SUSTAINABLE IT

REDUCING CARBON FOOTPRINT AND MATERIALS WASTE IN THE IT ENVIRONMENT

LECTURE THREE

CLIENT EQUIPMENT

Developed by:

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EDUCATIONAL AIMS OF LECTURES

Lecture 1: Drivers and Benefits of Sustainable IT

The aim of this lecture is to discuss the drivers and benefits of *Sustainable IT*, particularly for the customer. Drivers and benefits range through business, economic, environmental and legislative domains.

Lecture 2: Product Service Systems and the Product Cycle

The aim of this lecture is to discuss *product service systems*, their barriers and lessons from past implementations, as well as the opportunities to reduce energy and materials consumption in packaging and equipment through end-of-life processing.

Lecture 3: Client Equipment

The aim of this lecture is to discuss a four-step process for reducing energy consumption, materials consumption and materials toxicity in client equipment.

Lecture 4: Data Centres and HP Case Study

The aim of this lecture is to discuss a seven-step process for reducing energy consumption in data centres and to present a *Sustainable IT* case study of IT vendor HP.

Lecture 5: Roadmap and Success of Sustainable IT

The aim of this lecture is to discuss the strategies, activities and actions upon which customers and vendors should focus in order to successfully transition to, maintain and promote their *Sustainable IT* solutions at the organisation and industry level.

Sustainable IT

Lecture 3: Client Equipment

Educational Aim

The aim of this lecture is to discuss a four-step process for reducing energy consumption, materials consumption and materials toxicity in client equipment.

Required Reading

Reference	Page
Smith, M., Hargroves, K., Stasinopoulos, P., Stephens, R., Desha, C. and Hargroves, S. (2007) *Energy Transformed: Sustainable Energy Solutions for Climate Change Mitigation*, 'Lecture 5.3: Opportunities for Energy Efficiency in the IT Industry and Services Sector', The Natural Edge Project (TNEP), Australia. Available at http://www.naturaledgeproject.net/Sustainable_Energy_Solutions_Portfolio.aspx. Accessed 30 May 2008.	pp 9-14
Hargroves, K., Stasinopoulos, P., Desha, C. and Smith, M. (2007) *Engineering Sustainable Solutions Program: Industry Practice Portfolio – E-Waste Education Courses*, 'E-Waste Curriculum Development Project - Phase 1: Literature Review', The Natural Edge Project (TNEP), Australia. Available at http://www.naturaledgeproject.net/EWasteHome.aspx. Accessed 30 May 2008.	pp 4-8, 13-16, 24-27, 37
Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*, HP. Available at http://h50281.www5.hp.com/tawpost/presentations/9607_Energy_Efficiency_Whitepaper.pdf. Accessed 30 May 2008.	pp 2-16

Learning Points

Client Equipment

1. A customer's client environment consumes a considerable quantity of energy and materials, and introduces toxic substances into the biosphere. If client equipment is not effectively managed, service can be degraded and energy and material resources can be consumed unnecessarily, and unacceptable toxic dispersion may occur. This Lecture presents a four-step process for creating and maintaining a client environment that provides high quality service while minimising energy and materials consumption, as well as toxic dispersion.[1]
2. *Step 1: Assess*: Assess energy consumption using metering and monitoring client equipment; assess materials consumption by measuring client equipment use over time; and identify unnecessary energy and materials consumption.[2]
3. *Step 2: Consolidate*: Operate client equipment only when necessary and remove unnecessary equipment in order to simplify the client environment, reduce costs and reduce energy and materials consumption. It is common to find opportunities to consolidate desktop computers, imaging equipment and supplies inventory.[3]
4. *Step 3: Innovate*: Incorporate the latest innovations in sustainable design and technology into client equipment to further reduce costs and energy and materials consumption.
5. *Energy Consumption*. There are several benefits of reducing the energy consumption of client equipment, including reduced energy costs, extended equipment life, reduced cooling load and reduced greenhouse gas emissions.[4]
6. *Step 3 (a): Select the appropriate client equipment:* Often the energy consumption of client equipment can be reduced at no cost by simply using the right-sized item. Compared to oversized equipment right-sized equipment has several benefits. The energy consumption of client equipment can also be reduced at no cost by using the item with the right features. There are also specific features to consider for most common items of equipment – computers, printers, photocopiers and combined machines.[5]
7. *Step 3 (b): Use power management strategies:* It is common for a client environment to have many items operating for a large portion of time while not engaged in tasks. Power management strategies reduce energy consumption by turning off client equipment when they are least likely to be used. Generally, turning off client equipment after hours can reduce power consumption by about two-thirds, while a combination strategy of setting them to consume minimal power when in use and setting them to turn off after just a few minutes of inactivity can reduce power consumption by about an additional third.[6] Power management options in modern client equipment usually rely on the function of both hardware and software – processor, chipset, system BIOS, operating system and processor driver.[7]
8. *Step 3 (c): Use low-energy client equipment:* There are a range of component options for many

[1] Kong, P. (n.d.).
[2] Kong, P. (n.d.).
[3] Kong, P. (n.d.).
[4] Carbon Trust (2006), p 2.
[5] Carbon Trust (2006), pp 5-9; Doyle, E. (2004).
[6] Ministerial Council on Energy (2003), pp 17-19.
[7] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.

items of IT equipment. These components can have quite varied energy consumption despite providing the same services. There are low-energy technologies for common IT equipment components such as processors, monitors, power supplies, storage memory and computers. Indirect energy consumption can also be reduced using internet communication technologies. Internet communication technologies can provide common communication services, such as face-to-face meetings[8] and phone calls,[9] and enable new employment and operations models[10] without the associated travel and serviced infrastructure. Internet communication technologies can also enable remote access to targeted or costly information services, such as processing power, storage and software. Remote access reduces the need for physically transporting input information and prevents the need for replicating the required service's infrastructure.

9. *Materials Consumption*: There are four main activities to reduce the materials consumption and toxicity of client equipment: 1) reduce equipment mass and size; 2) use innovative and renewable or recycled materials; 3) replace potentially harmful materials; and 4) eliminate 'materials of concern'.[11] These activities are supported by several standards and regulations.[12] These activities can be applied to develop low-material and low-toxicity items of client equipment, such as computers, monitors, combined machines,[13] and printing supplies.

10. *Eco-Labels*: Many eco-labels have been developed to meet the increasing demand for information on the environmental characteristics of IT equipment.[14] These eco-labels assist in identifying low-energy, low-materials and low-toxicity client equipment.

11. *Step 4: Manage*: Continuously manage and monitor the client environment for opportunities to reduce energy and materials consumption, thereby potentially reducing costs. These opportunities may include: replacing inefficient client equipment with efficient equipment when cost effective, and ensuring appropriate end-of-life processing of the replaced equipment; recycling spent print cartridges and paper; monitoring and reporting energy and material consumption; introducing or updating sustainable purchasing and procurement policies;[15] and scheduling non-critical, high-energy activities out of peak periods.[16]

[8] Hewlett-Packard Development Company (2007) *Global Citizenship*.
[9] Australian Computer Society (2007).
[10] Australian Computer Society (2007); Taylor, P.W. (2008), p. 20.
[11] Hewlett-Packard Development Company (2007) *Global Citizenship.*
[12] ECMA International website – *Standard ECMA-328: Determination of Chemical Emission Rates from Electronic Equipment, 3rd edition*; Europa website; European Union (2003) ''Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment'; European Union (2006); International Organisation for Standardisation (2000); Official Publications of the European Communities (2004).
[13] Hewlett-Packard Development Company (2007) *Global Citizenship*; OECD (2003) cited in Brigden, K. *et al* (2005), p 26.
[14] EcoLabelling website.
[15] Kong, P. (n.d.).
[16] Australian Computer Society (2007).

Brief Background Information

A customer's client environment consumes a considerable quantity of energy and materials, and introduces toxic substances into the biosphere. Client equipment is usually distributed across floors, buildings, cities and even countries.

If client equipment is not effectively managed, service can be degraded, energy and material resources can be consumed unnecessarily, and unacceptable toxic dispersion may occur. This Lecture presents a four-step process for creating and maintaining a client environment that provides high quality service while minimising energy and materials consumption, as well as toxic dispersion:[17]

Step 1: Assess

Step 2: Consolidate

Step 3: Innovate (main focus of this Lecture)

Step 4: Manage

Step 1: Assess

Step 1 involves, for each group of client equipment:[18]

- *Assess energy and materials consumption*: A common method of assessing energy consumption is to install meters at strategic positions in the electricity circuits of the target equipment and then monitor the output over time. A common method of assessing materials consumption is to count the number of non-consumable items and measure the consumption rate of consumable items over time, and then compare these numbers to the number of users and services over time.
- *Identify waste*: An assessment may reveal obvious unnecessary consumption of energy and materials, particularly during high consumption periods, during peak consumption periods and after business hours.

Step 2: Consolidate

Step 2 involves, for each group of client equipment, operating items only when necessary and removing unnecessary items in order to simplify the client environment, reduce costs and reduce energy and materials consumption. Some examples include:[19]

- *Desktop computers*: It is common for a client environment to have excess desktop computers. In a typical client environment, consolidation can reduce power consumption by up to 25 percent. In terms of carbon dioxide emissions, removing 12 PCs is the equivalent of taking about one car off the road.
- *Imaging equipment (printers, copiers and scanners)*: It is common for a client environment to have excess printers, especially personal printers, when communal printers are just as convenient. Consolidating and standardising imaging equipment can greatly reduce energy consumption per service, since imaging equipment spends most time in idle.

[17] Kong, P. (n.d.).
[18] Kong, P. (n.d.).
[19] Kong, P. (n.d.).

- *Supplies inventory*: It is usually necessary for some supplies to be stored for immediate access when required. However, an excessive supplies inventory can be economically costly by risking the equipment expiring or becoming obsolete, and can tie up energy and materials resources unnecessarily. In fact, the economic value of supplies inventory is one of the largest components of a typical organisation's warehouse cash flow. It is also quite common for material resources to be tied up in the form of used consumables, such as ink and toner cartridges in cupboards and desk drawers.

Step 3: Innovate

Step 3 involves incorporating the latest innovations in sustainable design and technology into client equipment to further reduce costs and energy and materials consumption.

Energy Consumption

Client equipment consumes a large amount of energy. Estimates from the UK suggest client equipment is the fastest growing energy consumer in business, consuming about 15 percent of total electricity used in offices and expected to increase to 30 percent by 2020.[20] Figure 3.1 shows the estimated energy consumption of various items of IT equipment as a percentage of total IT energy consumption in the USA.

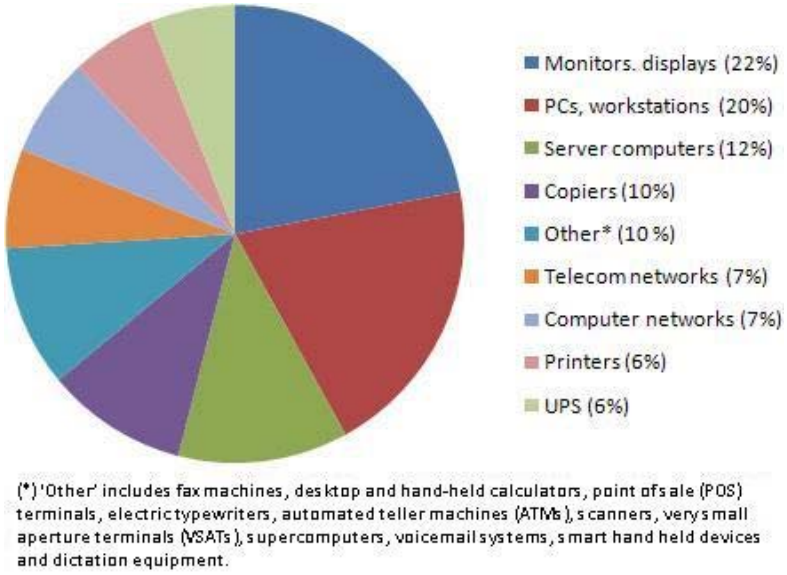

Figure 3.1. Estimated energy consumption of various items of IT equipment as a percentage of total IT energy consumption in the USA

Source: Roth *et al* (2002)[21]

A typical array of client equipment in a building consumes 10 W/m^2 or 200 W per person, assuming that each person has one computer plus part-share of other office equipment.[22] The energy consumption of a variety of items is shown in Table 3.1.

[20] Carbon Trust (2006), p 3.
[21] Rothe *et al* (2002) cited in Ministerial Council on Energy (2003), p 7.

Table 3.1: Energy consumption of various items of client equipment

Item	Power demand (W)	Item	Power demand (W)
Personal computers with monitor	100-120	Laser printers	100
Mini/mainframe computer workstations	160	Small photocopier	150-300
Fax machine	40	Large photocopier	300+
Electronic typewriters	40	Dot-matrix printers	60
Modems	20	B/W A4-A0 electrostatic	300
Overhead projector	300	Colour A4-A0 electrostatic	850
Slide projector	350	Colour A4 thermal	400
		Colour A0 thermal	750

Source: Australian Greenhouse Office (2006)[23]

There are three factors to consider in reducing the energy consumption of client equipment: a) select the appropriate client equipment, b) use power management strategies, and c) use low-energy client equipment.

a) Select the Appropriate Client Equipment

Often, the energy consumption of client equipment can be reduced at no cost by simply using the right-sized item. Compared to oversized equipment, which is sometimes selected because the customer incorrectly perceives these appliances to be better value for money, right-sized equipment has several benefits, including: they are often cheaper to purchase because they are lower capacity; they operate near their design loads, which can make them up to twice as energy efficient as oversized equipment operating at low load; they emit less heat and thus contribute less to cooling load; and they are generally smaller, lighter and safer to handle.

The energy consumption of client equipment can also be reduced at no cost by using the item with the right features. Some important features include:[24]

- *Sleep and wake speed*: Standby mode is more likely to be used on machines with fast sleep and wake speeds. Generally, newer machines have faster sleep and wake speeds.
- *Computers*: Energy consumption generally increases with both computer performance and monitor area. Reviewing current and future task requirements assist in matching computers and monitors to tasks. Not all tasks require high performance computers with large monitors.
- *Printers and photocopiers*: Energy consumption generally increases with print speed, colour diversity, colour intensity, page count and ink melting point. For non-time-sensitive, internal documents, it may be appropriate to print and copy with slow machines, in monotone rather than colour, in low quality and double sided. Avoid unnecessary printing by taking advantage of 'print preview' functions available on word processing software to review document layout and style.

[22] Australian Greenhouse Office (2006) *Office Equipment: Why is Office Equipment Important?*
[23] Australian Greenhouse Office (2006) *Office Equipment: Office Equipment Energy Issues*.
[24] Carbon Trust (2006), pp 5-9.

Many high-volume machines are optimised for specific ranges of print run length and response time. Ink-jet printers consume about 90 percent less energy than laser printers.[25]

- *Combined machines*: Machines that combine printer, fax, scanner and photocopier functions may be suitable in client environments such as small offices. Having only one machine operating rather than four machines consumes substantially less energy and requires less space.

b) Use Power Management Strategies

It is common for a client environment to have many items operating for a large portion of time while not engaged in tasks. For example, while almost all computers are left on, only a third are engaged at any one time.[26] Power management strategies reduce energy consumption by turning off office equipment when they are least likely to be used.

Compared to having equipment on all the time, using power management strategies also has other benefits, including: reduced heat production (which leads to lower fan speeds and hence quieter and more efficient operation), and increased battery life in mobile equipment.[27]

The spectrum of power management strategies varies from simply turning off equipment after hours to a combination of setting equipment to consume minimal power when in use and setting them to turn off after just a few minutes of inactivity. Most modern equipment has these funtionalities built in as a user option. Setting monitors to turn off when not in use is typically the single most significant strategy to reducing energy consumption.[28]

Figure 3.2 shows the effect on power consumption and operating costs of common client equipment with no power management and with the two extremes of power management strategies described above. Turning off equipment after hours (red) can reduce power consumption by about two-thirds, while the combination strategy (green) can reduce power consumption by an additional third.

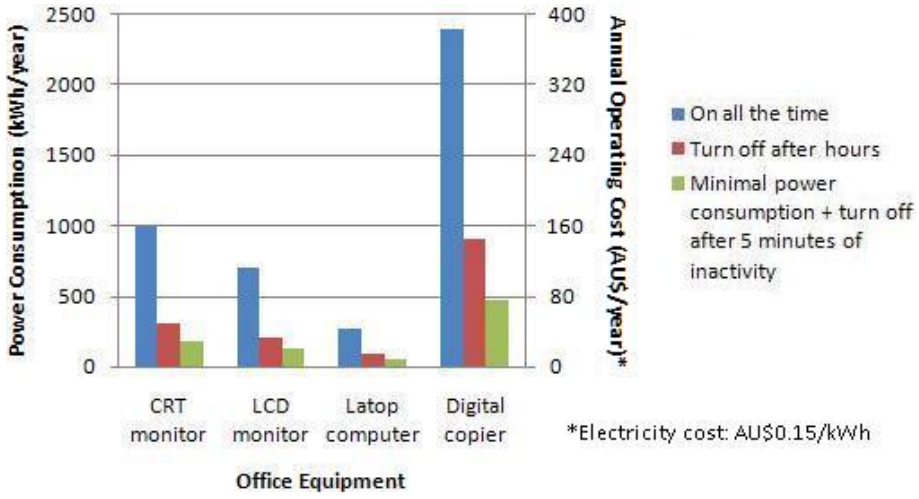

Figure 3.2. Comparison of power consumption and operating costs of office equipment with no power management, with simple power management and with aggressive power management
Source: Adapted from Ministerial Council on Energy (2003)[29]

[25] Doyle, E. (2004).
[26] Australian Greenhouse Office (2006) *Office Equipment: Why is Office Equipment Important?*
[27] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.
[28] Australian Greenhouse Office (2006) *Office Equipment: Computers*.
[29] Ministerial Council on Energy (2003), pp 17-19.

Power management options in modern client equipment usually rely on the function of both hardware and software. For example, in a desktop or notebook computer, these options rely on the processor, chipset, system BIOS (basic input/output system), operating system and processor driver.[30] In all IT equipment, these options rely on at least the processor and system BIOS:

- *Processors*:[31] Many modern processors have power management features that can dynamically adjust the voltage and core frequency (clock speed) up to tens of times per second depending on the processor load. Since processors usually spend only part of the time at full load, these adjustments can reduce energy consumption and heat generation by up to 40 percent without affecting user productivity. In most processors, the front side bus (FSB) frequency is not adjusted.
- *System BIOS*:[32] The BIOS (basic input/output system) is software, usually hardcoded in ROM, that supports information transfer between system components such as memory, the keyboard, the monitor, thermal sensors and cooling components.[33] The BIOS has two main roles in power management:
    - The first role is to support the system in dynamically adjusting its energy consumption. An example is the processor adjusting its voltage and core frequency, as described above. Another example is a desktop or notebook computer going into various sleep states – standby (only processor halted), suspend to RAM standby (only RAM operating, <5W power) or suspend to disk hibernation (only hard disk operating) – or into soft off state (almost off but can wake from external input, <2W power).[34] These states provide low energy alternatives for users who would rather leave their computers on after hours than wait for a full boot every morning. The target power consumption for electrical and electronic appliances, including most IT equipment, is 1W by 2010.[35] This target was proposed by the International Energy Agency in 1999, and in 2000 Australia became the first nation to publically commit to the target.[36]
    - The second role is to adjust the cooling system to optimise the internal thermal environment (temperature) and acoustic levels (noise). Cooling systems in most current items of IT equipment are fan systems that circulate air. The fans are usually the noisiest component in the equipment. [Some high performance and over-clocked computers use liquid (water) cooling systems. Water has a much higher thermal conductivity (0.611W/mK at 27°C[37]) than air (0.0281W/mK at 47°C[38]), which means water can remove heat more effectively.] Cooling systems prevent processors from getting too hot by causing them to throttle (core frequency slowed) at times and hence reduce heat generation until the computer's temperature decreases sufficiently. Reducing the core frequency may result in perceivable degradation of the system's performance. The BIOS controls the cooling system to: 1) maintain a favourable internal temperature and activate audio alerts if the temperature gets too hot, and 2) minimise fan noise and smoothly ramp up/down fan speeds.

[30] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.
[31] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.
[32] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.
[33] Microsoft website – *Other Glossary Sources*.
[34] Hewlett-Packard Corporation, Intel Corporation, Microsoft Corporation, Phoenix Technologies Ltd. and Toshiba Corporation (2006), pp 405-407.
[35] International Energy Agency (2007).
[36] Energy Rating website.
[37] Mills, A.F. (1999), p 894.
[38] Mills, A.F. (1999), p 888.

c) Use Low-Energy Client Equipment

There are a range of component options for many items of IT equipment. These components can have quite varied energy consumption despite providing the same services. In general though, manufacturers have been steadily reducing the energy consumption of their components and IT equipment.

- *Processors*: Processors have varied power consumption depending on their application. The power ratings for mainstream processors in mid-2008 are given in Table 3.2. Note that a processor's idle, average and peak power consumption varies substantially.

Table 3.2: Power ratings for mainstream processors in mid 2008

Computer Type	Processor Power Rating	
	Intel	AMD
Desktop (quad-core)	95W	95-125W
Desktop (dual-core)	65W	65W
Notebook (dual-core)	35W	31-35W
Server	50-150W	55-75W

Source: Intel Corporation[39] and Advanced Micro Devices Inc. (AMD)[40]

- *Monitors*: While, in mid-2008, LCD technology is standard for monitors, it is quite common for organisations to use some older CRT monitors. Compared to CRT monitors, LCD monitors consume up to 70 percent less energy, have up to double the operating life, and require several times less desk space, which helps reduce overhead costs such as office furniture, lighting and rent.[41]
- *Power supplies*:[42] As of mid-2008, the most energy efficient mainstream power supplies are more than 80 percent efficient. Compared to standard power supplies, these power supplies are up to 33 percent more efficient and hence generate less heat, are more reliable, require less maintenance and have a longer operating life. The increased efficiency is a result of:
  - Improved basic power conversion efficiency from about 70 percent to over 80 percent.
  - An active power factor correction (PFC) of 0.9, which is relatively high for complex systems such as IT equipment. PFC is a measure of the correlation between the 'apparent power' drawn by the system and the 'real power' available for the system to use. A PFC of 0.9 means that there is a 90 percent correlation. Incorporating PFC features requires an active circuit, but has the benefits of: reduced RMS input current by nearly 50 percent; reduced peak AC input current by over 75 percent; operation over the entire AC voltage range (90VAC to 264VAC) without an input voltage select switch; and no variations in AC voltage that can affect or damage other equipment on the same circuit.
- *Storage memory*: The most common technology for storage memory is the hard disk drive (HDD). Typically 3.5-inch HDDs are used in desktop computers and 2.5-inch HDDs are used in notebook

[39] Intel Corporation website.
[40] Advanced Micro Devices Inc. (AMD) website.
[41] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.
[42] Hewlett-Packard Development Company (2007) *Energy Efficiency Setup Guide*.

computers. Each form factor (size) has its advantages and disadvantages – 3.5-inch HDDs generally have a greater capacity and are faster whereas 2.5-inch HDDs generally consume less power and require fewer materials. However, it appears as though HDDs will soon be superseded by solid state drives (SSD). Compared to HDDs, SSDs consume less power during operation, are faster, are more reliable and have a longer operating life. The benefits of SSD over HDD, according to one manufacturer, are presented in Table 3.3. Many other manufacturers present similar benefits.[43] The main shortcomings of SSDs, as of mid-2008, are that they have lower capacity and they are more costly. The difference in manufacturing energy cost between SSD and HDD is not yet clear.

Table 3.3: Comparison of a solid state drive (SSD) and a hard disk drive (HDD) (2.5-inch, SATA, 3.0Gbps)

	Solid State Drive	**Hard Disk Drive**
Mechanism type	Solid NAND flash	Magnetic rotating platters
Capacity	64GB	80GB
Weight (2.5")	73g	365g
Read speed	100 MB/s	59MB/s
Write speed	80MB/s	60MB/s
Active power consumption	1W	3.86W
Operating vibration	20G (10-2000Hz)	0.5G (22-350Hz)
Shock resistance	1500G/0.5ms	170G/0.5ms
Operating temperature	0-70°C	5-55°C
Endurance (mean time between failure)	> 2 million hours	< 700k hours

Source: Samsung[44]

- *Computers*: Thin clients can be used in place of desktop computers. Thin clients are network computers with low processing power and few components that rely on servers for software applications, data storage and administration.[45] Multiple thin clients are connected to a single server, which performs the majority of operations including only a single instance of programs that would otherwise run on every desktop computer. Since thin clients perform far fewer operations, they require fewer and smaller components, and hence consume 5[46]-15[47] times less energy and generate far less heat. However, it is important to compare this reduction in energy consumption with the increase in energy consumption and cost of providing the additional servers, uninterruptable power supplies (UPS), air-conditioning and maintenance.
- *Internet communication*: Internet communication technologies can reduce energy consumption by providing the services of the technologies that they replace without the associated travel and/or serviced infrastructure. For example:

[43] Akin, W. (2007); Lenovo website; Samsung (2007); SanDisk website; STEC (2008).
[44] Samsung website.
[45] Microsoft website – *Glossary of Networking Terms for Visio IT Professionals*.
[46] Hewlett-Packard Development Company (2007) *Global Citizenship*.
[47] Australian Computer Society (2007).

- Video conference systems enable face-to-face meetings without the associated travel.[48]
- Integrated IP telephones enable phone calls from computers over the Internet rather than through telephones over a phone network.[49]
- Distributed computing enables large and complex calculations to be decomposed and performed simultaneously by multiple computers in different geographical locations.

Internet communication technologies can reduce energy consumption by enabling new employment and operations models, such as teleworking,[50] that reduce demand for commuting and transport energy and can replace private automated branch exchange (PBAX) systems.[51] These models are better served by providing employees with mobile devices, such as notebook computers rather than desktop computers, which further reduces energy consumption.

Internet communication technologies can reduce energy consumption by enabling remote access to targeted or costly information services, such as processing power, storage and software. Remote access reduces the need for physically transporting input information and prevents the need for replicating the required service's infrastructure. Information services with large fixed overheads, such as data centres, usually consume less energy per unit service when they are centralised (rather than distributed) due to economies of scale and efficiencies of scale for some equipment, such as cooling system equipment.

Finally, Internet communication technologies can be innovatively applied to reduce energy and materials consumption of specific business tasks. For example, one shipping company[52] gives shippers full, on-line access to dynamic information records regarding their ships, staff, jobs and itineraries. The company sought an alternative to a traditional IT system, which was too complex and costly to manage given that it would be constantly moving. The solution was to use RSS in combination with some other commercial software to instantly inform shippers of itinerary changes so that delays could be more effectively managed. This solution has enabled the company to reduce fuel oil consumption by 8 percent (saving $395 million per year) and reduce lube oil consumption by 6 percent (saving $12 million per year).

Materials Consumption

Client equipment consumes a large amount of materials and introduces toxic substances into the biosphere. Worldwide, 20 to 50 million tons of waste electrical and electronic equipment (e-waste) are generated annually,[53] with this figure growing, especially for short-life IT equipment. In 2008, it is estimated that 302 million computers will be sold worldwide,[54] bringing the total number of computers in use to more than 1 billion after 27 years.[55] It is estimated that 2 billion computers will be in use by as soon as 2015, with 775 million of the new computers arising in Brazil, Russia, India and China.[56] The increasing e-waste resulting from the increasing computer sales is compounded by decreasing computer operating life. The operating life of a modern computer has decreased from 4-6 years in

[48] Hewlett-Packard Development Company (2007) *Global Citizenship*; Taylor, P.W. (2008), p. 21.
[49] Australian Computer Society (2007).
[50] Taylor, P.W. (2008), p. 20.
[51] Australian Computer Society (2007).
[52] Johnson, J.L. (2008) *Enterprise RSS Saves >$400M in Oil*; Johnson, J.L. (2008) *Managing a Floating System Via RSS*.
[53] Brigden, K. *et al* (2005), p. 3.
[54] IDC (2008).
[55] Forrester (2007).
[56] Forrester (2007).

1997 to 2 years in 2005.[57] E-waste is the fast growing component of municipal trash streams, growing three times faster than any other type of waste in the European Union.[58] E-waste also represents valuable materials being made unrecoverable in landfill.

Most electrical and electronic equipment (EEE) is toxic.[59] In fact, EEE can contain up to 1000 different toxic substances, many of which can be released into the industrial and natural environments at all stages of processing and operation,[60] and thus can result in an array of negative health impacts on humans and other organisms.[61] Furthermore, with the exception of some plastics, the recycling rate for almost all of these substances is zero,[62] so there is a good chance that they will contaminate soil and water bodies near landfills.

There are four main activities to reduce the materials consumption and toxicity of client equipment:[63]

1. *Reduce equipment mass and size*: reduces equipment materials consumption and transportation load.
2. *Use innovative and renewable or recycled materials*: facilitates end-of-life processing and enhances end-of-life materials value, thus enabling vendors to cost-effectively satisfy legislation such as the European Union's *Waste Electrical and Electronic Equipment* Directive,[64] which stipulates that, as of 31 December 2006, the recovery rate of waste appliances must be at least 70-80 percent by weight, depending on product type.
3. *Replace potentially harmful materials*: frees equipment of any substances that are suspected to be hazardous. Currently, these substances pose a threat to people and the environment at all stages of the product lifecycle.[65]
4. *Eliminate 'materials of concern'*: ensures that equipment complies with legislation such as the European Union's two Directives – *Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)*[66] and *Registration, Evaluation and Authorisation of Chemicals (REACH)*, which stipulate the banning of specific 'materials of concern'.[67]

These activities can be incorporated into client equipment in many ways:

- *All client equipment*:[68] According to the ISO 11469 standard,[69] moulded plastic parts of mass greater than 25g are to be marked with material codes to facilitate recycling. Post-consumer recycled plastic content in equipment should be measured as the percentage of plastic content that makes up the total plastic content.
- *Computers*:[70] Compared to desktop computers, notebook computers require about 80 percent less material mass and about a third of the packaging mass.

[57] Jayakody, C.S. (2004).
[58] Schmidt, C.W. (2002).
[59] Earth tones (2006).
[60] Brigden, K. *et al* (2005), p. 3.
[61] Brigden, K. *et al* (2005); Environment Victoria (2005) pp. 8-9.
[62] Environment Victoria (2005) pp. 8-9.
[63] Hewlett-Packard Development Company (2007) *Global Citizenship*.
[64] European Union (2003) 'Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE)'.
[65] Brigden, K. *et al* (2005), p. 3.
[66] European Union (2003) 'Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment'.
[67] European Union (2006).
[68] Hewlett-Packard Company (2008), p 4**.**
[69] International Organisation for Standardisation (2000).
[70] Hewlett-Packard Development Company (2007) *Global Citizenship*.

- *Monitors*: Compared to CRT monitors, LCD monitors require slightly more than half of the materials mass,[71] and require several times less desk space. In addition, CRT monitors use glass panels that contain 1-3 kg of lead[72] (a hazardous substance) whereas LCD monitors use lead-free plastic panels.
- *Combined machines*:[73] Machines that combine printer, fax, scanner and photocopier functions can reduce materials use by up to 40 percent compared to four separate machines.
- *Batteries and accumulators*: According to the European Union's *Directive on Batteries and Accumulators*,[74] batteries and accumulators cannot contain more that 0.0005 percent of mercury or 0.002 percent of cadmium by mass, with a few exceptions. The Directive also sets recycling targets and requires that recycling activities must at least remove fluids and acids.
- *Printers and printing supplies*: Printing supplies are the most heavily recycled items of client equipment. Take-back and recycling is facilitated by clearly labelling the retail packaging and the print cartridge as a product of the manufacturer or distributor.

  Printers and printing supplies are also a leading source of emissions in a client environment. Emissions of volatile organic compounds (VOC), other aldehydes and ketones, ozone and particulate matter need to be measured and reported in accordance with the ECMA-328 standard.[75]

  Printing supplies contain heavy metals that need to be controlled. The concentrations of heavy metals by weight in ink and toner need to be less than:[76]

  - Cadmium: 100ppm
  - Chromium VI: 1000ppm
  - Lead: 1000ppm
  - Mercury: 1000ppm
  - PBB's and PBDE's: 1000ppm

  Restrictions for other substances that may be in client equipment are given in European Union's Directive *76/769/EEC*,[77] its amendments[78] and adaptations.[79] Restrictions on some common substances in ink and toner include:

  - Azocolorants: concentration to release aromatic amines in concentrations below 30ppm
  - Short-chain chlorinated paraffins: maximum of 1 percent by mass

  The concentrations of hazardous substances by weight in printing supplies' plastic housing and external parts of mass greater than 25g need to be less than:[80]

  - Chlorine: 1000ppm

[71] Hewlett-Packard Development Company (2007) *Global Citizenship*.
[72] OECD (2003) cited in Brigden, K. *et al* (2005).
[73] Hewlett-Packard Development Company (2007) *Global Citizenship*.
[74] Europa website.
[75] ECMA International website – *Standard ECMA-328: Determination of Chemical Emission Rates from Electronic Equipment, 3rd edition*.
[76] Hewlett-Packard Company (2008), pp 5-6.
[77] Official Publications of the European Communities (2004).
[78] European Commission website – *Adopted Amendments to Directive 76/769/EEC*.
[79] European Commission website – *Adopted Adaptations of Directive 76/769/EEC*.
[80] Hewlett-Packard Company (2008), pp 5-6.

- Bromine: 1000ppm

Electrophotographic (EP) systems in printers also contain heavy metals that need to be controlled. Specifically, the concentrations of heavy metals by weight in photoconductor drums need to be less than:[81]

- Cadmium: 100ppm
- Selenium: 1000ppm

Eco-Labels

Many eco-labels have been developed to meet the increasing demand for information on the environmental characteristics of consumer products. Most of these eco-labels encompass IT equipment, including: Energy Star®[82] (worldwide), IEEE 1680 EPEAT™[83] (Electronic Product Environmental Assessment Tool) (worldwide), Blue Angel[84] (Germany), ECMA-370 IT Eco Declarations[85] (Sweden, Norway and Demark), TCO (Sweden), China Energy Conservation Program (CECP)[86] (China), China State Environmental Protection Administration (SEPA), Climate Savers Computing Initiative's (CSCI)[87] (worldwide), GREENGUARD™[88] (worldwide), Japan PC Green Label (Japan), KoEco (Korea)[89], Taiwan Green Mark (Taiwan), and Environment Choice New Zealand (New Zealand).[90] Information on about 30 eco-labels for electronics is available at EcoLabelling.[91] These eco-labels assist in identifying low-energy, low-materials and low-toxicity client equipment.

Step 4: Manage

Step 4 involves continuously managing and monitoring the client environment for opportunities to reduce energy and materials consumption, thereby potentially reducing costs. These opportunities may include:[92]

- Replacing inefficient client equipment with efficient client equipment when cost effective, and ensuring appropriate end-of-life processing of the replaced equipment. When assessing cost effectiveness, it is important to consider: energy costs; alternative uses for the replaced equipment; the impact on user productivity when running newer software; and technical staff costs, including salary, infrastructure and transport – a single technical staff member can manage about 130-160 new in-warranty computers (no costs for parts and labour) or as few as 50 old out-of-warranty computers.
- Recycling spent print cartridges and paper.
- Monitoring and reporting energy and material consumption.

[81] Hewlett-Packard Company (2008), pp 5-6.
[82] Energy Star website; Energy Star website – *Office Equipment*; Energy Star website – *Product Specifications: Eligibility Criteria & Partner Commitments*; Energy Star Australia website.
[83] EPEAT website; EPEAT – *The Criteria*.
[84] Blue Angel website.
[85] ECMA International website – *Standard ECMA-370: TED – The Eco Declaration, 2nd edition*.
[86] CECP website.
[87] Climate Savers Computing website.
[88] GreenGuard Environmental Institute website.
[89] KoEco website.
[90] Environment Choice New Zealand website.
[91] EcoLabelling website.
[92] Kong, P. (n.d.).

- Introducing or updating sustainable purchasing and procurement policies.
- Scheduling non-critical, high-energy activities out of peak periods.[93]

[93] Australian Computer Society (2007).

Optional Reading

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Key Words for Searching Online

Sustainable IT, client environment, IT energy consumption, IT energy efficiency, IT materials consumption, materials toxicity, energy audit, energy assessment, right-sized equipment, power management, eco-label.