



White Paper
Eco-technology Innovation

Advancing Global Sustainability Through Technology

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Executive Summary

Since Intel introduced its first processor in 1971, Intel has delivered continuous improvements in microprocessor performance, cost and energy efficiency. The result has been a new digital economy that has phenomenally transformed the world through a dizzying array of new business and communication models – everything from e-commerce to wireless broadband. These innovations are delivering previously unimaginable gains in productivity and connectivity as the PC revolution and Internet era continue their spread and development around the globe.

This revolution is far from finished. In fact, in an age of global warming, it's becoming ever more important. Doing more with less is vitally important if we are to responsibly manage our finite resources and continue to grow our economies.

Intel believes the future is bright if we all accept these global challenges head on and share in their solution. For Intel, this means providing eco-technology innovation and leadership. Our efforts include continuing to develop technological breakthroughs in energy-efficient performance processors and technology, collaborating with industry and governmental agencies to drive sustainable standards, solutions and products, and championing operational sustainability to positively impact global climate change.

We believe now is the time for governments, business, industry, environmental organizations, and individuals to join together in solutions to creating a sustainable world for this generation and those that will follow. Now is the time to act. Work together. And take advantage of the best technologies and tools available.

Introduction

For more than three decades, Intel® microprocessors have played a significant role in helping drive the spread of the digital economy that continues today to transform business and communications throughout the world. Every new increase in Intel's compute performance provides yet another exponential increase in productivity that enables the production of more with less.

Yet, while performance, capabilities and demand are increasing, so is our awareness of the cost and scarcity of the energy required to power these systems. Intel co-founder Gordon Moore, a long-time champion of the environment, instilled a deep environmental consciousness in our company. Today, this focus manifests itself in our continuing efforts to reduce greenhouse gas emissions and global warming.

For us, this means continuing advances in what we believe can become the most energy-efficient, emission-reducing device ever created: the microprocessor. This will have great impact as very few other inventions in history have spread so quickly throughout the world to contribute to global productivity, efficiency and sustainability. Arguably, no other single device is so important in aiding the scientific exploration and calculations that will provide answers for our world's issues.

At Intel, we are addressing greenhouse gas emissions and global warming in three primary ways.

1. Reducing our own ecological footprint through responsible management of our own manufacturing and operations as we continue to drive innovation in processor technology for a sustainable world.
2. Pursuing rapid gains in energy-efficient performance and advancing the computing experience to spur new usage models and productivity gains that will help reduce energy consumption and greenhouse gas emissions.
3. Supporting and investing in technological innovations that create new sustainable economic, environmental and social benefits.

Fortunately, Intel and the entire information and communication technology (ICT) sector are accustomed to moving rapidly. This makes our industry well poised to swiftly contribute to the development of a wide range of solutions to reducing global warming and improving energy efficiency, as well as empowering sustainable economic growth, productivity and job creation.

Of course, many innovations already helping decrease energy consumption and greenhouse gas emissions depend on Intel® processors. These include everything from logistical applications used to improve supply chain efficiency to collaboration software reducing business travel. Nonetheless, achieving the magnitude of change necessary to solve many of today's most pressing environmental, economic and societal challenges is going to take a much bigger, concerted effort from governments, industry, business, environmental organizations, and each of us. The place to start is by embracing the challenge head on.

In a world looking for solutions, resolutions will be found where we've found them before. Human ingenuity. Government action. And technological advances. Intel believes now is the time for us all to join together in collective effort to create a sustainable world for this generation and those that will follow. Through Intel's commitment to working with governments and industry in reducing greenhouse gas emissions worldwide, curbing energy consumption, and using technology to create new sustainable solutions, we are doing our part to turn today's challenges into tomorrow's opportunities.

Corporate responsibility begins at home

At Intel, we believe that if you want to do something about a problem, you set your mind to it and solve it. That goes for something even as daunting as global warming. And the place to start is close to home. That is why we are working hard to reduce Intel's own energy consumption, greenhouse gas emissions, and ecological footprint.

Intel's publicly stated goal is to reduce its energy consumption by more than 30 percent by 2010. So far, we have demonstrated exceptional results. We have reduced our normalized energy use by 5.7 percent per year since 2002, for a normalized energy usage reduction of more than 20 percent through 2006! Since 2001, Intel has also approved more than 200 improvement projects brought forward by our employees that have saved more than 400 million kilowatt hours (kWh).² That is enough electricity to power more than 40,000 American homes or reduce air pollution from electricity generation equivalent to removing 50,000 automobiles from the road.³

Intel is also making renewable energy a priority. In Oregon, Intel has purchased wind power since 2004 and grown to become the largest purchaser of wind power in the Portland General Electric program.⁴ In New Mexico, Intel is the largest industrial consumer of renewable energy in the state.⁵

Intel is also making great strides in reducing its ecological footprint by reducing the natural resource use and waste byproducts of its manufacturing process. In the past three years, Intel has saved more than nine billion gallons of fresh water and reduced its global warming gas emissions. We have reduced hazardous materials in our products and now recycle more than 70 percent of our combined chemical and solid wastes.⁶

It takes a village. A global village.

However, this is not a time to work alone. The problems the world faces require a concerted effort from governments, businesses and individuals around the globe. For this reason, Intel is working with a long list of governments and other organizations. Here we mention just a few.

On the government side, Intel is working with the European Union (EU) on ways the technology sector can help meet the EU's target of cutting greenhouse gas emissions by 20 percent by 2020. For Intel, we're setting even more ambitious goals than those suggested by the EU for companies. In the United States, Intel is participating in the U.S. Environmental Protection Agency (EPA) Climate Leaders program, an organization working to develop long-term, comprehensive climate change strategies. We're also a member of the Chicago Climate Exchange, a voluntary, legally binding greenhouse gas emissions reduction, registry and trading program.

On the industry side, Intel is a key participant in The Green Grid, an industry group dedicated to the advancement of energy efficiency in data centers and computing ecosystems. In June 2007, we also announced the formation of the Climate Savers Computing Initiative with Google. This is a global industry consortium committed to increasing world computer energy efficiency by 50 percent by 2010. This would create a USD 5.5 billion in aggregate global energy savings and reduce carbon dioxide (CO₂) emissions by 54 million tons per year (equivalent to the annual output of 11 million cars or 10-20 coal-fired power plants).⁷

The ultimate invention for achieving sustainability: the microprocessor

Arguably, one of the greatest inventions ever for spurring global productivity may be the microprocessor. Since Intel introduced its first processor in 1971, processors have been at the heart of much of the world's progress. The result is a digital economy with an astonishing array of new business and communications models, from e-commerce to voice over IP (VoIP). What's more, this revolution is far from finished. Every new increase in compute performance provides yet another exponential increase in productivity that enables the production of more with less.

What does this do for sustainability? It has a major impact. A recent study by the Information Technology and Innovation Foundation (*Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution*, March 2007) cited ICT as directly responsible for contributing to two-thirds of the productivity gains in the U.S. economy between 1997 and 2002.⁸ These gains have significantly offset carbon usage, enabling more to be done, less miles traveled, and greater operational and material efficiencies. During this period an unprecedented phenomenon occurred: each gross national product gain required less energy than it did before. (See Figure 1.)

With each compute performance increase, processors enable economies to scale in clean and efficient ways. Consider for instance, what the use of intelligent algorithms running on high-performance computers can do for businesses like UPS and DHL

to improve delivery efficiency, enable them to handle more packages, and reduce fuel usage. Or what gains in compute performance have done for the CAD systems used to design more efficient wind turbines or other power-generation devices.

Equally impressive is the speed at which Intel is making processors more powerful and efficient. The efficiency is incredibly important since the very device we all depend on to advance productivity requires energy which can cause significant heat. In 2006, Intel began shipping Intel® Core™2 Duo processors based on our new Intel® Core™ microarchitecture. Intel Core 2 Duo processors for desktops offer up to 40 percent more performance with advancements in energy efficiency.⁹ Similar efficiencies are gained in our mobile and server lines. Intel is about to top this with a new family of 45-nanometer (nm) processors code named Penryn,¹⁰ which will have more transistors but are about 25 percent smaller in silicon area than Intel's current 65nm products and operate at the same or lower power than the current Intel Core 2 processors.

This drive for greater compute performance is incredibly important. The world's data is already outstripping our ability to comprehend it. According to the "How Much Information" project at the University of California, Berkeley, print, film, magnetic and optical storage media produced about 5 exabytes of new information in 2002 alone.¹¹ That's the equivalent of 37,000 new libraries with book collections the size of the Library of Congress (17 million books).

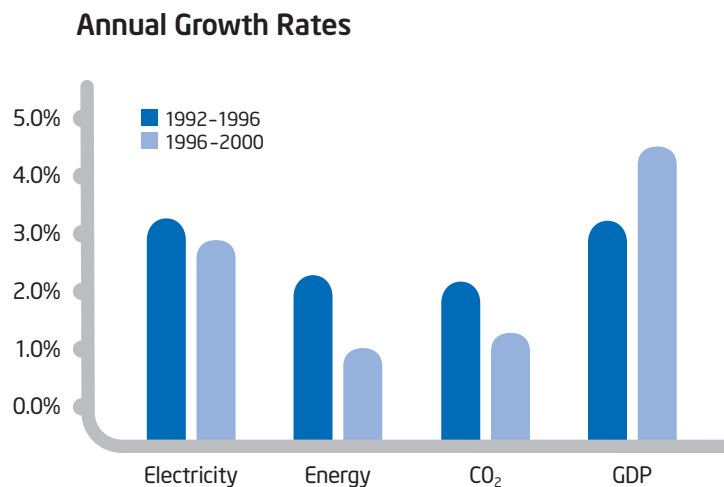


Figure 1. U.S. gross domestic product (GDP), the total value of goods and services produced by a nation, shows a greater annual growth rate in the 1996-2000 than the prior four years, yet growth rates in energy use and CO₂ emissions have actually decreased. (Source: U.S. Department of Energy, Energy Information Administration.)

Meanwhile, millions more people are logging on to the Web, and applications from weather forecasting to data analysis are continuing to become more compute-intensive. This makes Intel’s rapid “tick-tock” cadence for delivering a new process technology with enhanced microarchitecture or an entirely new microarchitecture every year incredibly important. It will enable us to meet tomorrow’s compute needs and enable fewer servers to do more work with the same or less power.

The increasing role of ICT in empowering sustainable progress

Digital technology is anything but static. It continues getting cheaper, faster, better, and easier to use, enabling the invention of new and expanded uses for ICT every day. What’s more, there’s considerable evidence of the effectiveness of processor-based ICT in providing sustainable economic, environmental and social benefits on a national and global basis.¹²

On the economic front, a North American study, “The Internet Economy and Global Warming – A Scenario of the Impact of E-commerce on Energy and the Environment,” concludes that the forecasts for energy consumption and emissions of carbon dioxide to 2010 for the North American economy may have to be adjusted down by around 5 percent due to the rapid impact of the Internet economy.¹³ Another study, by the Lawrence Berkeley National Laboratory, found that the IT economy could reduce the growth in carbon emissions by 67 percent over what they would otherwise be between 2000 and 2010.¹⁴ Similar observations have been made in the United Kingdom. (See Figure 2.)

The environment is also seeing ICT benefits. Although the United States is using more energy than 20 years ago, it would be using even more without ICT. From 1996 through 1999, the United States experienced an unprecedented 3.2 percent annual reduction in energy intensity (energy used per unit of gross domestic product–GDP), four times the rate of the previous 10 years.¹⁶ While several factors may account for this, including the shift in the U.S. economy toward less energy-intensive sectors, the incorporation of IT into business practices appears to be a key source of this improvement.¹⁷

ICT is also responsible for a phenomenon known as *dematerialization*. Through dematerialization, the same or an increased quality and quantity of goods and/or services are created using fewer natural resources (material or energy). Decreased consumption of paper is a good example. The Internet economy is projected to provide a 0.50 percent reduction in total consumption of energy by the paper industry and emissions of greenhouse gases in 2008.¹⁸ Compared to reading a newspaper, receiving the news on a PDA wirelessly results in the release of 32 to 140 times less carbon dioxide and several orders of magnitude less nitrogen oxides and sulfur oxides.¹⁹ For years, the potential for video conferencing has been discussed. Today’s bandwidth makes the technology truly viable. Existing video conference solutions indicate that if 5 to 30 percent of business travels in Europe were substituted by video conferencing, more than 5.59 to 33.53 million tons of CO₂ emissions would be saved.²⁰ Based on German experiences, a 20 percent reduction of business travel in the EU through video conferencing could save 22 million tons of CO₂.²¹

Decoupling Economic Growth from Energy Consumption

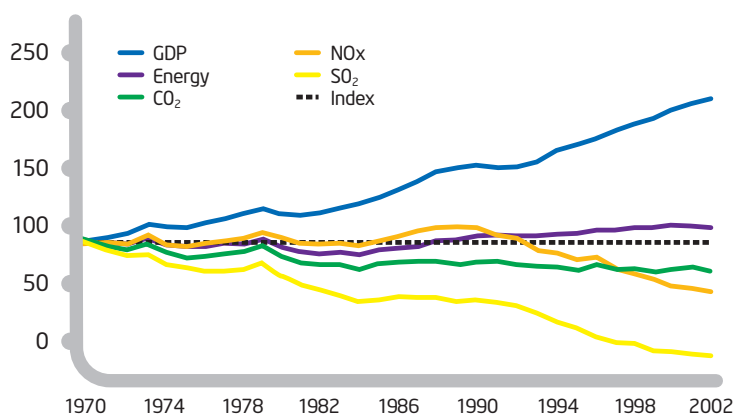


Figure 2. The effect ICT is having in decoupling GDP increases from corresponding increases in energy and greenhouse gas emissions.¹⁵ (Source: DTI, ONS, NETCEN.)

Dematerialization: Lower Overhead = Less Energy

	Traditional Superstore	Online Bookstore (Amazon.com)
Titles per Store	175,000	2,500,000
Revenue per Operating Employee	\$100,000	\$300,000
Annual Inventory Turnover	2-3 times	40-60 times
Sales per Square Foot	\$20	\$8
Rent per Square Foot	\$250	\$2,000
Energy Costs per Square Foot	\$1.10	\$0.56
Energy Costs per \$100 of Sales	\$0.44	\$0.03

Figure 3. New business practices like Amazon.com’s Internet-based operations and central warehousing are not only more productive, but also require less energy and are thus less damaging to the environment. (Source: World Wildlife Fund.)

ICT is also bringing many social benefits to life. ICT productivity increases are helping to raise incomes, enable people to more easily afford investments to reduce energy use (such as buying more expensive hybrid cars or energy-efficient appliances). ICT can also play a big social role in making energy markets more efficient. While consumers have long paid for electricity, only recently has it been cost efficient to charge residential consumers based on the time of day and time of year. Smart meters that allow utility companies to charge higher prices during periods of higher demand and lower prices for use in other times, also give more choice to consumers. These meters enable them to realize large savings by not buying electricity at peak periods. If smart meters were installed across California, for example, during the recent heat wave, it is estimated that consumers would have helped save an estimated 5,000 megawatts of power, the equivalent of the output of 10 power plants.²²

Another area where ICT is having an enormous impact is in enabling flexible work options such as telecommuting. Interestingly enough, many studies indicate that reduced need for office space from flexible work will yield even bigger savings than the obvious reduction through fewer commutes. Existing and implemented use of flexible work indicates that 10 million “flexiworkers” in Europe could save more than 11 million tons of CO₂ emissions through office space and commuting savings. Thirty million flexiworkers could save more than 34 million tons of CO₂ emissions.²³

Looking forward

In a world beset with overconsumption, environmental degradation, global warming, growing resource scarcity, and social change, humanity is facing its greatest challenges ever. The microprocessor and the ICT revolution it has spawned provide ideal tools for helping us scope the extent of the problems we’re facing, develop solutions for reducing our consumption, improve our productivity in sustainable ways, and measure our progress.

How do we use them most effectively? A crucial ingredient is going to be government involvement. Governments have a crucial supportive role in providing the appropriate enabling environment – such as institutional, policy, legal and regulatory frameworks to sustain investment flows and for effective technology transfer – without which it may be difficult to achieve emission reductions and sustainability at a significant scale. For instance, mobilizing the financing of ICT and enabling international technology agreements could help speed up the deployment of the very technologies we need to reduce global warming and achieve sustainability.

In general, the more concerted the effort made by governments, businesses, industries, and individuals across the planet in applying ICT in everything from reducing the daily commute and the energy consumption of our cars to designing green homes and buildings, the greater and faster the success we will achieve. There are enormous opportunities, for example, in creating programs and incentives in many nations that encourage energy savings. A good example is how Intel joined together with another industry player, VMware, to help Northern California utility Pacific Gas and Electric Co. (PG&E) develop rebates for virtualization-driven data center deployments. In addition to the rebate, PG&E estimates that customers save \$300 to \$600 in annual energy costs for every server removed through virtualization-based consolidation. These savings can almost double when reduced data center cooling costs are taken into account.²⁴

The future is bright if we accept the challenge. We need to act now. We need to act decisively. We need to act together. And we need to use the best tools and technology available.

Learn more

To find out more about what Intel is doing on a global and corporate scale to help sustainability, see the environment section of our Corporate Responsibility Report at www.intel.com/intel/finance/social.htm

To learn more about our efforts in energy-efficient performance, advancing the computing experience, and driving innovations in processor technology for a more sustainable world, see the Intel Technology and Research Web site (www.intel.com/technology).

¹ "Building Corporate Responsibility," Intel 2006 Corporate Responsibility Report.

² Ibid.

³ Ibid.

⁴ Ibid.

⁵ Intel Global Responsibility Report 2005. See: www.intel.com/intel/finance/gcr05/global_climate_change.htm

⁶ "Building Corporate Responsibility," Intel 2006 Corporate Responsibility Report.

⁷ Source: Intel and Google calculations based on published indexes. Source for 54 million tons of CO₂ was Intel/Google calculations on potential energy savings, combined with U.S. average of 1.5 lbs. CO₂ per kWh of electricity (U.S. Energy Information Administration). Eleven million cars figure comes from U.S. EPA assumptions that "average" car travels 10,000 miles per year and gets 20 mpg. This translates to roughly 5 tons CO₂ per year per car. Figures on coal fired power plants come from U.S. Department of Energy. Plant sizes and CO₂ emissions vary widely, so figures were based on a 500MW-size facility. A range of 10-20 such plants was developed by looking at the high and low CO₂ emitters among 500MW facilities for 2002.

⁸ See: Atkinson, Robert D. and McKay, Andrew S., "Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution," The Information Technology and Innovation Foundation, March 2007. (Copies available at: www.itif.org/index.php?id=34)

⁹ Performance measured Intel® Core™2 Duo desktop processors compared to Intel® Pentium® D processor 805 on SPECint*_base2000 and SPECint*_rate_base2000 (2 copies). Actual performance may vary. See www.intel.com/performance for more information.

¹⁰ See: www.intel.com/technology/architecture-silicon/45nm-core2/index.htm.

¹¹ For more on the How Much Information study, see www2.sims.berkeley.edu/research/projects/how-much-info-2003/

¹² Ibid.

¹³ Romm, Joseph, Arthur Rosenfeld, and Susan Hermann, "The Internet Economy and Global Warming: A Scenario of the Impact of E-Commerce on Energy and the Environment," The Center for Energy and Climate Solutions, The Global Environment and Technology Foundation, Arlington, VA, December 1999.

¹⁴ Laitner, John A., "Information Technology and US Energy Consumption," Journal of Industrial Ecology 6.2, 2003.

¹⁵ Source publication: e-Digest of Environmental Statistics, Published December 2003, UK Department for Environment, Food and Rural Affairs. See www.defra.gov.uk/corporate/contacts/index.htm

¹⁶ Romm, Joseph, "The Internet and the New Energy Economy," E-Vision 2000 Conference. U.S. Department of Energy, Jun. 2001.

¹⁷ Ibid.

¹⁸ Romm, Joseph, Arthur Rosenfeld, and Susan Hermann.

¹⁹ Toffel, M.W., and A. Horvath, "Environmental Implications of Wireless Technologies: News Delivery and Business Meetings," Environmental Science & Technology 38, 2004.

²⁰ Pamlin, Dennis and Szomolányi, Katalin "Saving the Planet @ the Speed of Light," European Telecommunications Network Operators Association and World Wildlife Fund. (They note that "the numbers are based on German business travels' trend, prepared by Potsdam Institute on Climate Impact Research for Deutsche Telekom. The basis of the research was the trends in travels between 1976 and 2000. The research did not take the video-conference's equipments own impact on GHG emission, as it is negligible.")

²¹ Ibid.

²² Tribble, Sarah Jane. "New Push to Boost Peak Energy Rates: But Law Limits Utilities' Ability to Tie Cost, Demand" San Jose Mercury News, July 29, 2006.

²³ Pamlin, Dennis and Szomolányi, Katalin (They note: "the original study was prepared by Sustel project for British Telecom. The research is based on a survey among BT flexi-workers about their travel-savings per week.")

²⁴ PG&E press release, "PG&E Collaborates with Silicon Valley Companies to Announce Rebates for New Energy Efficient Server Technology, November 8, 2006. (See: www.pge.com/news/news_releases/q4_2006/061108.html)

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