April 19, 2007

The Greening Of IT

by Christopher Mines and Frank E. Gillett

TRENDS

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with Galen Schreck, Will McEnroe, and Emily Van Metre

EXECUTIVE SUMMARY

Environmental responsibility is emerging as an important topic for corporate IT organizations and their technology suppliers. This report outlines the key drivers of green IT and the range of green imperatives taking hold in the design, manufacture, operation, and disposal of computer systems and devices. Both IT management and technology suppliers still have much work to do to overcome organizational and other barriers to making corporate IT a greener place.

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NOTES & RESOURCES

Forrester interviewed 9 vendor companies including: Advanced Micro Devices, American Power Conversion Corp, Dell, EMC, Hewlett-Packard, IBM, Intel, Sun Microsystems, and Verari Systems.

Related Research Documents

"Decoding Virtualization's Present And Future"
January 9, 2007, Question & Answer

"Corporate Social Responsibility And You"
September 7, 2006, Best Practices

"Pragmatic Approaches To Server Virtualization"
June 19, 2006, Trends

"Power and Cooling Heat Up The Data Center"
March 8, 2006, Trends

"The Future Of Data Center Automation"
February 3, 2006, Trends

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THE EMERGING LANDSCAPE OF GREEN IT

At first glance, these issues would seem to have little in common: managing a data center's growing power requirements, complying with European recycling regulations, and mitigating the risk of bad publicity arising from manufacturing pollution. But for high-tech manufacturers, and increasingly for their corporate customers, these three issues and others are interweaving into a set of challenges and opportunities known as green IT, which Forrester defines as:

> *IT suppliers and their corporate customers changing the way computing assets are designed, manufactured, operated, and disposed of to gain efficiency and cost savings while reducing environmentally harmful impacts.*

Tech marketers are seeing the concept of green IT surfacing among systems suppliers in enterprise data centers and IT organizations, in the media, and in corporate boardrooms. This is taking place in the context of rapidly-growing environmental awareness, and a growing consensus that industries and businesses must take a leadership role in environmental stewardship. Against that backdrop, what's driving stakeholders to focus on greening their IT operations and products? The principal drivers include:

- **Leading IT vendors' search for differentiation.** Virtually all major IT systems vendors are publicizing their environmental awareness and stewardship.[1] They are looking to don a "green halo" in the eyes of customers, investors, regulators, and the public. More important, they are betting that they can gain a competitive edge as enterprise customers start to focus on suppliers' environmental awareness and track record as well as ability to deliver cost savings.

- **A power and cooling capacity crunch in the data centers.** As chipmakers jammed more transistors operating at ever higher speeds onto processor chips, electricity demand grew exponentially, rising in some cases above 100 watts. By 2005, data center operators seeking to cram the maximum compute power into the minimum space found they didn't have enough electricity to power full racks of the latest servers, nor enough cooling capacity to remove the heat that was generated.[2] Even had they tried to plan ahead, many would have found their electric utility unable to provide more juice at the local substation.

- **Enterprise IT shops' climbing electric bills.** Even as average retail electricity prices in the US remained basically flat, the growth of corporate data centers, more power-hungry systems, and burgeoning corporate PC populations drove IT's overall power consumption up twofold from 2000 through 2006 to the point that it accounts for roughly 3% of total US electricity consumption.[3] Forrester's surveys of corporate IT organizations in North America and Europe

reveal strong interest in finding solutions to the intertwined issues of data center power and cooling.[4]

- **Government regulation of hazardous substances and mandated recycling.** Here, the European Union (EU) is in the lead with its Restrictions on Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) regulations. Many high-tech manufacturers that sell products globally align with the tightest regulatory regime they face. For green IT, this is the EU. US regulatory involvement is more limited. EPA's EnergyStar power consumption ratings for PCs have been in place since 2005, and the agency is working to include servers in its certification program during 2007.

- **Recognition and risk management drive boardrooms to become better corporate citizens.** IT operations are for most non-manufacturing firms the largest consumer of energy. Many companies are emphasizing environmental responsibility as part of their overall corporate social responsibility (CSR) efforts. A greener data center and IT operation can both save money and win points with customers, regulators, employees, and investors.
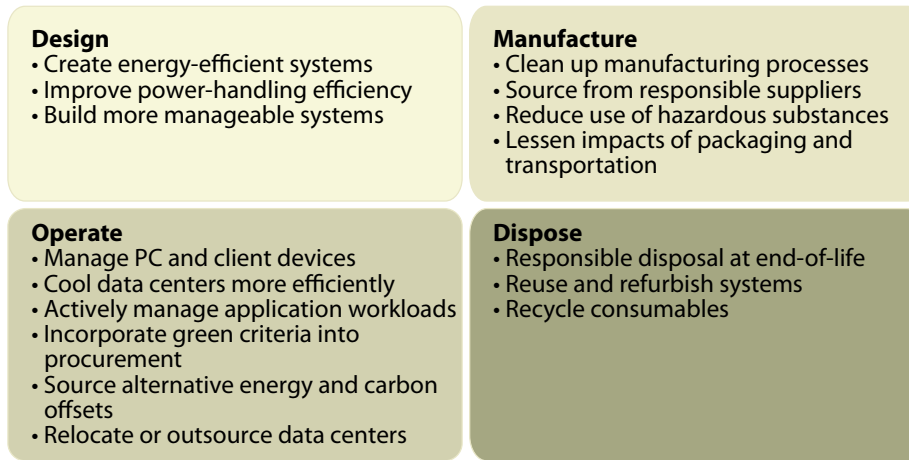
Relating IT To Business And To The Environment

Green IT is sufficiently complex that different stakeholders describe its associated problems and opportunities quite differently. But encompassing as it is, green IT is a subset of two larger trends:

- **Corporate social responsibility efforts.** For both suppliers and users of IT equipment, green computing is part of a larger effort to be good corporate citizens. Nearly half the companies in the S&P 500 now publish an annual review of their CSR programs, which encompass environmental, social, and ethical dimensions.[5]

- **The improving relationship between business and the environment.** As environmental awareness has increased, there has been an accompanying shift in the historically conflicted relationship between business profitability and environmental stewardship. A consensus is emerging that taking care of the environment can in fact be good for business and not simply drive up costs, drain profits, or otherwise hurt business results.[6]

THE SCOPE OF GREEN IT

Forrester classifies green IT into four broad categories of IT suppliers' and users' initiatives (see Figure 1):

- **Design.** Technology manufacturers are reexamining all aspects of IT system design, from semiconductor materials up through data center facilities, with green in mind. Coalescing industry consortia will create standards, spur investment, and push innovation.

Figure 1 The Scope Of Green IT

Design
- Create energy-efficient systems
- Improve power-handling efficiency
- Build more manageable systems

Manufacture
- Clean up manufacturing processes
- Source from responsible suppliers
- Reduce use of hazardous substances
- Lessen impacts of packaging and transportation

Operate
- Manage PC and client devices
- Cool data centers more efficiently
- Actively manage application workloads
- Incorporate green criteria into procurement
- Source alternative energy and carbon offsets
- Relocate or outsource data centers

Dispose
- Responsible disposal at end-of-life
- Reuse and refurbish systems
- Recycle consumables

42070   Source: Forrester Research, Inc.

- **Manufacture.** High-tech manufacturing uses hazardous materials and is highly energy and water intensive. Systems manufacturers and their subcontractors are working to clean up their processes and supply chains. Even under increased regulatory and public scrutiny, improvement in this complex, capital-intensive stage will come steadily but slowly.

- **Operation.** Changing how IT systems are purchased, deployed, and operated can have at least as great an effect on their environmental impact as changing how the systems are designed and manufactured. IT users are starting to implement policies and processes that significantly reduce the environmental footprint of their IT operations.

- **Disposal.** Manufacturers and customers share responsibility for proper disposal of IT systems and devices at the ends of their useful lives. Both parties, spurred in many cases by regulation, are changing their behavior with an eye towards more effectively reusing and recycling gear at the end of its normal product life cycle.

Designing Greener IT Systems

The green IT cycle starts with the design and development of computing devices, systems, and peripherals. Companies' needs for more computing capacity, coupled with ever-denser server architectures, could push energy costs up from 40% to more than 100% of the server hardware cost over a typical four year life cycle.[7] IT vendors and their suppliers hard at work improving the green characteristics of their products and services are focused particularly on:

- **Improving power-handling efficiency.** Server power supplies convert conventional AC power into the low-voltage DC power needed by electronic equipment. Typical power supplies operate

at 65% to 75% efficiency; the rest of the power is wasted (actually, worse; it is converted into heat that must be removed from the data center).[8] Manufacturers of servers and other data center gear like storage and power equipment are working to boost power supply efficiency into the 80% to 90% range. The industry consortium 80PLUS is bringing together manufacturers, distributors, and utility companies to develop and promote more efficient computer power supplies.[9]

• **Creating more energy-efficient processor and server designs.** Servers soak up 30% or more of a large data center's total electricity requirement. Servers also generate heat, the removal of which from the data center via HVAC systems consumes still more power. So microprocessor manufacturers are pursuing energy efficiency by incorporating multiple processors on a single chip (multicore designs) and using advanced materials and manufacturing processes that reduce chips' power consumption. Further up the stack, server vendors are redesigning their systems with power and cooling in mind, for example, developing "smart" fans within server enclosures that handle the higher density and heat generation of blade servers while lowering overall power requirements.

As standards are developed that consistently measure server energy consumption per unit, buyers will be able to more easily compare tradeoffs between computing performance and energy performance during product evaluations.[10] This is job No. 1 for the Green Grid consortium, for example.

• **Building more manageable hardware.** Systems and PC designs are incorporating ever-more energy efficient features, enabling users to save power, money, and the environment. Server technology continuously monitors power consumption and places components into standby mode when consumption is low, systems management software can consolidate application workloads to shut off unneeded servers during periods of low demand, and PCs and monitors are typically sold with power management that switches the unit into a low-power mode after a period of inactivity. Vendors, aware that these features are often disabled by customers or software vendors, are working to better educate customers about power management features.[11]

• **Reducing use of hazardous materials.** Technology manufacturers selling products in Europe must limit the incorporation of hazardous or toxic materials in their products under the guidelines of the EU's RoHS directive, which applies to products shipped after July 1, 2006. California and other states are enacting legislation that incorporates the RoHS standards, as are China (March 2007), South Korea (July 2007), and other countries. Technology suppliers must anticipate that such regulations will become not only more pervasive, but tighter, over time.[12]

Towards Greener High-Tech Manufacturing

Building technology devices and components involves the use of environmentally dangerous chemicals and substances. A February 2007 report from Greenpeace highlighted continuing

environmental contamination resulting from electronics manufacturing (typically performed by Asian subcontractors to the well-known systems vendors).[13] Although Greenpeace is still far from the corporate mainstream, such research will heighten awareness of the perils of high-tech manufacturing, and portends more intense customer and public scrutiny of manufacturers in the future.

System and device suppliers are working to make their manufacturing processes and supply chains greener on several fronts:

- **Cleaning up manufacturing processes.** This is an enormous area of investment for manufacturers seeking to reduce hazardous waste in manufacturing, conserve water in semiconductor manufacturing, cut energy consumption, and reduce carbon emissions. Most manufacturers, especially those in new, US-based facilities, can report solid progress on these metrics.[14]

- **Ensuring the behavior of a global supply chain.** As the Greenpeace report highlights, high-tech manufacturing is often well out of sight of its large customers in first-world nations. The systems suppliers that run lengthy, complex, global supply chains are beginning to step up to the significant challenge of ensuring the environmental responsibility of their suppliers, and suppliers of their suppliers.[15] This effort, one of the most difficult for those striving to become truly green IT suppliers, has a long way to go.

- **Reducing packaging and transport impacts.** Manufacturers are addressing as well the environmental impact of packing and shipping their products. Minimizing packaging material, making it more eco-friendly (e.g., using cardboard instead of plastic or wood), and recycling what is left all contribute to the "dematerialization" of computer products. Some manufacturers are finding that shifting from air to ground transport for product shipping reduces the overall emissions impact.[16]

Operating A Greener IT Shop

Driven by cases of corporations not being able to get additional electric power for data center expansion, corporate IT shops are beginning to consider the energy costs and environmental impact of their computing equipment. Lack of power and lack of expansion space for urban data centers are precursors to lifetime energy costs *exceeding* the initial acquisition cost of data center equipment.[17] And electricity prices are only heading higher; a federal cap-and-trade system for reducing carbon emissions could raise average electricity prices in the US by 5% to 35% depending on how aggressive a system is eventually adopted.[18]

IT managers are starting to pursue with their colleagues in procurement and facilities management a broad portfolio of approaches to improving the energy efficiency and simultaneously reducing the negative environmental impact of data centers and other IT operations. These efforts must fit into the regular cycles of IT planning and refresh within and beyond corporate data centers (see Figure 2):

Figure 2 A Spectrum Of Options For Greener IT Operations

	Opportunity	Action
High impact **• High capital cost** **• Five or more year cycle**	• Site a new data center	• Find low-cost or cleaner power source
	• Design or renovation of building	• Specify energy efficient structure and materials
	• Design or renovation of data center infrastructure	• Optimize electricity and cooling flows to data center • Minimize electricity conversion losses • Consider high-voltage DC power distribution • Specify variable speed cooling units
	• Design of rack system	• Choose rack with the best cooling airflow
Medium impact **• Medium capital cost** **• One to four year cycle**	• Reconfiguration of gear in racks	• Configure gear for best cooling airflow
	• Selection of servers and storage	• Choose the most energy-efficient gear
	• Setup or reconfiguration of applications on servers	• Enable server power management • Implement server virtualization
Low impact **• Low capital cost** **• Short term**	• Daily data center operations	• Turn off unused lights and gear
	• Printer setup or reconfiguration	• Set printer defaults to double-sided printing • Train users on two up printing
	• Disposal of consumables	• Recycle, rather than trash, dead rechargeable batteries, empty toner or ink cartridges, and paper

42070   Source: Forrester Research, Inc.

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- **Increasing server utilization.** Virtualization helps consolidate application workloads onto fewer, more highly utilized servers and storage devices.[19] Reducing the number of physical servers (or, more often, creating headroom in the server population to accommodate more workload without adding more servers) reduces the energy requirement for those servers as well as requirements for associated cooling, uninterruptible power supplies (UPSs), and peripheral systems. In California, the giant utility Pacific Gas and Electric is partnering with virtualization software leader VMware to offer electricity bill rebates to customers that apply virtualization to eliminate servers in their data centers.[20] Further out on the horizon is policy-based server automation that actively moves IT workloads so that idle servers can be shut off.[21]

- **Incorporating green criteria into IT systems procurement.** Several emerging standards and guidelines will help IT procurement officers evaluate the greenness of systems, devices, and suppliers. The Electronic Product Environment Assessment Tool (EPEAT) guidelines are used in the IT procurement processes of numerous large US government agencies including the GSA and Department of Homeland Security. EPEAT evaluates PCs and monitors against 51 criteria that span materials usage (e.g., compliance with RoHS), energy conservation (including EPA EnergyStar certification), and supplier environmental policies (like ISO 14001 compliance).[22]

  Even as these standards take hold, we expect that customer behavior with respect to purchasing and operating IT assets will be driven first by performance, second by cost, and only third by products' efficiency or green characteristics. Forrester predicts that enterprise customers by and large will not pay a premium for greener computers; rather, they will favor green products that have equal or better price/performance characteristics. In parallel, buyers will come to favor suppliers with strong green track records only if those suppliers' products at least match the price/performance characteristics of competing vendors' products.

- **Cooling data centers more efficiently.** Keeping data centers cool even as the heat generation and density of IT equipment increases is a critical challenge for IT management. Cooling equipment consumes 40% to 55% of the electric power in a typical corporate data center.[23] Using that power more efficiently can be a key source of cost savings as well as reduce emissions from both the energy source (power plant) and data center. Green approaches to cooling include simply turning up the data center temperature (which is kept conservatively low in many data centers), using closely-coupled cooling systems that directly chill specific areas occupied by dense rows or racks of equipment that create hotspots, and changing the layout of server racks, HVAC, and venting/tiles to optimize cooled versus heated airflow.[24]

- **Managing PCs on corporate desktops.** Outside the data center, IT operations will find potential energy savings in managing their PC population more effectively. Client management software, for example, can reduce power consumption by simply turning off inactive PCs and monitors. Saving energy will likely become another reason for corporate IT to consider thin clients instead of full desktop PCs. Multiplied by the tens of thousands of PCs in many large enterprises, the power and cost savings as well as environmental benefits add up quickly.[25]

- **Buying alternative energy and/or carbon offsets.** In addition to trimming their energy consumption, some companies will opt to source their energy from clean(er) producers like wind or geothermal and/or buy carbon offset credits that invest in renewable energy sources. Although the ROI of these approaches is less direct than that of reducing energy consumption outright, they will find a place in a portfolio of green IT practices. The US EPA runs a Green Power Partnership that drives the development of renewable energy sources for electricity. Its top 25 partners each buy upwards of 1 million kWh of green power annually, which in some cases is 100% of the company's total electricity consumption.[26]

- **Moving data centers to locations with lower energy prices.** Companies with fast-growing computational requirements are seeking new locations for data centers that are close to sources of cheap, clean electricity. The Pacific Northwest is seeing tiny towns transformed into Internet engine rooms as companies like Yahoo! and Microsoft build new data centers close to hydro power sources.[27] Relocating the data center is not an option for most large companies, but outsourcing some of the IT workload to such data centers can be part of the green IT portfolio of options that companies consider as they look to trim their IT-related energy costs and create greener operations.

Disposing Of E-Waste

Green computing extends to the end of the product life cycle, and beyond. Many leading technology companies offer recycling and buyback programs for their old hardware, both corporate IT equipment and individual devices like PCs and cell phones. Systems manufacturers partner with third parties to offer take-back programs to comply with government regulations, avoid bad PR, and ensure that old computers, PCs, and printer cartridges do not poison or clog landfills, but rather are responsibly reused or recycled. High-tech manufacturers are increasingly taking responsibility for:

- **Complying with a quilt of regulations.** Manufacturers selling in Europe since 2005 operate under the aegis of the Waste Electrical and Electronic Equipment Directive (WEEE directive), which requires that they provide for recycling end-of-life devices and systems. Regional and city governments in North America and Asia are beginning to adopt similar regulations and guidelines. Some states including California have put the onus on the buyer with an up-front fee that will cover the costs of eventual recycling. A combination of regulation, PR benefits, and peer pressure will continue to push technology manufacturers towards cradle-to-grave responsibility for their products.[28]

- **Refurbishing and recycling old systems and devices.** Equipment returned to manufacturers is often refurbished in-house and resold.[29] Other goods are recycled, either in-house or by third-party asset recovery firms that salvage useful parts for remanufacture and reuse (often as field replacement parts) by systems vendors. The remaining equipment is either refurbished and resold by the third-party vendor or "demanufactured" for recovery of useful parts and

raw materials. Because some of this recycling activity takes place in low-wage countries where environmental regulation is nascent at best, manufacturers are establishing global programs that put their recycling contractors under the same compliance regimes as the manufacturer.[30]

• **Recycling cartridges, supplies, and other consumables.** E-waste extends beyond systems and devices to supplies, and manufacturers likewise have programs for recycling common consumables. Hewlett-Packard, for example, estimates that it has recycled some 112 million printer cartridges since 1992.[31]

OVERCOMING BARRIERS TO GREEN IT

Computing suppliers and enterprise IT organizations are investigating and implementing many of the green IT efforts outlined in this report. But our research shows a low level of overall awareness and adoption among IT organizations in the US and Canada, which certainly face many barriers to implementing green IT. The most significant are:

• **IT buyers are simply unaware of the problems.** The 29% of respondents to our recent survey that identified data center power and cooling issues as important means that 71% did not. And our recent round of qualitative interviews with IT operations and sourcing professionals confirmed that many are simply unaware of green IT, even when positioned in its most concrete, cost-savings-oriented form.

  Supplier action: Continue your evangelism and education. Tune your message appropriately; understand the interplay of your customers' green motivations and their desire for cost savings. Tap into European sources and customers for success stories. Use European regulation as a preview of things to come for North America and elsewhere.

• **IT is often not the locus of a company's green activities.** Green responsibilities, if they are identified at all, are typically spread around an organization, in marketing, procurement, facilities, HR, and executive management (see Figure 3). One result is that in many enterprises the IT organization neither sees nor pays the electric bill, and so is not directly incented to save energy. IT and facilities management organizations often do not engage or cooperate in the design or operation of the data center.

  Supplier action: IT suppliers can be the catalyst that brings disparate roles together. Tech marketers need to learn and speak the languages of different roles within customer organizations, and create a common incentive to work together. Often, shared cost savings will be the most concrete and irresistible statement that brings diffuse stakeholders to the table.

Figure 3 Green Responsibilities Are Spread Among Many Roles

Role	Responsibility
CIO and IT organization	• Reduce environmental impact of computing • Apply IT to other green initiatives, e.g., travel reduction
Procurement and sourcing	• Choose green suppliers • Choose electricity source and associated carbon impact
Facilities	• Plan, monitor, and manage electricity consumption
CSR officer	• Set corporate policies and guidance on use of assets; set carbon reduction goals
CMO	• Use CSR to differentiate firm and products
Product marketing	• Use environmental characteristics to differentiate product
Manufacturing and distribution	• Reduce process, packaging, and transport waste; eliminate hazardous materials
All business leaders	• Reduce environmental impact of corporate travel, commuting, etc.
R&D and product design	• Design products that minimize resource consumption in manufacturing, distribution, and customer use

42070   Source: Forrester Research, Inc.

- **IT's goals of reliability and performance might be compromised.** An IT organization's goals, which are related to uptime, throughput, and reliability of technology-enabled business processes, might be at odds with, or at least threatened by, goals related to energy efficiency, cost savings, and greenness. The IT organization and data center managers might see little direct reward for efforts from which the firm overall might realize savings and environmental benefits.

  Supplier action: Develop standards, benchmarks, and case studies around customers that conserved energy without compromising uptime or throughput. These constitute the first set of goals for consortia like the Green Grid (see Figure 4). Also, suppliers must eat their own cooking. Vendors' internal IT organizations will be the best test-beds and proof points for demonstrating that cost savings can be realized without incurring performance penalties.

- **Payback from green IT initiatives is uncertain or long term.** Companies might be hesitant to aggressively pursue green IT because payback from the requisite capital investments in new infrastructure, data center redesign, and new client devices is uncertain or extremely long term.

Supplier action: Develop ROI or TCO calculators that demonstrate tangible cost savings under realistic assumptions and conditions. Gear up services teams to energy audits and recommendations as part of infrastructure pre-sales activities.

• **Customers see green IT as vendor marketing hype or "greenwash."** Given the breadth of potential green initiatives, and the increasing volume of green marketing coming from suppliers, it's easy to anticipate some eye-rolling on the part of oft-jaded IT customers.

Supplier action: Communicate green IT initiatives in a coordinated and holistic fashion. Make sure your server, PC, software, and services marketing messages are in synch, and backed by results. In many cases, vendors will want to put their services arm, or services partners, front-and-center in marketing green IT because they can lead with an understanding of customers' issues and tackle underlying design and organizational barriers before getting to selling new hardware.

Figure 4 Selected Resources For Further Information On Green IT

IT supplier environmental information

Advanced Micro Devices	www.amd.com/ehs
American Power Conversion Corp	www.apc.com/corporate/environmental.cfm
Dell	www.dell.com/environment
EMC	www.emc.com/about/environment
Hewlett-Packard	www.hp.com/hpinfo/globalcitizenship
IBM	www.ibm.com/responsibility
Intel	www.intel.com/intel/other/ehs
Sun Microsystems	www.sun.com/aboutsun/csr

Green IT industry consortia

80 PLUS	www.80plus.org
EPEAT	www.epeat.net
Green Electronics Council	www.greenelectronicscouncil.org
Green Grid	www.greengrid.org

Consultants, academics, and government

Alliance To Save Energy	www.ase.org
European Union	europa.eu/pol/env
Greenpeace	www.greenpeace.org
Lawrence Berkeley National Laboratory	www.lbl.gov
UK Department Of Trade And Industry	www.dti.gov.uk
UN Intergovernmental Panel On Climate Change	www.ipcc.ch
Uptime Institute	www.uptimeinstitute.org
US Environmental Protection Agency	www.epa.gov

42070   Source: Forrester Research, Inc.

WHAT IT MEANS

WE'RE JUST GETTING STARTED

The greening of the IT industry will be a long-term shift in the way the industry operates paralleling developments in the broader economy and society. Forrester will be regularly analyzing the impacts of increasing environmental awareness on both buyers and sellers of IT systems. It is clear already that the emergence of green imperatives in enterprise IT organizations will have profound implications for technology suppliers and the industry at large:

- **Vendors scramble for green supremacy.** The next year or two are likely to be marked by a scramble by technology manufacturers to tout their green credentials. Programs and practices embedded in internal operations will surface in marketing presentations and product promotion. Tech suppliers will tread carefully between downplaying their efforts and promoting them too heavily, risking a customer and PR backlash.

- **Data center outsourcing gets another boost.** Environmental considerations will be another factor tipping companies' calculations towards data center outsourcing. The availability and price of energy will weigh on companies, along with ongoing issues like staffing and efficiently operating a private data center. We expect the current shared-data-center revival, coming off the trough of 2001 to 2003, to be accelerated by energy and other environmental concerns.

- **Green IT initiatives move from easier to harder.** Both suppliers and customers will move from low-hanging fruit and win-win projects to harder, longer-term, environment-first projects. In our framework, this will mean moving from IT operations and recycling to design and especially manufacturing. Our research with OEMs consistently revealed the longest-term, biggest-impact efforts to be in the manufacturing realm, where "design for the environment" thinking is just getting started. Similarly, customers' efforts will evolve from the short-term ROI of energy efficiency to longer-term programs aimed at reducing their overall carbon footprint.

- **IT becomes an enabler for green business.** The IT industry's smarts, capabilities, and money will be applied to wider problems of environmentally responsible business and economic growth. Companies will use IT resources, for example, to find, evaluate, and develop alternative energy sources. Venture capital talent and money will shift from IT towards environmental technologies.

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SUPPLEMENTAL MATERIAL

Companies Interviewed For This Document

Advanced Micro Devices	IBM
American Power Conversion Corp	Intel
Dell	Sun Microsystems
EMC	Verari Systems
Hewlett-Packard	

ENDNOTES

[1] See, for example, the "IBM 2006 Corporate Responsibility Report" (at www.ibm.com/responsibility), or "Sun's 2006 Corporate Social Responsibility Report" (www.sun.com/aboutsun/csr).

[2] As with many subjects in this overview, data center cooling is a deep and "hotly" debated topic. See the March 8, 2006, Trends "Power and Cooling Heat Up the Data Center."

[3] Source: Jonathan Koomey, "Estimating Total Power Consumption by Servers in the U.S. and the World," Lawrence Berkeley National Laboratory, 2007. The paper more precisely estimates that "aggregate electricity use for servers doubled over the period 2000 to 2005 in the U.S. and worldwide" (http://hightech.lbl.gov/documents/DATA_CENTERS/svrpwrusecompletefinal.pdf).

[4] The issue of "Finding solutions to power and cooling limitations in the data center" was ranked "Important" or "Very Important" by 29% of North American and 26% of European respondents. See the February 8, 2007, Data Overview "2006 Enterprise Server Buyer Profile."

[5] Corporate social responsibility incorporates environmental, social, and economic dimensions that provide leadership and differentiation opportunities for savvy organizations. However, enterprises need to adequately plan, govern, and anticipate in order to capitalize on these opportunities without exposing themselves to risk and liability. See the September 7, 2006, Best Practices "Corporate Social Responsibility And You."

[6] There is a funny moment on this topic in the film, "An Inconvenient Truth." See also, among many examples of this bandwagon gathering steam, *Green to Gold*, by Daniel Esty and Andrew Winston, Yale University Press, 2006.

[7] Clearly, there is a wide range of variation around these numbers, which include power delivery inefficiencies and cooling requirements, but do NOT include peripherals like storage and network devices and PCs, and other gear outside the data center. See "The Price of Performance," by Luiz Andre' Barroso of Google in the ACM Queue, September 2005 (www.acmqueue.com).

[8] See, for example, "High-Tech Means High-Efficiency," Lawrence Berkeley National Laboratory, December 2005.

[9] 80PLUS efficiency levels are incorporated in the US EPA's updated Energy Star Computer Specification that will go into effect in July 2007 (www.80plus.org).

[10] A good summary of the state of play in this effort can be found in "Server Energy Measurement Protocol," by Jonathan Koomey et al., which briefly outlines work being supported by the US EPA (www.energystar.gov/datacenters). Other organizations working on this issue include the Green Grid consortium and the Standard Performance Evaluation Corp (SPEC) (www.spec.org).

[11] See, for example, www.hp.com/globalcitizenship/environment/productdesign.

[12] For example, RoHS currently exempts the use of lead in circuit boards, but manufacturers are working to create lead-free connectors in anticipation of tightening regulations. See IBM's corporate responsibility statement for an example (www.ibm.com/corporateresponsibility).

[13] "Cutting Edge Contamination: A Study of Environmental Pollution During the Manufacture of Electronic Products," February 8, 2007 (www.greenpeace.org/international).

[14] See, for example, "Designing For The Environment Turns Intel Fabs Green" (www.intel.com/ehs).

[15] In a recent Forrester supply chain survey, manufacturers and retailers stated that they face continuing pressures for cost savings through outsourcing, mounting competition through globalization and persistent disappointment with returns on current technology investments. Worse yet, firms realize that widely accepted supply chain strategies are inherently ill-suited for these new challenges. See the April 11, 2006, Trends "The State Of Global Supply Chain Management."

[16] Source: The Dell Sustainability Report for examples of packaging reduction efforts (www.dell.com/sustainabilityreport).

[17] See, for example, "Data Center Energy Efficiency and Productivity," from the Uptime Institute (www.uptimeinstitute.org).

[18] Source: "Carbon Curbs Gain Backers," *Wall Street Journal*, February 27, 2007.

[19] Server virtualization adds a new dimension of complexity to the way the data center is managed. Today, 40% of North American enterprises surveyed by Forrester say they have already implemented server virtualization. See the January 9, 2007, Question & Answer "Decoding Virtualization's Present And Future" and see the June 19, 2006, Trends "Pragmatic Approaches To Server Virtualization."

[20] Source: PG&E press release, November 8, 2006 (www.pge.com/news/news_releases/q4_2006/061108.html).

[21] Forrester believes that data center automation software, which is today used to reduce manual tasks and speed IT changes, will be used to selectively turn off gear that is not being used. For details on data center automation, see the February 3, 2006, Trends "The Future Of Data Center Automation."

[22] Source: EPEAT's Web site (www.epeat.net) for the full list of criteria and information about organizations' IT purchasing processes that request EPEAT-registered products. For information about the US EPA's EnergyStar certification that is being extended from PCs to server systems during 2007, see the agency's Web site (www.energystar.gov/datacenters).

[23] Source: "Implementing Energy Efficient Data Centers," American Power Conversion, 2006 (http://www.apcmedia.com/salestools/NRAN-6LXSHX_R0_EN.pdf).

[24] Source: "Guidelines for Energy Efficient Data Centers," The Green Grid (http://www.thegreengrid.org/pages/content.html).

[25] Desktop virtualization has existed in some form for more than 15 years, but in the past three years, new models have emerged that will dramatically change desktop computing. See the January 5, 2006, Trends "Desktop Virtualization Is The Future Of The Corporate PC."

[26] Cisco, IBM, and Sprint Nextel are among the technology companies in the EPA's top 25 partners (www.epa.gov/greenpowerpartnership).

[27] Source: "One Tiny Town Becomes Internet-Age Power Point," *Wall Street Journal*, March 7, 2007.

[28] Customer loyalty often hinges on the quality of the after-sales experience. Winning companies are able to not only improve the after-sales customer experience but also find ways to recoup lost profits on returned goods, taking advantage of secondary markets to resell repaired and refurbished products. See the November 8, 2006, Best Practices "Taking Control Of Your Aftermarket Supply Chain."

[29] IBM, for example, resells approximately $1.7 billion of returned PCs, servers, and storage equipment each year.

[30] Source: The Dell sustainability report (www.dell.com/sustainabilityreport).

[31] See HP's recycling policy for details (www.hp.com/recycling).

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