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Green IT: An Overview

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Key Points

- Explains what green IT is and examines the significance of green IT.
- Discusses environmental concerns, global warming and the principles of sustainable development.
- Examines the environmental impacts of IT.
- Describes the three key dimensions of green IT and explains green IT 1.0 and 2.0.
- Presents a holistic approach to greening IT.
- Discusses how data centres, cloud computing, storage systems, software and networks can be made greener.
- Highlights how IT could help businesses in their environmental initiatives and reduce their carbon emissions.
- Outlines enterprise green IT strategy.

1.1 Introduction

Enterprises, governments and societies at large have a new important agenda: tackling environmental issues and adopting environmentally sound practices. Over the years, information technology (IT) has fundamentally altered our work and life and improved our productivity, economy and social well-being. IT now has a new role to play – helping to create a greener, more sustainable environment whilst offering economic benefits. But IT has been contributing to environmental problems which most people do not realize. Computers and other IT infrastructure consume significant amounts of electricity, which is increasing day by day, placing a heavy burden on our electric grids and contributing to greenhouse gas (GHG) emissions. Additionally, IT hardware poses environmental problems during both its production and its disposal.

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Whilst many people consider IT to be part of the problem to environmental pollution, it can be its saviour too. In other words, IT is both a solution and a problem for environmental sustainability. We can exploit the power of IT in innovative ways to address mounting environmental issues (Aronson, 2008; Ruth, 2009) and make our IT systems – and their use – greener. Green IT, also known as green computing, is the study and practice of designing, manufacturing and using computers, servers, monitors, printers, storage devices and networking and communications systems efficiently and effectively, with zero or minimal impact on the environment (Murugesan, 2007, 2008). Green IT is also about using IT to support, assist and leverage other environmental initiatives and to help create green awareness (Murugesan, 2008). Thus, green IT encompasses hardware, software, tools, strategies and practices that improve and foster environmental sustainability.

Green IT benefits the environment by improving energy efficiency, lowering GHG emissions, using less harmful materials and encouraging reuse and recycling. Thus green IT includes the dimensions of environmental sustainability, the economics of energy efficiency and the total cost of ownership, which includes the cost of disposal and recycling. Increased awareness of the harmful effects of GHG emissions, new stringent environmental legislation, concerns about electronic waste disposal practices and corporate image concerns are driving businesses and individuals to go green.

Green IT is an economic as well as environmental imperative. And, as many green advocates will attest, it is our social responsibility as well (Murugesan, 2007). The imminent introduction of more green taxes and regulations will trigger a major increase in demand for green IT products, solutions and services. Hence a growing number of IT vendors and users have begun to develop and offer green IT products and services. As business and governments try to balance growth with environmental risks, we will be legally, ethically and/or socially required to 'green' our IT products, applications, services and practices.

To foster green IT, we should understand the following issues: What are the key environmental impacts arising from IT? What are the major environmental IT issues that we must address? How can we make our IT infrastructure, products, services, operations, applications and practices environmentally sound? What are the regulations or standards with which we need to comply? How can IT assist businesses and society at large in their efforts to improve our environmental sustainability?

Beginning with a brief account of IT's environmental impact, this chapter outlines what green IT means and presents a holistic approach to greening IT. It also highlights how IT can help in different ways to improve our environmental sustainability, and outlines a green IT strategy for enterprises.

1.2 Environmental Concerns and Sustainable Development

Numerous scientific studies and reports offer evidence of climate change and its potential harmful effects. Specifically, the growing accumulation of GHGs is changing the world's climate and weather patterns, creating droughts in some countries and floods in others and pushing global temperatures slowly higher, posing serious worldwide problems. Global data show that storms, droughts and other weather-related disasters are growing more severe and frequent.

Global warming is an average increase in the temperature of the atmosphere near the Earth's surface which can contribute to changes in global climate patterns (EPA, 2009,

2012). Global warming can occur from a variety of causes, both natural and human induced. In common usage, however, *global warming* often refers to warming that can occur due to increased GHG emissions from human activities which trap heat that would otherwise escape from Earth. This phenomenon is called the greenhouse effect. GHGs comprise a range of different elements, and the common characteristics of them are that they can absorb thermal infrared radiation (heat) which is emitted from the Earth, and then re-emit it, increasing the Earth's temperature. The most significant constituents of GHG are carbon dioxide (CO_2), methane, nitrous oxide and chlorofluorocarbon (CFC) gases. Electricity is a major source of GHGs as it is generated by burning coal or oil, which releases CO_2 into the atmosphere. Reducing electric power consumption is a key to reducing CO_2 emissions and their impacts on our environment and global warming. The 1997 Kyoto Protocol mandates reducing carbon emissions. The Protocol requires computer manufacturers to undertake energy audits to calculate the electricity used by devices over their lifetime and determine the quantum of CO_2 emissions to take remedial action. In order to stop the accumulation of GHGs in the atmosphere, global emissions would have to stop growing and be reduced by an astonishing 60% from today's levels by 2050 (Lash and Wellington, 2007).

1.2.1 The Inconvenient Truth

Climate change presents a new kind of risk; its impact is global and long term, and the damage it causes is essentially irreversible. The imminent dangers of climate change and the state of global warming are highlighted by former US Vice President and environment activist Al Gore in the Oscar®-winning documentary film *An Inconvenient Truth* and the book *An Inconvenient Truth* (Gore, 2006). Sir Nicholas Stern, in his landmark report, discussed the economics of global warming and warned, 'It was not action, but inaction, on climate change that would devastate global economies' (Stern, 2007).

Not everyone agrees, however, with these predictions regarding global warming and its impacts. For instance, controversies exist concerning the causes of global warming, whether this warming trend is unprecedented or within normal climatic variations, predictions of additional warming, what the consequences are and what actions should be taken. These controversies are scientific, political and/or social in nature (for a good overview of these, see Wikipedia's article on 'Global Warming Controversy'). Environmental groups, numerous governmental reports and many in the media are, however, in agreement with the scientific community in support of human-caused warming. Several scientific societies and academies of science, including all major countries' national academies of science, endorse that global warming is mainly caused by human activity and will continue if GHG emissions are not reduced.

Driven by the disastrous impact of recent storms, floods, droughts and excessive heat that many people have experienced around the world, various studies on global warming and its impact and major global campaigns, many people have begun to think seriously about global warming and its impacts and to do whatever they can to address this problem. Governments, enterprises and people all have roles in combating global warming and building a sustainable environment. There is now greater awareness and a growing commitment to address environmental problems. Inaction to arrest environmental degradation would significantly affect not only current but also future generations and our further

progress, and there is need for multipronged action. The highlighted awareness drives us to ask: What can, and should, IT do in creating a greener, sustainable environment? What can each of us – those in business and industry or in IT departments, CEOs, CIOs, CTOs, IT professionals and employees – do individually and collectively to stop global warming and create a sustainable environment?

1.2.2 Sustainable Development

Sustainability is all about meeting needs and seeking a balance between people, the environment and the economy. According to the United Nations Global Commission on the Environment and Development's 1987 *Brundtland Report*, sustainable development is the 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Sustainable development comprises economic, environmental and social dimensions.

1.2.3 Why Should You Go Green?

Enterprises are now increasingly interested in creating strategies that will help them to handle environmental issues and pursue new opportunities. The reasons for going green are manifold: increasing energy consumption and energy prices, growing consumer interest in environmentally friendly goods and services, higher expectations by the public on enterprises' environmental responsibilities and emerging stricter regulatory and compliance requirements. Enterprise will increasingly feel the effects of environmental issues that impact their competitive landscape in ways not envisaged earlier. For instance, investors have started discounting the share prices of companies that poorly address the environmental problems they create. When making purchasing, leasing or outsourcing decisions, many customers now take into consideration the company's environmental records and initiatives. Investors are increasingly placing their money on initiatives that are green or that develop and promote green products and services. Government agencies, investors and the public are demanding more disclosures from companies regarding their carbon footprint and their environmental initiatives and achievements. Companies with the technology and vision to provide products and services that address environmental issues will enjoy a competitive edge (Lash and Wellington, 2007).

1.3 Environmental Impacts of IT

As mentioned in this chapter, IT affects our environment in several different ways. Each stage of a computer's life, from its production, through its use and to its disposal, presents environmental problems. Manufacturing computers and their various electronic and non-electronic components consume electricity, raw materials, chemicals and water, and generate hazardous waste. All these directly or indirectly increase carbon dioxide emissions and impact the environment.

Total electrical energy consumption by servers, computers, monitors, data communications equipment and data centre cooling systems is steadily increasing. This increase results in greater GHG emissions, as most electricity is generated by burning fossil fuel

like coal, oil and gas. For instance, each PC in use generates about a ton of carbon dioxide every year. Computer components contain toxic materials. Increasingly, consumers discard a large number of old computers, monitors and other electronic equipment 2–3 years after purchase, and most of this ends up in landfills, polluting the Earth and contaminating water.

The increased number of computers and their use, along with their frequent replacements, make IT's environmental impact a major concern. Consequently, there is increasing pressure on the IT industry, businesses and individuals to make IT environmentally friendly throughout its life cycle, from birth to death to rebirth. As many believe, it's our social and corporate responsibility to safeguard our environment.

1.4 Green IT

IT now has a new role to play in creating a greener, more sustainable environment, whilst offering economic benefits by becoming greener.

Green IT is an umbrella term referring to environmentally sound information technologies and systems, applications and practices. It encompasses three complementary IT-enabled approaches to improving environmental sustainability (Murugesan, 2008) (see Figure 1.1):

1. the efficient and effective design, manufacture, use and disposal of computer hardware, software and communication systems with no or minimal impact on the environment;
2. the use of IT and information systems to empower – that is, support, assist and leverage – other enterprise-wide environmental initiatives and
3. the harnessing of IT to help create awareness among stakeholders and promote the green agenda and green initiatives.

Green IT is not just about creating energy-efficient IT systems (hardware, software and applications), though this is an important component, especially as the use of IT proliferates. Green IT is also about the application of IT to create energy-efficient, environmentally sustainable business processes and practices, transportation and buildings. IT can support, assist and leverage environmental initiatives in several areas and also help create green awareness. IT contributes to only about 2–3% of GHG emissions. The vast majority of emissions come from non-IT sources. So, broader applications of IT in

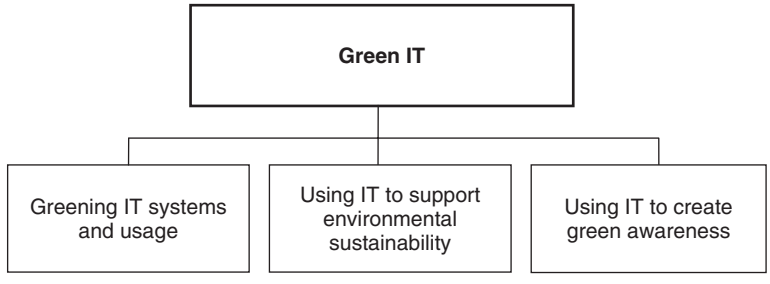

Figure 1.1 Green IT dimensions.

other areas of the economy could bring significant energy savings and improve overall environmental sustainability. According to the SMART 2020 report, IT's largest influence will be by enabling energy efficiencies in other sectors, an opportunity that could deliver carbon savings five times larger than the total emissions from the entire information and computer technology (ICT) sector in 2020. IT can help organizations to minimize their environmental impacts in areas such as GHG emissions, toxic contamination and energy and water consumption.

1.4.1 OCED Green IT Framework

The Organisation for Economic Co-operation and Development (OECD) has proposed a green IT framework consisting of three analytical levels (OCED, 2010) (Figure 1.2). Its objectives are similar to the 'Green IT Dimensions' described in this chapter:

1. **Direct impacts of IT:** These are IT's first-order effects on the environment and include both positive and negative impacts due to the physical existence of IT goods and services and related processes. The sources of IT's direct environmental impacts are IT manufacturing and services firms, including intermediaries and goods producers and final consumers and users of ICTs.
2. **Enabling impacts of IT:** These are the second-order effects that arise from IT applications that reduce environmental impacts across several economic and social activities. For instance, IT can be harnessed to streamline and modify how other products are designed, produced, consumed, used and disposed of, making production and consumption more resource efficient and environmentally sound. This may include consolidations, integration, optimization, dematerialization and substitution.
3. **Systemic impacts of IT:** These impacts and their application on the environment, also called third-order effects, involve behavioural change, process change and other nontechnological factors.

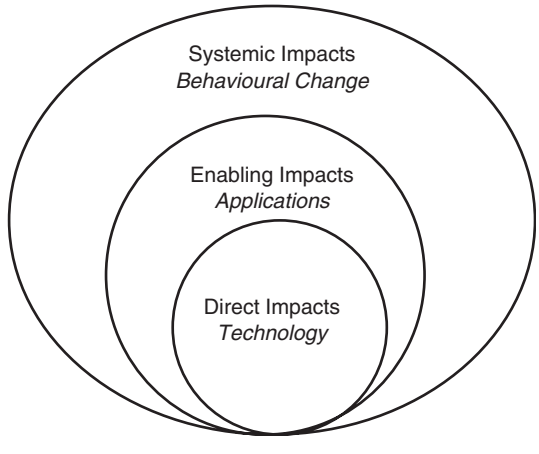

Figure 1.2 OCED green IT framework.

1.4.2 Green IT 1.0 and 2.0

The first wave of green IT – the greening of IT, or Green IT 1.0 – was internally focussed on reengineering IT products and processes to improve IT's energy efficiency, maximize its use and meet compliance requirements. However, as mentioned the vast majority of GHG emissions that deteriorate our environment come from non-IT sources. So, to create significant energy savings and improve overall environmental sustainability, we need to focus our attention and efforts on other areas.

The second wave of green IT, Green IT 2.0, is externally focussed and empowers a range of other green initiatives aimed at reducing environmental degradation and reducing GHG emissions. It is focussed on environmentally sound business transformation, IT-based sustainability innovation, sustainability-based IT innovations and enterprise-wide sustainability. For instance, in addition to being green itself, IT can help create a more sustainable environment by

- coordinating, reengineering and optimizing the supply chain, manufacturing activities and organizational workflows to minimize their environmental impact;
- making business operations, buildings and other systems energy efficient;
- helping decision making by analysing, modelling and simulating environmental impacts;
- providing platforms for eco-management and emissions trading;
- auditing and reporting energy consumption and savings; and
- offering environmental knowledge management systems and decision support systems.

1.5 Holistic Approach to Greening IT

To comprehensively and effectively address the environmental impacts of IT, we must adopt a holistic approach that addresses the problems along these six complementary directions (Murugesan, 2008) (see Figure 1.3):

1. **Green design.** Design energy-efficient and environmentally sound components, computers, servers and cooling equipment.
2. **Green manufacturing.** Manufacture electronic components, computers and other associated subsystems with minimal or no impact on the environment.
3. **Green use.** Reduce the energy consumption of computers and other information systems, and use them in an environmentally sound manner.
4. **Green disposal.** Refurbish and reuse old computers, and properly recycle unwanted computers and other electronic equipment.
5. **Green standards and metrics.** These are required for promoting, comparing and benchmarking sustainability initiatives, products, services and practices.
6. **Green IT strategies and policies.** These effective and actionable strategies and policies add value and focus on both short- and long-term benefits. These are aligned with business strategies and practices, and are key components of greening IT.

By focussing our efforts on these six fronts, we can achieve total environmental sustainability for IT and make IT greener throughout its entire life cycle.

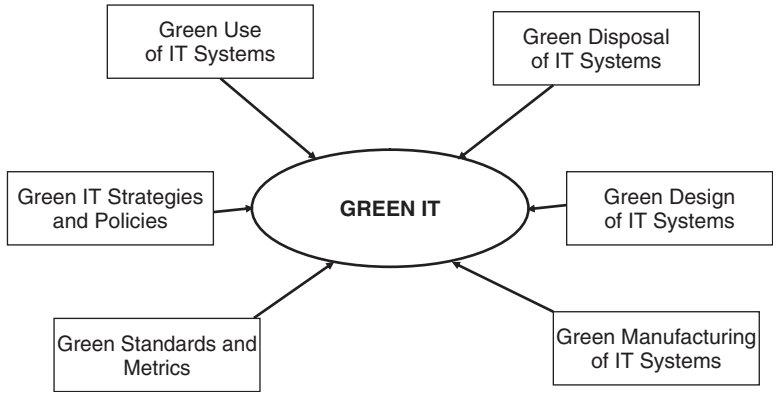

Figure 1.3 Holistic, multipronged approach to greening IT.

1.5.1 Greening Computer's Entire Life Cycle

As shown in Figure 1.4, the entire life cycle of a computer, server and storage system could be made greener, reducing their GHG emissions and carbon footprint and minimizing or eliminating toxic materials used and/or released to the environment. Chapter 2 discusses environmental issues arising from electronic devices, offers a range of solutions to address this problem and highlights best practices in each of the life cycle phases.

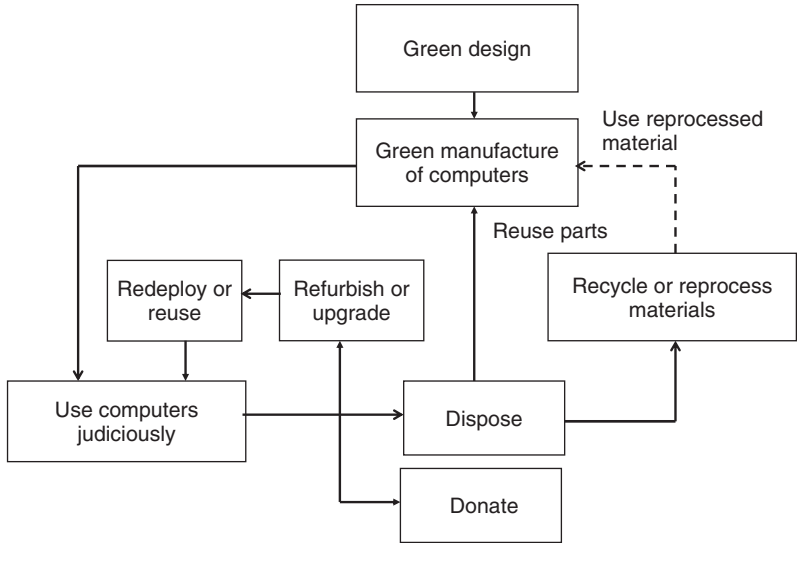

Figure 1.4 Greening computer's entire life cycle.

1.5.2 The Three Rs of Green IT

Unwanted computers, monitors and other hardware should not be thrown away as rubbish, as they will then end up in landfills and cause serious environmental problems. Instead, we should refurbish and reuse them, or dispose them in environmentally sound ways. *Reuse*, *refurbish* and *recycle* are the three 'Rs' of greening unwanted hardware.

- **Reuse.** Many organizations and individuals buy new computers for each project or once every 2–3 years. Instead, we should make use of an older computer if it meets our requirements. Otherwise, we should give it to someone who could use it in another project or unit. By using hardware for a longer period of time, we can reduce the total environmental footprint caused by computer manufacturing and disposal.
- **Refurbish.** We can refurbish and upgrade old computers and servers to meet our new requirements. We can make an old computer and other IT hardware almost new again by reconditioning and replacing some parts. Rather than buying a new computer to our specifications, we can also buy refurbished IT hardware in the market. More enterprises are now open to purchasing refurbished IT hardware, and the market for refurbished equipment is growing. If these options are unsuitable, we can donate the equipment to charities, schools or someone in need, or we can trade in our computers.
- **Recycle.** When we cannot refurbish or otherwise reuse computers, we must dispose of them in environmentally friendly ways by depositing them with recognized electronic recyclers or electronic waste (e-waste) collectors. E-waste – discarded computers and electronic goods – is one of the fastest-growing waste types and poses serious environmental problems. The United Nations Environment Program estimates that 20–50 million tons of e-waste are generated worldwide each year, and this is increasing. IT hardware contains toxic materials like lead, chromium, cadmium and mercury. If we bury IT hardware in landfills, toxic materials can leach harmful chemicals into waterways and the environment. If burned, they release toxic gases into the air we breathe. So if e-waste is not discarded properly, it can harm the environment and us. Waste electrical and electronic equipment (WEEE) regulations aim to reduce the amount of e-waste going to landfills and increase recovery and recycling rates.

Disposal of e-waste, if not properly done, causes serious environmental damage and health problems particularly to those directly involved in the disposal or recycling. Despite bans on the export and import of e-waste, e-waste gets into developing countries (such as India, China and Philippines) for 'recycling' as the cost of recycling is lower there. Unfortunately, as environmental regulations and proper means of e-waste disposal and recycling are not enforced in practice in these countries, e-waste is handled 'informally' in unofficial recycling markets by manual, crude, hazardous means to extract metals and other valuables.

Computer manufacturers should take their share of responsibility and take action to reduce pollution caused by their products' end of life. For instance, they should widely adopt a take-back option, whereby they take from consumers the computers that they no longer need, and arrange for their disposal in an environmentally friendly manner through an e-waste recycling plant. They should educate customers on what they should with do

their old computers. They should also gradually eliminate or minimize the use of toxic materials in computers, which some computer manufacturers are doing.

1.6 Greening IT

One might wonder how we should go about greening IT, and what subsystems of IT can be greened. In fact, every subsystem and peripheral of IT can be greened. The key among them are PCs, notebooks and servers, data centres and cloud computing, software (system and application software, along with the processes of software design and development), storage systems and networking and communication systems and protocols. Peripherals such as printers can be made energy efficient and environmentally friendly.

1.6.1 Green PCs, Notebooks and Servers

We can significantly reduce energy consumption by making small changes to the ways we use computers. Most desktop computers run even when they aren't being used, because users needlessly leave them on, wasting electricity (Nordman and Christensen, 2009). Furthermore, computers generate heat and require additional cooling, which add to the total power consumption and cost. Whilst the savings in energy costs per PC may not seem like much, the combined savings for hundreds of computers in an enterprise is considerable. We can reduce PC energy consumption by adopting several measures.

- **Enabling power management features.** Without sacrificing performance, we can program computers to automatically power down to an energy-saving state when we are not using them.
- **Turning off the system when not in use.** This is the most basic energy conservation strategy for most systems.
- **Using screensavers.** A blank screensaver conserves more power than a screensaver that displays moving images, which continually interacts with the CPU. But even that reduces the monitor's energy consumption by only a small percentage.
- **Using thin-client computers.** Users can choose to employ thin-client computers, which draw about a fifth of the power of a desktop PC.

These measures, though easily adoptable, will not become a practical reality without users' wholehearted willingness and active participation. Even simple steps by one individual or organization can make a huge difference when leveraged across the vast number of individuals and organizations across the world. Smart companies will adopt innovative environmental strategies to innovate, create value and build a competitive advantage. Chapter 2 describes the concept of green hardware including PC power management, energy-efficient power converters, the use of multicore processors, newer types of displays, the use of less toxic materials and related topics.

1.6.2 Green Data Centres

Enterprise data centres, the modern engine rooms that power the Internet and corporate computing, are growing in their number, capacity and power consumption. For instance,

according to an IBM estimate, the power demanded worldwide by data centres currently stands at 100 billion kWh a year, and data centres are one of the fastest-growing users of power (Pritchard, 2007). The carbon footprint of data centres has been increasing dramatically as they consume much energy to power their IT systems and data centre cooling systems.

A study by Jonathan Koomey reveals that the total power used by servers represented 0.6% of total US electricity consumption in 2005 (Pritchard, 2007). With the power needed for cooling and other auxiliary services, electricity use rises to 1.2%, equivalent to the power used by all the country's colour televisions. Aggregate electricity use for servers doubled between 2000 and 2005, and most of this came from businesses installing large numbers of new servers (Pritchard, 2007).

The continued rise of Internet and Web applications is driving the rapid growth of data centres and an increase in energy use. To handle more transactions in less time, to process and store more data and to automate more business processes, enterprises are installing more servers or expanding their capacity, all of which demands more computing power. As energy prices increase worldwide, data centres' operational costs also increases. Energy costs now account for nearly 30% of a data centre's operating costs. As a result, IT is increasingly coming under scrutiny, and data centre efficiency is a major issue facing IT departments.

The number of server computers in data centres has increased sixfold, to 30 million, in the last decade, and each server draws far more electricity than earlier models. Besides the cost, the availability of electrical power is becoming a critical issue for many companies whose data centres have expanded steadily. Energy suppliers need time to design, build and supply the huge amounts of additional electrical power (a few megawatts) demanded by data centres. These social, financial and practical constraints force businesses and IT departments to consider how to reduce, or at least limit, energy consumption by data centres.

So data centres must become greener as well. A green data centre is one in which IT system, air-conditioning systems, electrical and mechanical systems and the buildings that house the data centre are designed and operated for maximum energy efficiency, low carbon footprint and minimum environmental impacts. The data centre uses advanced cooling, heating and IT systems to tailor power consumption to processing and operational needs. Ways to save data centre energy consumption include server, storage and network virtualization, the use of blade servers, server clustering and consolidation and the use of energy-efficient power supplies. Chapter 5 details key sustainability challenges facing data centres and discusses strategies to minimize energy consumption and reduce the carbon footprint of IT systems and data centre facilities.

The EU Code of Conduct on Data Centres' Energy Efficiency is a voluntary initiative aimed at reducing the environmental, economic and energy supply security impact of data centres. The scope of the Code of Conduct encompasses both the equipment and system levels, focussing on two primary areas: the IT load (i.e. the IT capacity available for the power consumed) and facilities load (equipment and systems that support the IT load, such as cooling systems, power distribution units (PDUs) and uninterruptable power supply (UPS)). The flexible and adaptable Code of Conduct encourages data centre operators and owners to undertake a cost-effective adoption of energy-efficient practices without hampering their data centres' mission-critical functions.

1.6.3 Green Cloud Computing

Cloud computing represents a paradigm shift. It is a transition from computing-as-a-product to computing-as-a-service, which is shared and scalable on demand. Driven by the benefits that cloud computing offers, businesses, educational institutions, governments and individuals in both developed and emerging markets have begun to use it for several applications. Cloud offerings and use are growing, and hence these created huge demands on data centres that house the clouds. To cater to the growing demands of cloud-computing services, vendors use large-scale data centres which consolidate thousands of servers with other infrastructure such as cooling, storage and communication networks. With the growth of the cloud, therefore, comes increasing energy consumption by data centres. Then how can clouds be greener? Cloud computing is a green solution as cloud infrastructure embraces two critical elements of a green IT: resource efficiency and energy efficiency. Chapter 16 gives further details on on-going developments to make cloud computing greener.

1.6.4 Green Data Storage

Data and information storage requirements keep growing drastically. Storage systems in data centres consume significant amounts of power and cooling. For instance, in a data centre, storage systems consume anywhere between 24% and 40% of total IT power usage and are the centre's biggest power hogs. So, besides making servers energy efficient, the focus is on greening data storage. Several approaches including MAID (Massive Array of Idle Disks), disk spin down, tiered storage and solid-state drives (SSDs) are used for improving energy efficiency and cutting the overall costs of storing persistent data. System-level approaches such as storage virtualization, thin provisioning (TP) and data de-duplication helps reduce required storage space and make effective utilization of available space. For in-depth coverage of green data storage, refer to Chapter 6. Green storage has to be part of a bigger 'greener ICT' strategy.

Data de-duplication is the elimination of coarse-grained redundant data, typically to improve storage utilization. De-duplication may occur *in line*, as data are flowing, or *post process* after data have been written. It reduces the required storage capacity since only the unique data are stored. Depending on the type of information stored, de-duplication of data can yield a compression ratio from 3:1 to 10:1. Data de-duplication also reduces the data that must be sent across a network for remote backups, replication and disaster recovery.

TP is a method of storage resource management and virtualization that lets IT administrators limit the allocation of actual physical storage to what applications immediately need. TP operates by allocating disk storage space in a flexible manner among multiple users, based on the minimum space required by each user at any given time. NetApp, EMC, Compellent, Xiotech, Dell, 3PAR and several others offer tiering and TP systems.

Tiering, in addition to filtering out unnecessary data and files, allocates business data and files to the most efficient layer of storage available: for example, Tier 1 (on-demand data), Tier 2 (data not critical but still timely) and Tier 3 (archival data). Tiering also provides immediate access to timely business data so they can be used for internal corporate analytics if needed. Chapter 6 discusses the power consumption characteristics of different storage solutions and media, and highlights different energy management techniques for hard disks and system-level green measures.

1.6.5 Green Software

Does software impact the environment? Yes. Software plays an important role in determining overall energy consumption and computational efficiency. For instance, a single ill-behaving, computationally inefficient or power-unfriendly software component on a system can thwart all of the power management benefits built into the hardware.

Software is a key element in improving environmental sustainability. Green software is environmentally friendly software that helps improve the environment. Green software can be classified into four broad categories:

- Software that is greener – consumes less energy to run;
- Embedded software that assists other things in going green (smart operations);
- Sustainability reporting software, or carbon management software (CMS);
- Software for understanding climate change, assessing its implications and forming suitable policy responses.

The manner in which software is developed and the quality attributes of software impact the environment. *Sustainable software development* refers to creating software addressing environmental requirements and perspectives. Development-related attributes such as modifiability, reusability and portability and performance attributes such as computational time and efficiency, usability and dependability influence software's environmental impact. For further discussion on green software and on software design considerations and software methodologies to improve software energy efficiency, refer to Chapters 3 and 4.

Using open source methodologies for application development is expected to result in energy savings as collaborative development processes tend to be more efficient than traditional processes.

Organizations are now required to account and manage their carbon footprint, the amount of GHGs (in CO_2 equivalent) that they produce. This requires IT systems that can measure, analyse and manage carbon emissions in a cost-effective and efficient manner, called a carbon management system. A number of carbon management systems such as Carbonview (www.carbon-view.com), Carbon Planet (www.carbonplanet.com), Greenstone (www.greenstonecarbon.com/software.php) and EmissionsLogic (www.cemsus.com/cems/emissions-logic) are available in the market (see also the CMS Directory at www.carbonmanagementsoftware.com). CMS is also integrated with ERP software from vendors like SAP, Oracle and Microsoft.

1.6.6 Green Networking and Communications

Networks and communications play more significant roles than ever before, and facilitate data transfer and sharing. They enable us to communicate and share information, shop, learn and socialize online, make our work environment smarter and do many other things. The demands on communication networks, wired and wireless, have been constantly increasing, and as a result the energy consumption of communication systems has increased considerably. Traditional networking systems and communication protocols are not particularly designed for energy efficiency. Thus they have some negative impact on the environment.

Green networking refers to ways of minimizing networks' impact on the environment using energy-efficient networking technologies, protocols and products and minimizing resource use whenever possible. Green networking practices include the following:

- Using newer, more energy-efficient techniques, technologies and products;
- Upgrading older equipment with newer, greener networking gears;
- Employing smart systems, user management and energy conservation across IT networks to increase energy efficiency;
- Substituting telecommuting, remote administration and video conferencing for travel.

Chapter 7 describes energy-efficient networking solutions and network protocols, and outlines energy-efficient networking objectives, solutions and management strategies.

1.7 Applying IT for Enhancing Environmental Sustainability

IT can be a key driver in greening several industries and activities, and a positive force towards environmental sustainability initiatives. We should make IT a positive force in environmental change. As mentioned in this chapter, several studies reveal that IT contributes only about 3% of GHG emissions; thus the vast majority of emissions come from non-IT sources, almost all of which can realize enhanced energy efficiency and minimize their environmental pollution through the smarter use of IT (Aronson, 2008; Ruth, 2009).

Besides IT becoming green, it can also be a very helpful enabler and aid to create a better environment. Some of the opportunities for this are as follows:

- Software tools for analysing, modelling and simulating environmental impacts and for environmental risk management;
- Platforms for eco-management, emission trading and ethical investing;
- Tools for auditing and reporting energy consumption and savings and for monitoring GHG emissions;
- Environmental knowledge management systems, meaning the acquisition and transfer of environmental knowledge, decision support systems and collaborative environments; environmental ontologies;
- Environmental information systems engineering, including geographic information systems and environmental (meta-)data standards;
- Urban environment planning tools and systems;
- Technologies and standards for interoperable environmental monitoring networks; smart *in situ* sensor networks;
- Integration and optimization of existing environmental monitoring networks, easy plug-in new sensors, sensor cooperation and networks;
- Tools and systems for optimizing organizational workflows.

To reduce their carbon footprint, organisations can dematerialise some of their products and activities embracing IT. Dematerialization refers to the transformation of physical goods to information goods represented in digital form – "turning atoms to bits." Organisations can adopt electronic billing (e-billing) instead of paper-based billing, offer music and videos for online download rather than on CDs, use e-books and electronic

documents rather than printed documents and do video conferencing rather holding face-to-face meetings.

Chapters 11–13 explore further how the power of IT could be harnessed in several different ways to reduce carbon emissions and improve environmental sustainability. Chapter 17 discusses how Semantic Web technologies can be harnessed for the environmental sustainability of production systems.

1.8 Green IT Standards and Eco-Labelling of IT

To promote and adopt standardization, a number of green IT standards and directives have emerged. Key among them are EPEAT (Electronic Product Environmental Assessment Tool), RoHS (Restriction of Hazardous Substances Directive), WEEE, Energy Star, LEED (Leadership in Energy and Environmental Design), the ISO14001 core set of standards for designing and implementing an effective environmental management system and the EN 16001 Energy Management System. EPEAT is a popular, easy-to-use assessment tool to help organizations compare computer desktops, laptops and monitors based on their environmental attributes. EPEAT-registered products are classified as bronze, silver or gold (www.epeat.net) and they have reduced levels of cadmium, lead and mercury to better protect human health. They are more energy efficient and easier to upgrade and recycle. In fact, manufacturers of EPEAT products must offer safe recycling options for their products when they are no longer usable. For further information on green IT standards and regulation, see Chapter 15.

1.9 Enterprise Green IT Strategy

Green IT and green initiatives are becoming a key agenda for enterprises and governments. They are driven by the benefits they offer and by several on-going developments such as concerns about climate change, government regulations and peer pressure and influence, as shown in Figure 1.5.

Each enterprise must develop a holistic, comprehensive green IT strategy, which should be a component of, and aligned with, an enterprise-wide green strategy. It should then develop a green IT policy outlining aims, objectives, goals, plans of action and schedules. Large enterprises should also appoint an environmental sustainability officer to implement their green policy and to monitor their progress and achievements. To green their IT, enterprises can take any one or a combination of the following three approaches:

1. **Tactical incremental approach.** In this approach, an enterprise preserves the existing IT infrastructure and policies and incorporates simple measures to achieve moderate green goals such as reducing energy consumption. These measures include adopting policies and practices such as power management, switching off computers when not in use, using compact energy-efficient light bulbs and maintaining an optimal room temperature. These measures are generally easy to implement without much cost. However, enterprises should work towards these measures only as short-term, ad hoc solutions.

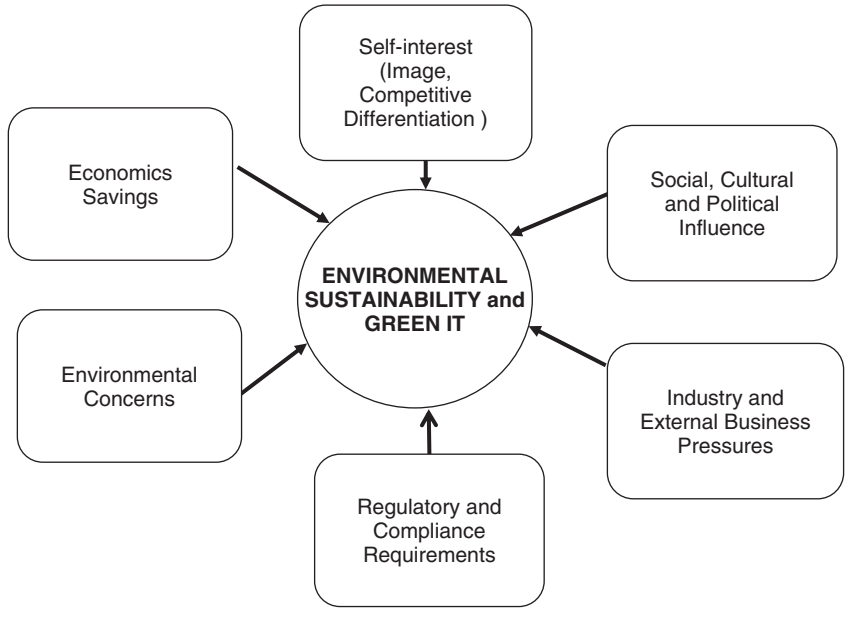

Figure 1.5 Drivers of environmental sustainability and green IT.

2. **Strategic approach.** In this approach, an enterprise conducts an audit of its IT infrastructure and its use from an environmental perspective, develops a comprehensive plan addressing broader aspects of greening its IT and implements distinctive new initiatives. For example, an enterprise may deploy new energy-efficient, environmentally friendly computing systems, or it may develop and implement new policies on procuring, operating and/or disposing of computing resources. Whilst the primary rationale is still cost efficiency and a reduced carbon footprint, this approach also considers other factors such as branding, image creation and marketing.
3. **Deep green approach.** This approach expands upon the measures highlighted in the strategic approach, wherein an enterprise adopts additional measures such as implementing a carbon offset policy to neutralize GHG emissions – including planting trees, buying carbon credits from one of many carbon exchanges or using green power generated from solar or wind energy.

An Accenture Report suggests that about 96% of CEOs are in favour of integrating sustainability issues with organizational strategies (Lacy *et al*., 2010). Chapter 8 discusses crucial steps and considerations in developing green IT strategies, and challenges in implementing green strategies and policies. Chapters 9 and 10 deal with 'Sustainable Information Systems and Green Metrics' and 'Enterprise Green IT Readiness', respectively. Chapter 14 outlines how to manage IT with a focus on environmental sustainability.

1.9.1 Green Washing

Green washing refers to the practice of organizations exaggerating their green credentials and environmental sustainability attributes, and making false claims. Green washing is an amalgam of the terms green and whitewash. It is an unjustified appropriation of environmental virtue. This socially irresponsible and unethical practice misleads customers and the public regarding the company's environmental practices or the environmental benefits of its product or services. It is a marketing ploy to establish an eco-friendly image to consumers, investors, businesses and regulators. It also uses vague claims regarding products' or services' environmental impact. In several developed countries including Australia, the United States, Canada and Norway, companies that provide misleading environmental claims are liable for punishment. For further information, refer to Greenpeace's Green Washing web site at www.stopgreenwash.org and Wikipedia's article on green washing (http://en.wikipedia.org/wiki/Greenwashing).

1.10 Green IT: Burden or Opportunity?

The green philosophy in general, and the 'go green' movement and green demands on corporate IT in particular, do not excessively or unduly burden IT systems, corporate IT departments or functional units. In fact, these initiatives provide an opportunity to revisit and examine our IT systems and their operations in terms of energy efficiency and resource utilization, and thereby enable us to go lean on IT, minimize IT's energy consumption and save on energy bills. Until recently, IT functions and activities primarily focussed on meeting their functional and performance requirements. Very little attention was paid to aspects such as energy consumption, effective utilization of IT resources, IT's operational costs or IT's negative impact on environments at the stages of design, manufacturing, use, reuse and disposal. There is a pressing need to address these neglected or overlooked aspects as they are now important for safeguarding our environment. IT is required to go green. It is good for IT, businesses and the entire planet. Though initially some might view going green as a burden, a closer examination of green philosophy reveals that it includes improving energy efficiency, improving resource utilization, reducing waste, promoting reuse and recycling and more such benefits. This will give the necessary impetus and motivation to turn IT green and use IT in innovative new ways to green all other corporate functions.

We also need to look at green requirements from another viewpoint. The implications of not going green might cost a lot in the context of emerging stricter environmental regulations, stakeholder demands, competitiveness, brand or corporate image and social responsibility. A holistic and objective view would reveal green IT – greening *of* IT and greening *by* IT – to soon become a necessity, not an option. Even if one feels overburdened with 'go green' initiatives and demands, it is better to adopt them in the interest of self and our planet.

Green IT will be a top priority for several years to come, as it is both an economic and environmental imperative. Several case studies on greening efforts reveal that businesses

that reduce their environmental (carbon) footprint can also reduce costs and improve their public image. IT professionals, CIOs and IT support staff are thus being called upon to deliver environmentally sustainable IT solutions (Wilbanks, 2008). Even simple steps that one individual or organization takes can make a huge difference when leveraged across the vast number of individuals and organizations across the world.

However, there is a disparity in the level of green IT understanding across companies, IT professionals, students and IT users. Many do not know how or where to begin or are unwilling to implement green IT. Although green initiatives are catching the attention of the corporate world, some IT professionals, executives and IT departments feel excessively burdened by the green philosophy. However, upon closer examination, they will find that going green is a sound strategy.

Green initiatives let us revisit and examine our IT systems and their operations in terms of energy efficiency and resource utilization, and thus can reduce energy bills. Until recently, very little attention was given to IT's energy consumption, effective use of resources, operational costs and negative environmental impacts during manufacturing, use and disposal. Now, however, a spotlight has been turned on IT, and there is a pressing need to address these overlooked aspects, which are important in safeguarding the environment for future generations.

Businesses also need to look at green requirements from another viewpoint – that is the implications of not going green in the context of stricter environmental regulations, stakeholder demands, competitiveness, branding and corporate image and social responsibility. Smart companies will adopt an environmental strategy to innovate, create value and build a competitive advantage. They will benefit by viewing these challenges as strategic opportunities.

Again, the greening of and by IT will soon be necessities – not options. To help create a more sustainable environment, IT professionals must understand green IT and its potential. Publications that describe new advances, outline current trends and present solid case studies demonstrating green IT's benefits will help provide this understanding and the motivation to 'green' IT.

1.11 Conclusion

As the climate debate heats up, IT finds itself part of the problem – and part of the solution. Environmentalism and economic growth can go hand in hand in the battle against global warming.

A vigorous green IT plan is an economic – as well as an environmental – imperative. Companies can outcompete their peers by tackling sustainability head on, engaging stakeholders, developing partnerships and adding environmental stewardship to their corporate culture. Every business, big or small, faces environmental risks and opportunities. Companies have benefited from taking these challenges as strategic opportunities (Esty and Winston, 2006).

Businesses must develop a positive attitude towards addressing environmental concerns and adopt forward-looking, green-friendly policies and practices. The challenges are immense; however, recent developments indicate that the IT industry has the will and conviction to tackle these environmental issues head on.

As Albert Einstein once said, 'The significant problems we have cannot be solved at the same level of thinking with which we created them'. The green IT agenda represents a major shift in priorities for the IT industry, and IT professionals, educators, researchers and users must be prepared to adjust their 'level of thinking' to realize IT's potential.

Review Questions

1. Briefly describe climate change, global warming, greenhouse gases and the greenhouse effect.
2. What is meant by green IT? Why is it gaining greater relevance and importance now?
3. What are the different dimensions or directions of green IT?
4. How can software impact the environment and the energy consumption of computing systems?
5. What are key subsystems of IT that could be made greener? Briefly explain.
6. Describe the 3Rs of green IT.
7. Why there is growing demand, and need, for greening data centres?
8. What is meant by 'green washing'? Explain with examples.

Discussion Questions

1. Is IT is more of a problem or a solution to environmental sustainability and sustainable development? Discuss.
2. For enterprises, do green initiatives and green IT present a burden or an opportunity to leverage their benefits?
3. Would you advocate effective use of power management features in enterprise computers?
4. What is meant by dematerialization in the context of environmental sustainability? Discuss with examples of how IT and the Internet can help in dematerialization.
5. Discuss how one can use social media, IT and the Internet to create awareness of environmental problems and promote green initiatives among individuals and businesses.
6. Discuss any two smart mobile phone or tablet computer applications (apps) that help individuals or enterprises become greener and environmentally more responsible.
7. Choose three types of carbon management software (CMS) and discuss their features and limitations.
8. Discuss the philosophy, pros and cons of carbon trading.
9. In your view, what are the barriers to individual and enterprise adoption of green IT? Discuss.

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Further Reading and Useful Web Sites

These additional resources will help you to explore green IT further and to keep abreast of on-going developments (all sites accessed April 2012).

Special Issues

- *IT Professional*, special issue on green IT, January–February 2011: http://www.computer.org/portal/web/csdl/abs/mags/it/2011/01/mit201101toc.htm. Download it for free from: http://bitly.com/HOu1bR.
- *IT Professional*, special issue on green computing, January–February 2008: http://www.computer.org/portal/web/csdl/abs/mags/it/2008/01/mit200801toc.htm.
- *SETLab Briefings*, special issue on green IT, 2011: http://www.infosys.com/infosys-labs/publications/setlabs-briefings/Pages/green-IT.aspx.
- Green High Performance Computing', *IEEE Computing in Science & Engineering*, no. 6, 2010: http://www.computer.org/portal/web/csdl/abs/mags/cs/2010/06/mcs201006toc.htm
- *Microsoft Architectural Journal*, special issue on green computing, no. 18, 2010: http://research.microsoft.com/pubs/78813/AJ18_EN.pdf.

Reports

- S. Murugesan, ed., 'Understanding and implementing green IT', Essential Set, IEEE CS Press, 2010: http://www.computer.org/portal/web/store?product_id=TS0000030&category_id=TechSets.
- Smart 2020: Enabling the low carbon economy in the information age,' Global eSustainability Institute, 2010: http://www.gesi.org/LinkClick.aspx?fileticket=tbp5WRTHUoY%3d&tabid=60.
- *Using ICT to Tackle Climate Change*, Global eSustainability Institute, 2010: http://www.gesi.org/LinkClick.aspx?fileticket=fzmFL3kXfOU%3d&tabid=60.
- Tom Worthington, *ICT Sustainability: Assessment and Strategies for a Low Carbon Future, 2011:* http://www.tomw.net.au/ict_sustainability/.
- Evaluating the Carbon-Reducing Impacts of ICT: An Assessment Methodology', Global eSustainability Institute, 2010: http://www.gesi.org/ReportsPublications/AssessmentMethodology/tabid/193/Default.aspx.

- Best Practices for the EU Code of Conduct on Data Centres', 2011: http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC/Best%20Practices%20v3.0.1.pdf.
- EU Code of Conduct for Data Centres, 2008: http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC%20data%20centres%20nov2008/CoC%20DC%20v%201.0%20FINAL.pdf.

Government Legislations

The Carbon Reduction Commitment (CRC) Scheme: http://www.decc.gov.uk/en/content/cms/emissions/crc_efficiency/crc_efficiency.aspx.

Web Sites

- Green Computing, IEEE Technical Committee on Scalable Computing (TCSC) – Technical Area of Green Computing: http://sites.google.com/site/greencomputingproject/ (requires log-in).
- Green Communications and Computing, Technical Subcommittee of IEEE Communications Society: http://sites.google.com/site/gcccomsoc/home.
- The Green Grid (www.thegreengrid.org) – industry-supported research and commentary site aimed at data centre activity with reports about design, energy measurement and so on.
- The Uptime Institute: http://uptimeinstitute.org/.
- Sustainable IT: http://weblog.infoworld.com/sustainableit.
- GreenBiz: www.greenbiz.com.