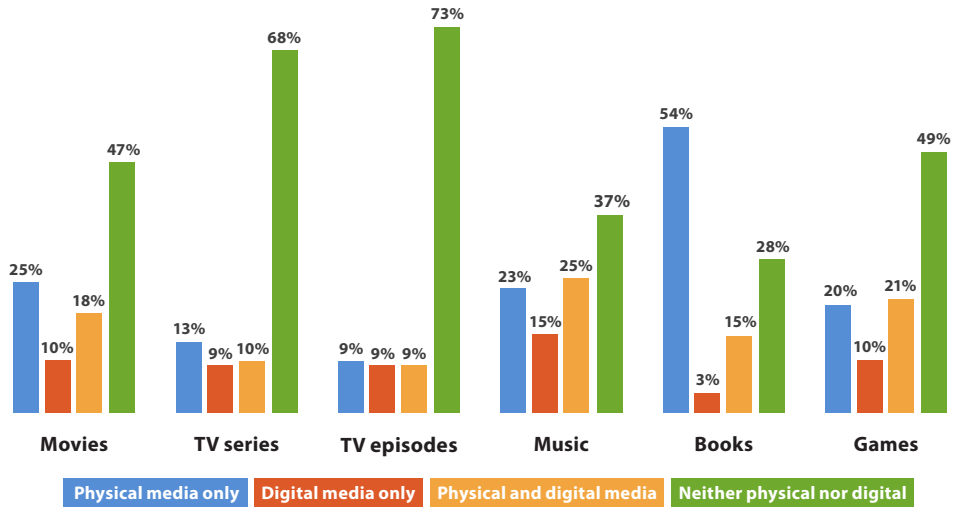


Digital Consumers

Characteristics: Digital consumers are respondents to our survey that say they currently purchase digital media for movies, TV shows, TV series or music. These purchases may or may not be in addition to physical media, and we separate the two as different sub-categories for purposes of this analysis.

We found wide variety in digital consumption patterns based on the type of media. This was expected due to the speed at which digital media has entered the market and served as a replacement for physical products. For example, among 6,000 respondents in our total survey, 1,481 said they purchase movies only in physical form while 3,214 said they only purchase books in physical form (see Exhibit 30). We attribute the difference to the fact that streaming and rentals of movies have been widely available for more than a decade while the printed word is just beginning to enter the digital age with the widespread availability of e-readers.

Exhibit 30: Digital Consumption Patterns Vary Based on Type of Media
Source: Yankee Group, 2012



Breaking out these various groups, we also find some differences in the level of other activities. Not surprisingly, those that purchase digital media as either a replacement for or supplement to physical products tend to have streamed a movie over the Internet at greater frequency. However, we find this difference in activity level extends to other—though not all—areas. For instance, there is only a slight difference in the level of e-banking between the groups, but there is a significant difference in the level of engagement with digital photographic processing and using the Internet to communicate medication needs.

Net Energy Savings

At this point, we have working profiles of current energy consumption within households together with estimates of existing broadband and ICT patterns of usage. Following the modified GeSI (2010) methodology, we also generated estimates of increased energy usage within the home and possible increases in personal errands and household shopping that might be done as a result of being at home.[9] Such comparisons allowed us to provide, therefore, estimates of net rather than gross energy savings associated with the specific consumer activities evaluated in this analysis. At the same time, there is a very large range of uncertainties associated with almost all energy end uses. The reason is that the data is not routinely collected to know the precise fuel economy of individual vehicles, and to determine exact patterns of household activities that might emerge from shifting work activities to the home.[10] As we suggested previously, we have attempted to overcome these severe data limitations with the application of a probabilistic analysis referred to as a Monte Carlo simulation, incorporating a range of estimates for the many variables that impact net energy consumption, to show a likely pattern of potential net energy savings.[11] To test the robustness of these results we generated a set of 10,000 simulations for each of the eight activity levels for both the U.S. and the EU-5 region of the global economy to determine the maximum likelihood of net annual energy savings. As reported in millions of barrels of oil equivalent,[12] the net energy savings from this set of eight different activities for each region are shown in Exhibits 31 and 32.

Exhibit 31: Summary of Monte Carlo Simulations for the EU-5
Source: ACEEE and Yankee Group, 2012

Savings in Million Barrels of Oil	Online News	Music Streaming	Online Banking	Telecommuting	Online Shopping	Online Education	Digital Photos	E-Mail	Total
Lower	-1.2	0.2	-1.2	62.8	0.7	-0.3	-1.4	-0.1	82.1
Upper	1.7	4.0	11.5	141.3	9.7	2.5	11.8	3.6	163.7
Average	0.2	2.1	5.1	102.0	5.2	1.1	5.2	1.8	122.9

Exhibit 32: Summary of Monte Carlo Simulations for the US
Source: ACEEE and Yankee Group, 2012

Savings in Million Barrels of Oil	Online News	Music Streaming	Online Banking	Telecommuting	Online Shopping	Online Education	Digital Photos	E-Mail	Total
Lower	-0.6	0.2	-2.2	130.8	1.5	-0.6	-3.6	-0.7	163.6
Upper	1.0	3.4	17.7	298.4	15.7	4.6	26.3	7.4	335.8
Average	0.2	1.8	7.8	214.6	8.6	2.0	11.3	3.4	249.7

9 There is an important distinction to be made between the substitution of one activity for another and the so-called rebound effect. If employees are now able to telecommute but they still maintain a comparable arrangement of personal errands and shopping, we might then suggest they are only substituting a new pattern of maintaining their current livelihood. On the other hand, if ICT activities result in lower energy costs, or if they prompt a small increase in household income or other form of social well-being, those net benefits might induce an incremental purchase of new goods and services. This higher level of spending, in turn, might prompt a small rebound in energy use driven by that improved benefit. For purposes of this analysis we explore the former, not the latter, effect.

10 Although beyond the scope of these "residential patterns" that involve adopting or adapting to ICT-related services, one very big future opportunity is a set of ICT activities that will be instrumental in allowing us to collect new kinds of data, and with greater granularity or detail, through the use of smart meters and other sensors. These will enable us to better evaluate net impacts and are very likely to dramatically increase performance as new insights from this data allow entirely new designs, systems and processes that can enhance net energy savings.

11 See Appendix I for a further discussion of the analytical technique employed here.

12 One million barrels of oil is roughly the energy equivalent of 5.8 trillion Btus or 6.1 petajoules. One million barrels of oil also contains the equivalent of approximately 317,000 metric tons of CO2 that might be emitted if released through the combustion or use of that energy.

The average savings for the EU-5 are shown as the equivalent of 123 million barrels of oil per year. For the U.S. the average savings are only slightly larger, at about 250 million barrels of oil. As expressed in barrels of oil equivalent, these suggested average energy savings imply an annual reduction of CO_2 emissions on the order of 39 and 79 million metric tons for the EU-5 and the U.S., respectively.

In general, and looking at the pattern of savings rather than simply the magnitude, we found some, but little significant, differences among any of the individual activity levels when comparing the EU-5 and the U.S. regions. Telecommuting provides the single largest energy benefit, generating about 83 to 89 percent of the net energy savings, because traveling to work represents a large share of both household expenses and energy use. Moreover, telecommuting practices may have a significantly greater level of market benefit compared to other activities such as banking or e-mail services. Reduced driving time and more time with family and friends, for example, may accelerate market penetration to a greater degree than other ICT-related activities.

The least prominent savings was in the use of the Internet as a news source and for online education. This outcome appears to be the result of consumers who may continue both the old and the new practices. For example, if households do some electronic banking but continue to drive to their local branch bank, they may save some energy through online activities, but those savings may be partially eroded by a continued pattern of driving and even continuing to receive banks statements by mail. Promoting the larger savings potential, therefore, will require a more complete transition to electronic banking instead of maintaining both sets of activities.

While we cannot categorically provide a precise estimate of the net energy savings generated by an expanded use of the eight activities—there are simply too many variables with insufficient data collected for all of the activities within the different countries—we can safely say that in most cases there is a measurable net savings. Under ideal circumstances, and assuming an upper end of reasonable adoption of all eight activities, the U.S. could generate a net energy savings of about 336 million barrels of oil equivalent per year. If all energy forms, whether the use of electricity or natural gas, were expressed in corresponding units of oil, this would be about 2 percent of total U.S. energy consumption.

Likewise in the five European countries under study, we find a high-end achievable net energy savings of 164 million barrels of oil annually. In a particularly useful contrast, however, because the U.S. consumes almost twice the energy as the EU-5 nations combined, the ICT-enabled efficiency gains in those countries would save between 2 and 2.5 percent of their total energy consumption. Interestingly, this is on the same order of the 2 to 4 percent savings enabled by smart work practices as estimated by Malmodin, Lundén and Lövehagen (2010a). As we noted before, however, if consumers are not encouraged to make the complete transition to the newer ICT-enabled activities, but they instead actually use both the old and the new services—that is, they purchase or download digital music, but they also burn the songs onto CDs—we may find that in some cases there actually can be a small net increase in energy usage patterns.

Key Findings and Recommendations

Whether the result of large-scale implementation as suggested by the Smart 2020 report (GeSI 2008) or at the individual level of household activities as reviewed in this analysis, two key insights emerge from the work completed here. First, ICT-enabled services can deliver significant net energy savings across a variety of activities and consumer end uses. Second, the operative word here is “scale.” As it turns out, while there are millions of people within both the EU-5 and the U.S., their many separate actions and behaviors may not add up to large savings collectively. That is to say, larger net savings are likely to result from systems or infrastructure improvements when they are done at scale—that is, when we tackle motor systems or whole building improvements that, in turn, are enabled by an array of ICT services.

While there is a need for a more regular and systematic collection of data to back up the conclusions, we offer the following findings and insights. We then offer a set of policy recommendations that might logically follow from these observations.

- The EU-5 appears to be slightly more energy-efficient than the U.S. so that despite a slightly larger population (318 million for the EU-5 compared to the 314 million in the U.S.) the expected net energy savings in the EU-5 from these eight ICT-enables services appear to be about one-half of what might be expected within the U.S. (an average energy savings of about 250 million barrels of oil in the U.S. compared to the smaller net benefit of 123 million barrels of oil in the EU-5).
- Telecommuting looms very large in the total savings for either region. Indeed, of the eight activities shown here, telecommuting—largely because of the scale of its impact and the magnitude of net savings associated with this expanded practice—is likely to provide on the order of 86 percent or more of the net energy savings for the U.S. and perhaps as much as 83 percent for the EU-5.

- The total savings in this report at first might seem small—an upper end of about 2 percent of total energy consumption for both regions. This is because the eight activities (besides telecommuting) turn out to play a relatively small part within their respective economies. Newspapers, for example, are less than 0.1 percent of economic activity in the U.S. The postal service and music industries are only slightly larger, but of a comparable scale. At a more aggregate and also a more consistent level of comparison, the combined "pulp, paper, paper products, printing and publishing" industries—among those sectors most likely to be impacted by ICT services—are only 1.8 and 2.3 percent of total economic activity in the EU-5 and U.S., respectively. Yet even at this scale the prospects for a 2 percent savings from these eight relatively small activities alone may generate a larger benefit than the 1.3 percent total CO_2 emissions impacts that result from the services provided by the entire ICT and electronic media industries (Malmodin et al. 2010b). Any further savings from systems and infrastructure improvements as envisioned by the GeSI (2008) study imply a significant increase in net benefits from ICT and broadband services.
- Drawing on and adapting from the 2008 GeSI study, if just 60 percent of U.S. commercial building stock implemented feedback and management control systems and achieved a combined 15 percent savings or better, the total net energy savings in that sector alone might exceed 270 million barrels of oil equivalent. In short, the potential systems improvement in just the U.S. commercial buildings might be 10 percent larger from the combined set of eight activities studied here (again noting that telecommuting alone scores almost as large as the buildings management improvements).
- Although not studied as part of this assessment, perhaps the largest source of immediate energy savings might be the result of new awareness and energy management control that broadband connectivity is likely to bring to household consumers. For example, one recent study (Ablondi and Abid 2011) suggested that home area networks (HANs) will penetrate nearly 57 million households by the end of 2014 (46 percent of all U.S. households). These HANs can also be extended to bring "smart home energy services" to market. Studies provide evidence of the strong connection between feedback and awareness as they motivate reduced energy use in the home. Ehrhardt-Martinez, Donnelly and Laitner (2010) document, for example, a range of feedback-related residential electricity savings on the order of 4-12 percent. They noted the possibility for an even larger impact as both customers and utilities learn how to better put information to work. In this context we might also reference the Envision Charlotte project in Charlotte, N.C. Using special monitors in high-traffic locations, and with near-real-time data and graphic displays about energy consumption and other sustainability practices, the goal is to spur sustainable behaviors and reduce energy use in Uptown Charlotte's business community by up to 20 percent in five years (see http://www.envisioncharlotte.com/).

Given these insights and findings, several key policy recommendations emerge from this study that, if implemented, are likely to magnify the level of energy savings described here:

- **Gather and analyze more impactful data.** While the opportunity to generate new levels of cost-effective energy savings appears to be significant, the current level of data that is now collected does not allow for a fully meaningful assessment of potential large-scale impacts. Hence, there is a critical need to gather ICT-related data that encourages a more productive assessment of the emerging potential. At the same time, more complete data may give rise to even greater energy savings as new systems and "smart infrastructures" catalyze even larger productivity improvements (GeSI 2008 and Laitner 2010).
- **At a national level, encourage and reward companies that adopt and enforce flexible work policies that encourage the use of broadband capabilities to reduce travel.** These measures should include tax incentives and credits that promote greater adoption of telecommuting.
- **At a local/municipal level, investigate public/private partnership models that bring broadband connectivity to all residents.** Given the cost of extending broadband to those that are unserved or underserved and the challenging business models, it is highly advantageous for municipal governments to consider the energy savings generated by broadband adoption as part of the equation for extended deployment of the technology.
- **National/local governments should actively encourage both innovation and collaboration that can lead to dematerialization of existing products/services within all sectors and industries of the economy, and not merely to residential ICT services.** As both the U.S. and the EU more broadly step up efforts to find productivity-led reductions in greenhouse gas emissions, ICT services should be seen as among the fundamental building blocks to manage national climate strategies and targets.

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Appendix 1: Setting Up the Fermi Problem and Monte Carlo Simulations

How do you solve a problem for which there is no meaningfully complete set of data, and for which there is very little available in the way of observations to help readers fully understand the array of answers? One of the first and perhaps classic answers was shown by physicist Enrico Fermi. His curiosity prompted him to estimate the strength of the atomic bomb that was detonated in 1945 at the Trinity test site. He based his estimates on the distance traveled by pieces of paper dropped from his hand during the blast. Fermi's resulting estimate of 10 kilotons of TNT was remarkably close to the now-accepted value of around 20 kilotons.[13]

In a very similar way we provide in this report a working estimate of net energy savings of a set of eight ICT-related activities, but ones for which we lack sufficient data to allow us to focus on the specific activities. In much the same spirit we implement what is called the Fermi problem (Von Baeyer 1993). A Fermi calculation, one that involves the multiplication of several estimated factors (e.g., the number of piano tuners in Chicago), will probably be more accurate than might be first supposed (assuming there is no consistent bias in the estimated factors) because there will probably be some factors (with a binomial distribution) that are estimated too high and other factors that are estimated too low. Such errors will partially, if not more completely, cancel each other out.

The classic Fermi problem, as Von Baeyer first outlined it, was asking the question, "How many piano tuners are there in Chicago?" A typical solution to this problem would involve multiplying together a series of estimates that would yield the correct answer if the estimates were correct. And to illustrate the point, we've estimated how many piano tuners there are in Tucson, Ariz., where one of the authors of this paper now resides.

We might begin, for example, with a guess that there are approximately 1,000,000 people living in the Tucson area. We might further imagine three people per household, with every sixth household owning a piano (or equivalent to reflect an estimate of pianos in commercial or institutional settings such as schools and churches). We guess that each piano might be tuned every seven years, which suggests that there might be just fewer than 8,000 piano tunings each year within the Tucson area.

From here we estimate that each tuner can do two tunings per day for an average 180 days per year. If we carry out the simple math implied in this example, we conclude there are 22 tuners. Turning to the phone book's yellow pages, it turns out there are 16 listings. Not knowing if each listing has more than one piano turner, our estimate of 22 tuners provides a credible and reasonably robust answer.

With this working perspective, and within the framework of a Fermi problem, we then rely on Monte Carlo simulations to provide us with a robust set of answers and emerging insights about the net impact of the eight ICT services. Monte Carlo simulations belong to a class of computational algorithms that rely on repeated random sampling to estimate their outcomes. Such methods are often used when replicating physical and mathematical systems and when data are wholly incomplete. Hence, Monte Carlo methods are especially useful for modeling phenomena with significant uncertainty in assumptions or inputs. This might include the calculation of risk in business or, in this case, something more specific such as the likelihood of adopting energy efficiency improvements from ICT-service when there is incomplete information or data.

13 See http://www.lanl.gov/history/story.php?story_id=13 for more information.

The most famous early use of this type of simulation was, again, by Fermi, who in 1930 used a random method to calculate the properties of the newly discovered neutron. Monte Carlo methods were central to the simulations required for the Manhattan Project, though they were severely limited by the computational tools available at the time. Therefore, it was only after electronic computers were first built (from 1945 on) that Monte Carlo methods began to be studied in depth.

Following Laitner (2003) and Weber et al. (2009), we rely on Monte Carlo simulations using triangular distributions in which we assume a reasonable or most likely value of a given variable. This might reflect, for example, the percentage of households that are mostly likely to adopt an online service, or the percentage of households that are likely to both subscribe online and drop their printed newspaper service, based on our survey data. At the same time, we rely on existing data to the extent possible and estimate a minimum and maximum likely set of values that might be taken as the largest and smallest available data point.

The Monte Carlo technique then generates a set of random numbers to more easily explore the interactions among the many different variables and their very large uncertainties. In this regard we stress that most of the distributions utilized here were assumed, and thus probabilistic results should be taken as approximate. Yet, as we shall find, the overall results fit intuitively within the expected pattern of other concrete savings estimates (within their contribution to the larger economy) and with other studies that have been undertaken with a more limited scope.

While there is no single Monte Carlo method or pre-determined set of algorithms that might be applied in a given context, the approach used here:

- Defines a domain of the eight possible ICT services and compares them to likely or standard information services (such as obtaining your daily news from an online resource compared to reading the morning paper that is delivered to your doorstep).
- Anticipates the likelihood of adoption or use of the ICT service in lieu of or as a complement to the standard service now provided, given the survey or other data.
- Maps the possible range of interaction effects that might reduce the net energy savings.
- Characterizes a range of energy savings that might likely follow the adoption of those measures.
- Aggregates the results of the individual computations into the set of outcomes described in the main text of the report.

Appendix 2: Illustrating the Analytical Methodology

As part of this study we carried out an assessment of eight different ICT-related activities in two separate regions of the world economy: the U.S. and the EU-5, which includes the European economies of France, Germany, Italy, Spain and the U.K. Without exception each of these activities were focused on ICT services used within the household or residential sector. To provide a more solid foundation for exploring the potential energy saving associated with each of those activities despite the huge uncertainties associated with many of the (non-survey) data, we designed a spreadsheet-based Monte Carlo simulation model (see Appendix 1 for a further discussion of the Monte Carlo analytical technique). In effect, the simulation exercise runs through 10,000 iterations of the data to identify the central tendencies that drive a given level of net energy savings.

The Data Assumptions

In this Appendix we provide more of the analytical detail behind the energy savings associated with telecommuting opportunities within the EU-5. The intent is to highlight the overall methodology for all activities evaluated within both the U.S. and the EU-5. For those interested in greater detail, the Excel workbooks can be made available. In general we followed the GeSI Assessment Methodology (2010), as that specific analytical framework parallels other telecommuting studies including TIAX (2007), Lister and Harnish (2010) and Lister and Harnish (2011). The latter analysis, focusing on the U.K., provided insights into the EU-5 region.

With advances in both ICT services and other complementary technologies and systems, it is no longer necessary for particular jobs to be anchored to a given time or place. This allows the shifting of work from a conventional business location to a home or other location. This shifting of work to a different location is described in this study as "telecommuting" but is also known variously as workshifting, telework or even e-work. It covers a broad range of work arrangements including mobile work, remote work at a client's location, work at a shared office center or hub, and work at home (Lister and Harnish 2011).

Of the estimated 136 million jobs in the EU-5, and based on Lister and Harnish (2011), the assumption is that anywhere from 40 to 60 million of those workers might be eligible for or able to take advantage of telecommuting opportunities. The other key variables are highlighted in Table 1 on the next page. One further comment might be helpful before continuing the description of key variables: As we have presently constructed the simulation model, the workbook randomly selects a value between the upper and lower range shown for each of the variables used to evaluate the anticipated net energy savings. To give the user the opportunity to provide for a non-symmetrical distribution of quantities, the model actually provides the user with three different choices—a low, middle and high value. For instance, the user may think there will be the tendency for a higher-than-average "take-back" of anticipated fuel savings because the employee may attend to more of his or her personal errands while working at home. If the average is a 20 percent erosion of savings (hence the deflator of 1.25), the high end of the savings range may be only a 13 percent erosion (with a 1.15 deflator) while the lower end of the net savings may be the result of a 34 percent erosion (with a deflator of 1.50)—or some other range of values altogether.

Table 1: Key Values for Illustrating Impacts of Telecommuting Rather Than Normal Work Driving Patterns
Source: ACEEE and Yankee Group, 2012

		Range of Values for Simulation			
Reference	Key Variables	Low	Mid	High	
1	Eligible jobs (in millions)	40	50	60	
2	Percent that might shift to telecommuting	40%	60%	80%	
3	Days per week to telecommute	2	3	4	
4	Commuting miles saved	18	27	34	
5	Weeks per year	42	45	47	
6	Fuel economy (MPG)	24	31.4	36	
7	Personal trip deflator	1.15	1.25	1.5	
8	Electricity use per employee (kWh)	7,050	8,700	10,350	
9	Electricity savings/employee	12%	18%	24%	
10	Home energy deflator	1.15	1.25	1.5	
Results					Net Energy Savings for One of 10,000 Iterations
calc	Primary energy savings (trillion Btu)	190.4	604.7	1,247.4	475.0
calc	Million barrels of oil equivalent	32.8	104.3	215.1	81.9
calc	Billion VMT saved	24.3	109.4	304.6	102.3

Notes on Sources

1. Lister and Harnish, Telework Research Network (2011) suggests 40 percent of potential employees could telecommute. By assumption for EU-5.
2. By assumption from Yankee Group survey, the range might vary from 40 percent to 80 percent of those who are eligible to those who actually would.
3. By assumption the range might vary from two to four days per week.
4. From the Yankee Group survey the mean round-trip commute is 27 miles per day with lower and upper bounds of 18 and 34 miles.
5. By assumption the range is 42 to 47 weeks of work per telecommuter per year.
6. Average fuel economy of 31.4 mpg suggested by Andreas Kroehling of Deutsche Telekom (2012), with lower and upper bounds of 24 and 36 mpg.
7. From TIAX (2007), an assumption that personal trips or shopping erodes commuting savings by 20 percent with lower and upper estimates of 15 to 50 percent.
8. Average values of energy use per employee are provided by Andreas Kroehling of Deutsche Telekom (2012).
9. Electricity savings per job taken from Romm (2002) as reviewed in TIAX (2007) and other sources with 50 percent upper and lower bounds by assumption.
10. Increased electricity use per home as a result of telecommuting from home from 15 to 50 percent of business consumption.

In the table above, the key values are identified in the far left column by a number from 1 through 10. The section immediately below the table notes the working assumption behind each of the 10 key variables. To provide some consistency so we might compare the net savings of a given activity in the EU-5 with the same set of activities within the U.S., we employ standard U.S. units of measurement for both regions of analysis. At the same time, however, we convert the final estimate of net energy from trillions Btus into barrels of oil equivalent.[14] We also showed, in this case, the anticipated net reduction in vehicle miles traveled.

14 Note that one trillion Btus is the rough equivalent of 1.055 petajoules, or about 177, 414 barrels of oil.

Moving down the table, and as documented in the notes for each key variable, with a randomly selected value of eligible workers (variable 1) chosen for each of the 10,000 iterations, the simulation model then selects a percentage of workers (variable 2) who might actually be able to take advantage of a telecommuting opportunity. By assumption, the number of days per week (variable 3), commuting miles per work trip (variable 4), work weeks per year (variable 5), average vehicle fuel economy (variable 6), and personal trip deflator (variable 7) are also randomly selected; this completes the set of commuting variables. Here we might note several important differences between the U.S. and the EU-5 economies as those differences translate into significant variations in net energy savings. From the Yankee Group survey (as shown in the main report) it appears the average round-trip commuting distance is about 32 miles in the U.S. while only 27 miles in the EU-5. Moreover, the EU-5 suggests only 45 work weeks per year (after backing out vacation, holidays and sick days) while, in this set of examples, the U.S. works at least one week longer per year. Finally, the average fuel economy per commuting vehicle is shown above as 31.4 miles per gallon in the EU-5 (or 7.5 liters per 100 kilometers) compared to only 25 miles per gallon in the U.S. (about 9.4 liters per 100 kilometers).

Further savings are anticipated from the displacement of energy in the workplace as employees work more at home. At this point the simulation exercise continues to randomly select the expected electricity consumption per employee (variable 8), expected savings per telecommuter (variable 9) and the home energy deflator (variable 10) or energy take-back from people working more at home. Again we have important differences between the U.S. and the EU-5. For the U.S. the assumption is that the average employee will use 17,500 kWh per year while the EU-5 might show only 8,700 kWh per employee per year. Hence, the net savings for this portion of the telecommuting benefits will also be smaller.[15] Not shown in this set of data, however, is a further scaling down of the EU-5 electricity consumption pattern. This results from a generally more efficient electricity generation system in the EU. Based on data from the European Environment Agency, it turns out that it takes only two units of energy to generate one kWh in the EU while it takes almost three units of energy in the U.S. So again, the magnitude of savings will be much smaller as a result of telecommuting in the EU-5. As we examine in the main text of the report, based on the set of assumptions outlined above, and running through 10,000 iterations, it appears that telecommuting might reduce the EU-5 energy consumption by about 102 million barrels of oil equivalent, while for the U.S. the total swells to about 215 million barrels—just over twice as much.

15 The electricity savings suggested here are at the end use, reflecting a heat equivalent of 3,412 Btus or 3,600 megajoules per kWh. At the same time, however, the production and distribution of electricity to homes and businesses is not an especially efficient process. In the case of the U.S. the system is only 32 percent efficient, meaning that it takes roughly three times the energy to provide electricity compared to its useful work value in the home or business. It appears the EU has system efficiencies that approach 50 percent, meaning that the work value of electricity requires about twice the total energy to produce and distribute it. Hence, the net savings shown in the table above reflect the total primary energy savings, including the inefficiencies of the electricity generation system.

How to Review the Results

Given the array of assumptions, the results shown both in this Appendix and in the main report appear to be robust. That is, given the uncertainties and the set of assumptions identified in the previous table in this Appendix, the numbers for what we call the "core telecommuting savings" seem to hover at about 100 million barrels for the EU-5 and about twice that amount for the U.S. In the subsection that follows we highlight additional factors that might further influence the savings, but which time and resources do not allow us to cover. For the most part, however, those additional variables that might be folded into a future assessment that builds on this or other studies, but which are not specifically covered in this study, may only nibble around the edges of the central findings published here. We can get a sense of that in Table 2, which reviews the correlation coefficient associated with each of the 10 variables described in Table 1.

Table 2: Telecommuting Correlation Coefficients
Source: ACEEE and Yankee Group, 2012

Variable	Description	Correlation
1	Eligible jobs	0.380
2	Percent shift	0.636
3	Days per week	0.370
4	Commuting miles	0.308
5	Weeks per year	0.072
6	Fuel economy	-0.219
7	Trip deflator	-0.153
8	Electricity use/job	0.154
9	Electricity save/job	0.279
10	Home energy deflator	-0.126

In this case the correlation coefficient shows the strength of each variable as it might influence the final estimate of net energy savings. In short, the higher the number shown, the stronger the influence that variable is said to have on the final outcome. For the EU-5, the single biggest influence on net energy savings is variable 2, or the percent of employees that actually shift from a standard work routine into some form of telecommuting (shown with a value of 0.636). Increasing the number of eligible jobs (variable 1) and the number of days per week that an employee will telecommute (variable 3), and encouraging employees with longer commutes (variable 4) all have correlation coefficients above 0.30. By comparison the work-related savings have a somewhat weaker contribution to the net total savings. The table also shows three variables with negative correlations; these could potentially erode a small part of the net energy savings. For example, if an employee begins to telecommute more often, but also buys a much more fuel-efficient car (variable 6), some of the savings from telecommuting will be eroded as a result of a higher fuel economy. Similarly, if people carry out more personal errands, or if they heat or cool their home more than normal, that might further erode the net savings. Since those last two values are smaller, however, the impact on net energy savings is also smaller.

If there are additional changes that can be introduced into the telecommuting assessment, and if they are similar to those variables with smaller correlation coefficients, the impacts may create only small changes from the core savings, whether positive or negative. On the other hand, if the changes are of sufficient scale, and if they impact the larger infrastructure of the regional economy, those improvements may create a more fundamental shift than we have been able to explore in this particular assessment. For example, if ICT systems enable a smarter transit system, or promote the use of intelligent street lighting systems that dynamically time the lights to improve the flow of traffic, the savings in those instances might become very large—even as those improvements weaken the telecommuting benefits as currently evaluated.

What's Not Covered

Following both TIAX (2007) and Lister and Harnish (2010), there are a significant number of factors that might be extended into this analysis and might significantly extend future energy savings. Without providing a full set of details in this assessment, some of the potentially large impacts might include: (i) increases in employee productivity, (ii) reduction in the costs associated with maintaining real estate and other work-based assets, (iii) reduction in unscheduled absences and job attrition, (iv) reduced traffic injuries and fatalities per 100,000 vehicle miles, (v) lower cost of highway and other infrastructure maintenance, and (vi) perhaps even greater opportunities for employees and contractors to collaborate and work together without being limited by logistics. All of these possibilities may increase the overall productivity and robustness of the economy without increasing total energy use. Hence, the economy may expand by some margin even as total energy needs are reduced.