Enhancing the Environmental Sustainability of ICT

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Introduction

A decade after the effects of global warming became a topic of discussion, environmental sustainability is still an issue that generates considerable controversy. While the arguments about climate change still rage, it is possible to identify several areas of common ground which can unite groups that might otherwise have opposing views on many green issues. In particular, factors such as corporate social responsibility, the need to conserve energy and an appreciation of the finite resources of the planet can help direct focus on the benefits of increasing environmental sustainability in ICT. Most importantly, environmental sustainability in ICT has a direct effect on an area that is a central consideration to organisations of all sizes: budgets.

The government has set targets for schools to increase environmental sustainability and this approach helps educational establishments enhance their green credentials and demonstrate increased corporate social responsibility. However, the main immediate improvements from adopting environmental sustainability are economic. In summary, green is thrifty.

The aim of this paper is to provide an overview of the general issues around environmentally sustainable ICT in the education sector. It also discusses some of the approaches and potential solutions that address environmental and energy cost concerns.

The background

The proposition of global warming is that man-made emissions of carbon dioxide from sources such as cars, aeroplanes and power stations are causing temperatures around the planet to increase. These increasing temperatures result in freak weather conditions, melting of the polar ice caps, and changes to behaviour in animals. Reports such as the Stern Review of the Economics of Climate Change (2006)[1] and the Garnaut Climate Change Review[2] highlight the economic impact of global warming. Information technology accounts for 2 per cent of global emissions of carbon dioxide, which is equivalent to the output of the aviation industry.

Opponents of the theory of global warming point to other possible causes of rising temperatures, such as solar activity, carbon dioxide from volcanoes, or the natural cycle of climate change on the planet. Whatever side people take on this issue, there is one overarching factor that unites them: the requirement of organisations of all sizes to conserve financial resources by saving money wherever possible. The recent increase in the price of oil up to $140 a barrel reminded people that energy costs can be considerable and are likely to increase as oil production inevitably

[1] http://www.hm-treasury.gov.uk/sternreview_index.htm
[2] http://www.garnautreview.org.au/index.htm

starts to fall. The current recession simply elevates the importance of financial prudence and energy conservation. Thankfully, promoting a green ICT agenda can avoid controversy by concentrating on the issue of reducing costs.
ICT is now a central part of educational strategy and practice. Even primary schools have networked classrooms, virtual libraries, and interactive whiteboards. Government policies that promote ICT as an aid to teaching have been extremely successful, with the number of PCs in schools increasing by about 65 per cent over the last five years to an installed base of 1.8 million units. However, this ever-increasing use of ICT resources has led to greater energy consumption, higher running costs, and increased production of carbon dioxide. A study by Jonathan Koomey in 2007 showed that electricity use for servers doubled from 2000 to 2005 and is set to increase by another 40 to 76 per cent from 2005. For more information, see 'Estimating Total Power Consumption by Servers in the U.S. and the World' [http://enterprise.amd.com/Downloads/svrpwrusecompletefinal.pdf].

Environmental sustainability is also becoming a central part of educational strategy and practice. But the considerations for what constitutes environmentally sustainable ICT is not simply devoted to the issue of the energy a computer consumes when it is switched on. There are other factors that come into play, such as the energy cost of manufacture and replacement of components. Lifetime energy consumption is an important consideration, albeit often one that is difficult to quantify, and is only one area that environmentally sustainable ICT considers. But what is the definition of environmentally sustainable ICT and why is it important? Both issues are considered in the next section.

What is environmentally sustainable ICT?

There are several definitions of the meaning of 'environmentally sustainable ICT'. This article takes the position that an environmentally sustainable ICT policy is one that minimises the total energy consumption over the lifetime of a piece of ICT equipment and maximises the useful computing work obtained from the energy the equipment consumes while operating.

Although this article focuses on environmental sustainability, it may also touch on issues that come under the banner of financial sustainability. It is important to understand that an environmentally sustainable ICT policy is not simply 'greenwash', as evidenced by companies making spurious claims to be protecting the environment. In contrast, an effective environmental ICT policy benefits everyone.

Creating an environmentally sustainable ICT policy requires educational establishments to look at several related areas that relate to ICT equipment. The obvious areas that most organisations consider include:

- purchasing costs
- delivery costs
- electrical costs (which include user lighting, cooling and wiring infrastructure)
- cost of any consumables.

Becta publishes advice on suitable polices on its web page 'Creating a strategy to reduce your school's carbon footprint' [http://schools.becta.org.uk/index.php?section=re&&catcode=ss_res_env_02&rid=16058].

However, there are other costs that organisations are beginning to identify, either as directly affecting the cost of running ICT equipment or as having a bearing on the overall energy usage of a device. These additional costs include:

- disposal costs
- replacement versus repair costs
- manufacturing and packaging costs
- environmental costs
- support costs (such as travel for technical staff).

Managing disposal costs

Legislation such as the EU Waste Electrical and Electronic Equipment (WEEE) Directive, places the responsibility for disposal of waste electronic equipment on manufacturers. However, manufacturers simply build the costs of disposal into the sale price of the item, so the end-user pays anyway. Schools have specific WEEE responsibilities only if the original equipment was bought prior to 13 August 2005 or if they are not replacing old equipment with new.

Note: When buying new electrical and electronic equipment, it is important to establish that the vendor is responsible for disposal when the time comes. Schools and colleges can sort and dispose of their own electrical and electronic waste but this is an expensive business and usually not financially viable.

Although there are no estimates for the total amounts of WEEE produced by the education sector, simple observation will note that even small establishments can generate several tonnes of electronic waste annually. A study by the Joint Information Services Committee (JISC) on Sustainable ICT in Further and Higher Education identified that a medium sized higher education college disposed of 70 tonnes in a year.

Yet many of these items can be recycled, either through reuse charities or by stripping them down into component parts. An effective environmental ICT policy should aim to achieve approaching 100 per cent reuse or recycling for 'end of life' equipment.

An environmentally sustainable ICT policy requires a holistic approach to reducing energy consumption, and therefore ICT operating costs, by considering all aspects of how ICT facilities use and abuse energy. But, as with all policies, it makes sense to target the areas that provide the biggest return for the effort expended. For most organisations, this benefit 'sweet spot' will be how much energy equipment uses in its day-to-day operations. Alternatively, organisations may identify one or more 'quick wins' that can show a rapid return and justify further strategy development.

Quantifying, measuring and owning benefits

A key issue to appreciate is that the benefits of an environmental ICT policy must:

- be quantifiable
- have an owner.

To achieve an effective environmental ICT policy, organisations will need to be able to quantify or measure the benefits gained.

Effective monitoring is vital for this measurement process, and should include creating baselines of energy usage and monitoring change over extended periods.

Measuring and monitoring justify the effects of actions for sustainability; many organisations fail to measure how well their environmental sustainability plan works and therefore cannot justify the effect of the plan.

Crucially, someone in the organisation must be made the owner of the benefits that this policy brings, otherwise the policy will not be implemented properly, managed effectively over the long term, or promoted to justify the effect of taking these sustainable actions. Because environmental sustainability is a journey, not a destination, organisations must ensure that they assign ownership of the benefits that the environmental ICT policy brings to an individual or group, thereby promoting long-term support and continued development of the policy.

Why is environmentally sustainable ICT necessary?

Educational establishments at all levels increasingly use ICT as an aid to teaching. Government targets include specific references to ICT, local authority plans constantly refer to increased investment in technology, and schools like to demonstrate that they have not been left behind in the race to introduce computers into every facet of the curriculum.

These trends have inevitably led to greater power demand and increasing use of material resources. When compared to a 300W digital projector and the PC that drives it, a blackboard and a piece of chalk is a model of environmental sustainability. Yet digital projectors and interactive whiteboards bring many benefits, enabling teachers to motivate their classes in previously unimagined ways. However, enhancing the curriculum with modern technology does not come for free. By implementing an effective ICT strategy, organisations can help minimise costs, benefit both students and teachers and help protect precious environmental resources. For further discussion on the importance of environmentally sustainable ICT, see 'Why you should reduce your school's carbon footprint' [http://schools.becta.org.uk/index.php?section=re&&catcode=ss_res_env_02&rid=16057].

The considerations of energy efficiency, costs and changes to environmental legislation such as the UK Carbon Reduction Commitment [http://www.defra.gov.uk/environment/climatechange/uk/business/crc/pdf/crc-policy-080716rev.pdf] and specific government commitments for schools are starting to affect procurement programmes for new equipment. The challenge here is that a truly sustainable ICT programme requires organisations to take into account not only the running costs but the total environmental cost of ICT equipment. More concisely, simply replacing equipment with more energy-efficient equipment may not necessarily be the answer.

Building new computer equipment incurs an energy and resource usage cost, as does disposal of old equipment (particularly where that equipment contains hazardous wastes such as selenium, arsenic, lead and mercury). In many cases, computer equipment is retired not because it is no longer of any use but because it has been replaced by more up-to-date servers or devices.

Newer computers or devices can be more efficient, using less power to deliver greater computing capacity. However, it is important to factor in the lifecycle cost and the inherent energy consumption of manufacture. Simply by delaying replacement for as little as six months, organisations can significantly reduce the energy cost that is inherent in replacing older equipment.

Educational establishments may also be failing to see where replaced equipment can be used to provide other services, extending the lifetime of that equipment and reducing the need to purchase new and dispose of the old. Other approaches include using operating systems that require less powerful hardware.

Organisations should review their equipment disposal strategies to ensure that the 'rip-and-replace' culture is not creating unacceptable environmental costs. With imagination, old equipment can still contribute to an organisation's ICT infrastructure, reducing computer waste and prolonging equipment lifetimes. And if it is not needed any more, life-expired equipment can be donated to charitable organisations that will put it to good use.

The carbon footprint

The educational sector is responsible for 15 per cent of all carbon produced by the UK public sector. To attempt to reduce this figure, the UK Government sustainable schools strategy sets a target is for all new schools to be carbon neutral by 2016. Becta provides guidance in 'Practical tips for reducing your school's ICT carbon footprint' [http://schools.becta.org.uk/index.php?section=re&&catcode=ss_res_env_02&rid=16059].

Additionally, all schools should be sustainable schools by 2020. An environmentally sustainable ICT strategy is an essential tool towards reaching this goal. The Energy Efficiency Partnership provides guidance for secondary schools on tackling climate change [http://www.eeph.org.uk/partnership/index.cfm?mode=view&category_id=39]. For more information, see Environmental Sustainability on the Becta site [http://schools.becta.org.uk/index.php?section=re&catcode=ss_res_env_02&rid=14635] and the ICT carbon footprint comparison tool [http://schools.becta.org.uk/index.php?section=re&&catcode=ss_res_env_02&rid=16075].

Also see the Sustainable Schools page on Teachernet [http://www.teachernet.gov.uk/sustainableschools].

For general information about school design, see Classrooms for the Future [http://www.teachernet.gov.uk/management/resourcesfinanceandbuilding/schoolbuildings/innovativedesign/sbschoolsforthefuture/futureclassrooms].

What are the benefits of environmentally sustainable ICT policies?

To be effective, environmentally sustainable ICT policies must be able to deliver measurable benefits such as:

- reducing overall ICT costs
- minimising waste
- conserving electrical power
- conserving natural resources
- improving reuse of equipment
- increasing equipment lifetimes
- reducing upgrade costs
- reducing support costs
- reducing travel costs.

The following organisations are already reaping the benefits of environmentally sustainable ICT policies:

- The University of Liverpool has implemented policy-based power-down of PCs when not in use.
- The University of Sheffield has installed low-energy managed servers.
- The City of Bristol College and Sheffield Hallam University use virtual servers.
- Cardiff University has applied innovative approaches to data centre cooling and power supplies.

For more information, see *Sustainable ICT in Further and Higher Education*, by JISC [http://www.susteit.org.uk/uploads/DOCS/42-SustainableICTreport_final.pdf].

Using technology to save resources

One way that ICT can make a major contribution to an organisation's overall environmentally sustainable practice is by reducing the requirement to travel. For example, all schools have broadband links to the internet and so can connect to other schools. Adding a professional webcam (which provides better quality output than a consumer model) to a PC provides the basis of a simple, low-cost video-conferencing facility. Teachers can then use the National Education Network facility to link up their classrooms with another school, to meet with their peers, or to attend a conference as part of their continuing professional development.

The National Education Network is a dedicated network that provides better quality connections and higher quality video links through the JANET video conferencing service (JVCS), as well as effective technical support.

Virtual meetings
Educational establishments can use the JVCS instead of travelling to physical meetings. This service is entirely free to use by schools. For example, consider a school in a rural area, such as Alston in Cumbria. To attend an educational meeting at the nearest large town, Penrith, staff from Alston would have to make a 40-mile round trip, including traversing Hartside Pass at an altitude of 1903 feet, which is also hazardous in winter conditions.
Assuming four staff members attend the meeting and share a car, then the additional costs for physically attending the meeting could be as follows:
Travelling time (1 hour 15 mins @ £10 per hour x 4) – £50.00
Travel expenses such as fuel, depreciation etc. (40 miles at 35p per mile) – £14.00
Total cost for physical attendance – £64.00
If that meeting occurs every month, the school is not only effectively paying £768 a year for travel but also paying the teachers' salary while travelling, wasting five person-hours for each meeting.
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If the school has suitable camera equipment to allow the teachers to attend the meeting by video conferencing, both these expenses disappear completely. In this case, both schools would be registered with JVCS but if necessary, guest sites can also be brought into links.
For more information about JVCS, see JANET [http://www.ja.net/services/video/jvcs/].

Remote working is another area where ICT can make a measurable difference to an organisation's environmental footprint. Although schools and teachers in the UK are unlikely to use the dedicated distance learning model that some Australian establishments have implemented, areas such as language teaching and virtual visits to museums and galleries can all benefit from the application of ICT. There are also teaching functions that a teacher, specialist tutor or practitioner with a broadband connection can provide from home or some other location such as a museum or art gallery. This approach can significantly reduce unnecessary travel. Examples include:

- one to one/one to many tutoring with conferencing software
- video conferencing for language teaching and practice

- remote support/communication (for example, for 14–19 diplomas where the learner is outside the home institution)
- marking of work submitted electronically through a document check-in portal, rather than on paper.

Administrative staff can also benefit from remote working opportunities. For example, finance officers typically do not need to be in the office every day. As long as they are contactable by telephone, have access to email, and can use their PCs safely and effectively, then this job can be mostly conducted from home. Add in an instant messenger account, and distance becomes almost immaterial.

Permanent internet connections enable technical support staff to connect to, fix and even reboot servers from a single central location. With suitable hardware to reset power supplies, up to 98 per cent of support incidents can be fixed remotely. This could reduce travelling for LA or commercial technical staff, for example.

Parents and students can also benefit from internet connectivity with the school, enabling access to school work and information on attendance and progress. This can reduce paper-based communications and trips to the school where appropriate. For more information, see 'Introduction to online reporting' [http://schools.becta.org.uk/index.php?section=oe&catcode=ss_es_fam_onrep_03&rid=14571].

Barriers to the adoption of such working environments typically include 'presenteeism' and issues of trust by employers or managers. Repeated studies by organisations such as BT show that working from home raises productivity and increases job satisfaction. Although not all employees can cope with a 100 per cent home working environment, those that have the right aptitude and attitude can benefit significantly from one or two days a week working from home. Not surprisingly, if those individuals benefit from this arrangement, then the organisation also benefits.

Implementing an environmentally sustainable ICT policy also provides proof that an organisation has a responsible and unselfish attitude towards the world's finite resources. This attitude helps display each educational organisation in a more positive light, creates good publicity, improves relationships both locally and nationally, and minimises costs. This symbiotic relationship between environmentally sustainable ICT policies and reduced operating costs should be a key driver that all establishments should consider.

Reducing energy consumption in ICT equipment

Power usage is a key factor in identifying the environmental impact of a particular ICT asset. It is important to understand how computer equipment generates heat and what approaches can help minimise this energy requirement.

Note: There are other indicators of environmental friendliness including for example, the level of water consumption. However, for the purposes of this paper, energy use is the primary area of discussion.

Identifying power usage

Even quite small changes can make a big difference is the area of heat generation. In semiconductors, such as the chunks of etched silicon that make up the very large-scale integration (VLSI) semiconductor assemblies in computer central processing units (CPUs) and graphics processing units (GPUs), there can be extremely high levels of current flow (measured in amps per square metre), even though the voltage can be relatively low (as low as 1.8 volts). This current flow through a poor conductor results in considerable heat generation.

With most conducting materials, there is a self-limiting mechanism in that resistance increases at higher temperatures, which reduces the current and thus heat production. However, higher temperatures in semiconductors causes electrical resistance to decrease, leading to greater current, which generates even more heat. *In extremis*, a condition called thermal runaway can occur. Hence, temperature control is extremely important with semiconductor components.

To achieve the recent advances in computing power, manufacturers have had to increase the number of transistors per unit volume in each semiconductor component. These components run at higher and higher clock speeds or, with CPUs, can consist of two or even four cores. In summary, modern, faster CPUs and GPUs tend to create more heat and use more power.

More than just PCs
Considerations of energy efficiency should not be confined to PCs but should incorporate all computing devices, including printers, network switches and routers. For example, the Nintendo Wii game console is a smaller, lower power, quieter, cheaper unit than the competing Xbox360 and PS3 devices. For more information, see the Yahoo Green blog [http://green.yahoo.com/blog/the_conscious_consumer/21/stop-wasting-money-video-games-and-energy-efficiency.html] and this Hard Core Ware review [http://www.hardcoreware.net/reviews/review-356-4.htm].

Faster CPUs thus need more cooling, which passive convection may not be able to provide. When passive convection is not adequate, fans (or even liquid cooling mechanisms) are required to ensure that the component stays within operating temperature and does not experience thermal runaway. So faster chips need active cooling, which in turn requires more power, thus generating even more heat.
Heat production can also affect electro-mechanical components, such as hard disks. The bulk of electronic data is now stored on these devices, which consist of aluminium platters coated with magnetic material that spin at up to 15,000 revolutions per minute. Above these platters, tiny heads attached to rigid arms 'fly' above the magnetic surface.

IBM was the first manufacturer to pioneer a hard disk where the distance between the head and the surface was so small that light could not pass between the two. Not surprisingly, these devices can be affected by heat and, when running at thousands of revolutions per minute, also generate considerable heat. Higher operating temperatures increase the probability of hard disk failure and very high temperatures can cause the platter coating to lose its magnetic orientation.

Controlling the heat that hard disks create includes running the disks at a reduced speed during periods when data is not being accessed and using caching technologies that reduce the frequency of data access requests to the hard disks. Alternatively, electro-mechanical hard disks can be replaced with solid state disks (SSDs), although current models of SSDs have reduced storage capacity compared to conventional hard disks.

Heat generation and removal is a primary factor when designing large-scale computer facilities, from dedicated server rooms to the vast data centres that drive global computer services such as Google, Microsoft Hotmail, or the myriad of computers that serve web pages, run e-commerce sites, or host online databases. These services come with a power cost, as was highlighted by some recent news articles, which indicate that a fully loaded rack system may consume as much power as an oven cooking five turkeys. For further information, see 'IT Going Green' [http://www.ft.com/cms/s/0/e12e64a4-4a45-11dd-891a-000077b07658.html?nclick_check=1].

Yet reducing cooling requirements has huge knock-on effects on the costs of providing computer facilities. The more natural cooling is used, the less electricity is required just to remove heat.

Although most educational establishments that run their own ICT infrastructure internally are unlikely to experience such a problem, large data centres have run into limits on their expansion because there is not enough utility power being supplied to the facility to drive all the computers and associated cooling systems. At a smaller level, a rural school with an ambitious ICT programme could find that it has to upgrade from single phase to three-phase supply in order to supply power to the equipment. With better control of cooling costs, this upgrade might not be necessary.

Calculating power usage

A key metric for identifying power usage within an organisation is Power Usage Effectiveness (PUE). Although this metric is more commonly used in large data centres to identify the proportion of energy that a data centre uses to generate computer services, a modified version of this metric is useful to identify the energy efficiency of an organisation and identify any improvements. PUE is defined as follows:

$$PUE = \frac{\text{Total Utility Load}}{\text{Total IT Equipment Power}}$$

The closer this value is to 1.00, the better. For example, Google's data centres claim a PUE figure of 1.21. There are some experimental data centres that have reached the figure of 1.00, but these data centres are situated in tents, horse trailers, and other unconventional locations.

If an organisation consumes 1MW and uses 200KW to drive the computing facilities, then that organisation has a PUE of 5.0. For a data centre, it would be financial suicide.

But of that 200KW, how much actually directly generates computer operations and how much is wasted? When assessing power usage, it is necessary to consider the following components that do not contribute directly to computer operations:

- Processor fans
- Graphic card fans
- Case fans
- Server room cooling.

Those four components can easily add a 25 per cent power overhead, simply from removing the heat that the computer operations generate.

Calculating power wastage

Power usage within an organisation is relatively easily identifiable, since the electricity supply company has a considerable vested interest in ensuring that any power used is paid for. Assuming the electricity company is billing for power usage correctly (it often pays to use supply monitoring to check), how much power is wasted to deliver that 1MW to the school in the first place?

The maximum efficiency of a coal-fired power station is in the region of 30 per cent, with most of the energy going up the chimney. Further losses take place as the pressure of the steam is converted into rotational energy of the turbine shaft. The generator then converts that energy into electricity at a further efficiency cost, before transformers convert the lower voltage output to a higher voltage for transmission to the consumer. Although transformers are incredibly efficient by mechanical standards, even 98 per cent efficiency still incurs a 2 per cent power loss at each transformer.

Losses from overhead pylons, more transformers (in some cases, requiring transformation from 440kV to 132kV to 256Kv to 11,000V to 240V domestic supply) all add to the wastage of power before the electricity enters the computer. There are opportunities to reduce this wastage by placing servers closer to the source of power, for example, in a managed data centre near to a power generation facility. Alternatively, power could be generated on-site and consumed locally, for example, by using micro-hydroelectric or wind power installations. *Homepower Magazine* gives a good summary of the factors in micro-hydroelectric power generation [http://www.homepower.com/basics/hydro/].

To supply that 1MW of power to the educational establishment, the power generation company must therefore generate 3.33MW at the power station. Coal produces approximately 24,000 megajoules or 6.67 MWh per tonne. To generate 3.33MW, the power station must consume half a tonne of coal an hour, which in turn emits around 450Kg of CO_2. Yet if the school can reduce its consumption by only 10 per cent, the budget, the environment and the community all benefit. Reduced consumption also minimises the requirement to increase the infrastructure that delivers the energy.

Reducing cooling and power usage

Most modern computers now implement some form of active cooling, with some models having five or six fans to expel air from the chassis, cool the power supply or remove heat from the CPU or GPU. Although intelligent fan management, which is typically part of the computer's Basic Input Output Settings (BIOS) can reduce (or even switch off) fans when they are not needed, not all systems implement such controls. Servers are the worst offenders for fan usage, with the noise of a fully-loaded rack making conversation difficult in the vicinity.

Mechanisms for reducing heat generation and hence cooling costs include:

- increasing natural airflow paths
- reducing the operating voltage and clock frequency of CPUs
- selecting lower powered processors
- running components at higher ambient temperatures.

Passive cooling removes the requirement to run a fan completely. However, there must still be enough airflow around the equipment to ensure the passive system works. Server rooms typically have alternating hot and cold aisles, with chilled air pushed into the cold aisles, sucked through into the hot aisles, then extracted and exhausted. In most current data centres, this airflow requires considerable air conditioning and heat extraction to maintain operating temperatures.

Blade computing (where servers consist of multiple vertically mounted motherboards that function as independent computers but share common power rails and sometimes disk storage) is a technological advance that exacerbates the cooling issue. Blade servers enable a 4U 'server' to hold not two or four CPUs with associated memory, north bridges, south bridges and GPUs but sixteen boards, each with dual processors, memory and so on. Blade servers multiply the amount of computing power in a fixed volume but at the expense of greatly increased cooling requirements.

Some technologies do help reduce heat output. For example, flash memory can cache reads and writes to data on a hard disk, thus reducing the number of disk accesses and even enabling the motor that powers the platters to 'spin down' for significant periods. NAND flash memory can also reduce boot times and enable administrators to put servers into low-power states during non-operational hours. By comparison, a hard drive typically has an internal cache of 16MB, whereas a NAND flash memory would be 4GB or more in capacity.

Specifying equipment

The need to increase power efficiency requires organisations to take a more proactive and informed view on the components that go into their computers. For example, server graphics cards do not need large amounts of memory, high clock speeds or fans, because servers should not display graphically intensive output. In consequence, larger passive heat sinks can replace smaller fan-based models. Emerging technologies, such as lower power consumption displays and components, energy-efficient processors, and low-voltage memory chips can also help to reduce overall power consumption.

Specifying the right equipment for the expected service level helps organisations to control purchase costs, minimise power usage and extend equipment lifetimes. Although some network services can make more intensive use of computer power (for example, when searching data), it is important to balance the service level expectations with a realistic assessment of the equipment necessary to deliver that service. Remember that only a small reduction in performance and power consumption can generate large power savings over the expected lifetime of the equipment.

The fact is that very few computer users carry out truly computer intensive tasks (such as 3D rendering or heavy number-crunching) that benefit from high-specification computers. As long as the computer responds faster than the user then the machine has acceptable performance.

Higher specification computers typically take more energy to produce and to operate, so organisations should take special care to ensure that they do not over-specify their computer hardware. Temperate climates, such as that in the UK, open up opportunities for the use of passive cooling. For example, the Microsoft data centre in Ireland is almost entirely passively cooled.

The increased interest in power reduction has resulted in CPU and motherboard manufacturers creating new processor designs that significantly reduce the waste heat that they generate. Examples of these processor designs include the Intel Atom, the VIA Nano and the significantly reduced Thermal Design Power (TDP) ratings in the Intel Centrino Core 2 Duo and AMD Opteron designs. Future laptop designs may use Advanced RISC Machine (ARM) processors and open-source operating systems for even lower power consumption. Using low-power components and processors, it is now possible to build servers that use only 20W in normal operation yet deliver enough performance to run a primary school network.

Examples of new, energy-efficient server designs include Microslice servers. These servers have high energy efficiency components and are available at under £350 a node [http://www.rackable.com/products/microslice.aspx?nid=servers_5]. New workstation designs such as energy efficient all-in-one PCs claim to reduce power consumption by up to two thirds.

Netbooks can also provide a useful approach for fulfilling environmental goals. These devices are cut-down laptops that often use a custom Linux distribution as the operating system, with the remaining computing power provided by online applications, such as Google Gmail and Google Docs. Netbooks typically use low-power processors similar to the Intel Atom and consume around a quarter of the power of a high-spec laptop.

Implementing alternative architectures

Another approach is to remove PCs altogether and replace them with thin clients. As well as not running local hard disks and using much less power than a full-specification PC, thin clients have additional security benefits. For an example of the claimed energy savings from thin clients, see Netvoyager [http://www.netvoyager.co.uk/general/energysave.html]. However, against this advantage, educational establishments would have to balance the greater server processing requirements with thin clients.

Cloud computing is another approach that may provide options to reduce environmental impact. Cloud computing uses multiple, scalable, virtualised computers to deliver services to remote clients.

Software as a Service (SaaS), Google Apps, and Amazon Web services are all examples of cloud computing. With cloud services, many organisations share the common facilities which should lead to efficiencies on energy usage. However, a key factor to consider with this form of outsourced model would be the PUE rating of the service provider.

Ensuring cost effectiveness

Notwithstanding the above, there are cases when spending more money to implement higher specification equipment is more cost-effective and does not contradict an environmentally sustainable ICT agenda. For example, the labour costs for installing CAT6 cable are the same as for CAT5, but CAT6 provides gigabit transfer speeds that modern workstation and server network cards could use for additional services on the network, such as on-demand video streaming from a central media server. If a building is only specified with CAT5 cabling, then that organisation cannot subsequently benefit from greater data transfer rates without upgrading the cabling again.

Replacing some ICT equipment types can make more sense if the replacement can be justified. For example, laptops are nearly as powerful as desktop computers yet use significantly less energy. A program to replace life-expired desktops with laptops can result in drops in power usage in the region of 40 per cent.

Modular replacement also reduces the environmental impact of upgrades. For example, a modern 24” 1920x1200 flat-screen monitor provides adequate screen space and performance for most users and has an expected lifetime of several years. Although the initial purchase price of these monitors may be slightly higher (from £143+VAT each), they would not need to be upgraded each time the computer base unit is replaced.

Identifying industry initiatives

Industry initiatives, such as the EU Energy Star programme [http://www.eu-energystar.org], and EU and UK government requirements have resulted in modern power supplies being significantly more efficient than older versions. Some newer workstation designs have integrated screen and base units that share one power supply. Although it rarely makes economic sense to replace correctly functioning power supplies, replacement power supplies should be checked to ensure they comply with the latest energy-saving standards.

Whilst many consumer electrical items such as fridges and washing machines have energy efficiency ratings, there is currently no standardised mechanism or ratings system for comparing items such as network cards or hard disks. Only careful scrutiny and comparison of current ratings or power consumption gives any indication of the relative power-saving performance of electronic components and devices. Programmes such as Energy Star only rate the base device and do not look at components that are not considered part of the base device, such as wireless cards or monitors.

Thankfully, power efficiency does seem to be creeping up the agenda of most manufacturers and this change will accelerate if consumers demand it. Processors (particularly mobile variants) are getting more efficient and there are energy efficiency improvements in motherboards, chipsets, and from replacing hard disks with SSDs. For example, if all educational establishments across the country started to insist that laptops consumed no more than 75W, then manufacturers would start to use this statistic as a key selling point, rather than sheer processing power.
To be truly effective, any power measurement statistics for electronic equipment should come from a respected and independent third party and should readily identify the processing power per watt that the device provides. A simple banding system similar to that used on domestic electrical devices would enable purchasers to make rapid and informed decisions based on power efficiency.

Identifying trade-offs

When purchasing computers, it is important for organisations to obtain equipment that is fit for purpose. However, purchasing computers according to an environmental ICT strategy will inevitably entail compromises. These compromises include the following factors:

- Performance against energy usage
- Cost of replacement against the cost of disposal
- Inability to quantify improvements
- Effect of unintended consequences.

The law of unintended consequences applies to environmental ICT as much as any other activity. For example, putting computers into a standby state after inactivity may result in them not being closed down properly at night. In this case, there should also be a policy that places the computer into hibernate state (where it is completely powered off) after a further period with no use. This policy could be combined with Wake-on-LAN technologies so that hibernating PCs can be restarted for administrative reasons, such as for back-up purposes, to install patches, or to update applications.

A key factor to appreciate when identifying trade-offs is to appreciate that everyone uses computers and electronic devices differently. Hence, for every person who simply can't work without a three-screen workstation, there will be another who only wants a portable netbook-type device they can take with them everywhere. Educational establishments can significantly reduce the carbon generated by their ICT equipment by adopting new behavioural practices as outlined by the Carbon Saving Trust [http:/www.carbontrust.co.uk]. Providing the right help and guidance for each user is an essential part of an environmental ICT strategy, as is making individuals aware of the consequences (both in terms of cost and environmental impact) of their choices and behaviour.

One potential positive outcome from the current economic recession is that users may be more inclined to accept lower-performance replacements or even to allow greater extension of the lifetime of their current equipment. By making users proud of their energy-saving credentials, organisations can also reduce costs in a fiscally challenging environment and occupy the moral high ground of good social responsibility.

Implementing virtualisation

Virtualisation technologies can provide useful approaches for implementing environmental ICT policies. In simple terms, a virtual computer is a complete computer environment (a guest) that runs on another computer (a host).

Understanding virtualisation

The host computer is a physical machine with one or more processors, memory, hard disks and network cards. This host computer runs an operating system or hypervisor that supports the virtualisation environment. There are several virtualisation environments available from suppliers such as Microsoft, VMWare, Citrix amongst others.

Some of these virtualisation environments are applications that run on top of the operating system, some are services, some are additional components to the operating system, and some replace the operating system entirely. Windows Hyper-V and VMWare GSX Server are examples of hypervisor-based virtualisation environments and this architecture is the most suitable for virtualising operational servers that provide network computing services.

The guest virtual computer is a self-contained environment which includes a BIOS, an operating system, and applications that can carry out computer operations, just like a physical computer. However, the guest computer boots up and runs entirely within the operating system of the host. Typically, the guest computer appears within a window on the host desktop.

Identifying resource usage in virtual environments

Virtualisation enables more than one virtual computer to run on a physical host. The guest operating system and applications make system calls to hardware resources as usual; however, it is the virtualisation environment that responds to these resource requests and routes those requests to the relevant physical resources. Because computers rarely make continual access requests to resources such as the CPU, hard disk, or network card, sharing these resources between several virtual computers makes sense and reduces power consumption significantly. It is then possible to network these virtual computers together to create multi-tier applications. For example, an administrator can either allow or prevent access to a virtual computer from the external network.

Virtual computers require considerable amounts of physical memory, as all the operating system components of the virtual computer must be loaded into the host computer's memory. However, virtual computers also provide considerable flexibility, such as enabling migration of older versions of operating systems onto newer hardware or allowing proprietary and open-source operating systems to run together on the same host computer. Some virtual environments provide a wizard-based interface that enables administrators to migrate an entire physical computer to an identical virtual computer image.

The important role for virtualisation within an environmental IT strategy is that this technique can significantly reduce power usage through the process of consolidation. For example, one well-specified host server can run four or five virtualised servers. If those virtual computers were on individual physical computers, the power usage would be in the region of three or four times as much as the single host computer.

Further independent advice on energy saving in server rooms is available from the BCS Data Centre Specialist Group [http://dcsg.bcs.org/] or from SusteIT [http://www.susteit.org.uk].

Jevon's paradox
Although virtualisation can reduce power requirements, it is important to understand a little-known side-effect. Virtualisation makes it easy to deploy additional servers to provide more computer services, as there is no requirement to purchase additional hardware. Jevon's paradox postulates that the ease of implementation of virtualised systems can result in increased power consumption from the additional services. For more information on Jevon's paradox, see http://www.eoearth.org/article/Jevons_paradox.

Virtual computers may not be suitable with certain types of hardware device (for example, printer port dongles). Also, applications and services that make unusual demands on hardware, such as very heavy processor usage or continual hard disk accesses, may also not be suitable for virtualisation.

Using hosted environments

Virtualisation can be used as part of a hosted environment, where the educational establishment has a contract with a service provider. In a hosted environment, the service provider hosts and manages the establishment's IT services at a remote central location, such as a data centre.

Using a hosted environment with a low PUE rating can deliver environmental benefits by ensuring that computer resources are shared by multiple customers. Some data centres also charge customers by resource usage, which rewards the careful use of computing power. Hosting organisations that use virtualisation can ensure that host computers are fully utilised before switching on more hardware. They can also rapidly migrate operating virtual computer images from one host to another with minimal downtime.

Hosted services can be used in conjunction with other technologies, such as thin client computers with no local hard disks, or Wake-on-LAN workstations that put the computer into a low power state until wakened by a packet on the network that is directed to that computer.

Identifying initiatives

Many manufacturers are starting to realign their product strategies to reflect a green agenda. It is certainly worth asking hardware and software vendors to identify any features that enable power saving, as these repeated requests will eventually encourage manufacturers to respond to these requests.

Industry energy saving initiatives include Climate Savers [http://www.climatesaverscomputing.org/] which brings together Google, Intel, Microsoft, HP, Dell, IBM, Lenovo, and other companies into a commitment to save $5.5Bn in energy costs and reduce greenhouse gas emissions by 54 million tons a year. The US Energy Star programme includes several enterprise server and data centre energy efficiency initiatives [http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency].

The Carbon Trust is the primary source of information for educational establishments on how to reduce carbon emissions and improve energy efficiency. For more information, see the Carbon Trust site [http://www.carbontrust.co.uk].

The UK Energy Saving Trust also publishes information and studies on a range of topics, including energy-saving recommended products. For more information, see the About Energy Saving Recommended Products [http://www.energysavingtrust.org.uk/Energy-saving-products/About-Energy-Saving-Recommended-products]. OGC Buying Solutions also provide information on sustainable procurement programmes for the public sector. For more information, see Sustainable Solutions [http://online.ogcbuyingsolutions.gov.uk/bcm/sustainablesolutions/].

Monitoring energy usage

Ultimately, any environmental strategy is not going to be effective unless the benefits can be monitored. Monitoring is a complex subject and could easily be the subject of a complete paper, so the following section only summarises the main points.

Monitoring can be carried out at several levels. The most obvious one is the electricity supply into the establishment. The electricity meter provides information on historic and current consumption, but the information is not easily understood. Total energy meters enable organisations to identify which devices are consuming large amounts of power and to measure the effect of turning off items on standby and unplugging transformers. For more information, see the Wireless Home Energy Meters page [http://www.ethicalsuperstore.com/category/electronics-and-appliances/home-energy-meters/].

It is also possible to monitor individual items and to display this information in graphical form. Monitoring data centres can involve more sophisticated technologies, such as specialised in-line rack meters and manageable power distribution units.

In the future, computers will include more facilities for monitoring power usage. Currently, system BIOS settings can monitor and control fan speeds and processor voltages. Add-on software can provide automatic powering down of client computers. Within two to three years, it should be possible to monitor remotely a server's power consumption and efficiency levels entirely in software.

Implementing an environmentally sustainable ICT strategy

Implementing an environmentally sustainable ICT strategy requires organisations to increase the focus on actions that further these goals within their overall ICT strategy. Although not all organisations will be able to implement the following guidelines, this list provides several examples of realistic changes that educational establishments of all sizes can make to reduce energy costs and promote sustainable and responsible use of ICT.

Procurement

- Consider the lifetime energy cost of ICT equipment.
- Request energy usage information from manufacturers and use that information to guide purchasing decisions.
- Specify energy efficiency rather than high performance when choosing server processors.
- Specify low-power CPUs and high-efficiency power supplies.
- Specify lower-power components for network cards, hard disks and monitors.
- Use pairs of very large hard disks (>500GB) in a mirrored Redundant Array of Inexpensive Drives level 1 (RAID1) rather than smaller disks in multi-disk RAID 5 arrays.
- Specify power-efficient operating systems that include power management features, such as Windows Server 2008.
- Assess equipment energy use before and after deploying new equipment.
- Carry out modular upgrades of PCs where possible.
- Consider deploying thin client technology.

Power management

- Run command line scripts to shut down servers overnight then power them on automatically by using BIOS scheduling.
- Use devices that power off monitors when the base unit is switched off.
- Switch off any unused equipment automatically, such as battery chargers.

- Enable active power management on client computers, placing them into standby and then into hibernate mode after preset periods of inactivity.
- Use timer switches on non-networked technology and printers.
- Use hardware devices with software control to power down PCs automatically.
- Use group policies to put desktop or laptop computers into sleep mode if not used for a set time.
- Use network policies to enforce operating system power-saving features automatically on multiple computers.
- Configure further settings to put the computer into hibernate mode if not awoken from sleep mode.
- Switch monitors to standby after five minutes of inactivity during the day and prevent use of active screensavers.
- Minimise the use of standby mode on monitors or projectors overnight – turn off the equipment instead.

Monitoring

- Monitor the power supply to the ICT facilities and take steps to reduce the power usage.
- Use monitoring technologies to identify how much power devices use and to monitor power usage over time.
- Integrate ICT facilities with building management systems and smart metering.
- Monitor power usage on items such as uninterruptible power supplies.

Virtualisation

- Implement server virtualisation instead of obtaining more physical servers.
- Migrate existing physical servers to virtual machines.
- Implement storage virtualisation and capacity management.

Printers

- Set up printers to print duplex and grey scale.

- Consolidate printers and use network printers rather than individual devices.
- Optimise power-saving modes on printers.

Miscellaneous

- Implement a multi-tiered storage solution to move unused data to back-up media and reduce the amount of data on hard disks.
- Reduce cooling in data centres and increase the ambient room temperature within acceptable levels.
- Turn down screen brightness on display devices, particularly with large monitors or multi-monitor arrays.

User education

- Encourage users to switch off monitors when not in use.
- Educate users about the importance of saving power.
- Create a power-saving awareness campaign within the organisation.

Equipment disposal

- Think carefully about equipment disposal and reuse.
- Identify any redundant servers and hard disks and decommission these items.
- Donate life-expired equipment to recycling charities.

Summary

An environmental ICT strategy should not simply be a series of good intentions with no discernable action that satisfies the need to be appearing to do something without committing an organisation to saving a single watt. Correctly implemented, an environmental ICT strategy can make a significant contribution towards reducing an educational establishment's running costs while simultaneously reducing the resources that this establishment consumes. With care, these gains can be achieved with no loss to the computing services on offer.

Educational organisations of all sizes should adopt environmentally sustainable ICT policies as a major strategic goal, thus reducing costs and minimising unnecessary consumption of resources.

Further information

The Becta website includes a section on Environmental Sustainability [http://schools.becta.org.uk/index.php?section=re&catcode=ss_res_env_02&rid=14635].

The Evaluating Resources link includes sections on choosing a video-conferencing system and how to dispose of redundant equipment. The site also includes a carbon footprint calculator that enables educational establishments to identify where they are using power and where they can cut this power consumption. For more information, tools and useful links, see 'Why you should reduce your school's ICT carbon footprint' [http://www.becta.org.uk/schools/carbonfootprint].

The primary source of information for educational establishments on how to reduce carbon emissions and improve energy efficiency is the Carbon Trust [http://www.carbontrust.co.uk].

The UK Energy Saving Trust publishes information on energy-saving recommended products [http://www.energysavingtrust.org.uk/Energy-saving-products/About-Energy-Saving-Recommended-products].

OGC Buying Solutions provide information on sustainable procurement programmes for the public sector. See Sustainable Solutions [http://online.ogcbuyingsolutions.gov.uk/bcm/sustainablesolutions/].