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Project Document Cover Sheet

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Sustainable ICT Service Provision (SISP) Final Report (version 2)

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- External suppliers who provided goods or services to the project, in particular Data Synergy for their Powerman software and Green Energy Options (GEO) for their real-time power monitoring system, other green IT projects who provided information and advice and worked with us on specific aspects, in particular the University of Hertfordshire RARE-IDC project and the University of Bolton ECCILES project.

Finally, special thanks are due to the project's research assistant, Helen Bear (Yogi) and project technician, Nic Totten, who provided the core of the project team and had to cope with the demanding workload and adjustments to plan.

Executive Summary

The overall aims of this project were to determine the sustainability of UEA's ICT services in terms of their energy consumption and CO_2 emissions and to investigate and implement strategies for improving sustainability, thus aiding the University in its strategic commitment to lowering its carbon footprint. In pursuing these aims it was recognised that any measures must be cost effective, not compromise quality and resilience of services and allow ICT service enhancement programmes to continue. As a result of the JISC funding there was an additional aim of producing guidelines and useful information to assist other HE and FE institutions in progressing to more sustainable ICT service provision.

An ambitious set of outputs were identified at the start of the project in October 2008 and with the benefit of hindsight we would have perhaps been better to focus on fewer outputs as maintaining the necessary level of staff resource to fulfil these commitments has not been easy and in some cases we have done less than we had originally intended. Nonetheless the project has achieved a significant reduction in ICT energy consumption within the University and reports and guidelines have been produced to aid other HEIs/FECs in their carbon reduction strategies.

Data Centre power savings

In the Data Centre we have achieved a 22% reduction in our power draw equating to 949,000KWh (949MWh) per year and a reduction in CO_2 emissions of 513,000kg[1]. This represents an annual saving for the University of £97,000[2]. This saving has been achieved by:

- Changes to the electrical distribution equipment (mainly replacement of low voltage power distribution panel)
- Improvements to air flow brought about by re-organising server racks into hot and cold aisles
- Server de-commissioning and replacement

Because the implementation time periods for the above overlapped it is not possible to separate out the effects with any great certainty, however we have estimated that changes to the electrical

[1] Using emissions factor of 0.54055 kg per KWh (Defra 2007 data). Note, UEA does generate a significant proportion of its electricity from an on-site gas powered combined heat and power plant and the emissions factor for this is 0.44. A new Biomass gasification combined heat and power plant has also recently started operation on campus and will lower the emissions factor. However, as we still import electricity from the Grid and it is this electricity that would be reduced first, the Defra figure has been used in this project.

[2] Using an electricity cost of £0.102 per KWh as used in UEA costing processes. This cost may be lower than for some other HE/FE institutions as UEA generates the majority of its power on campus, using a gas powered Combined Heat and Power (CHP) plant and a recently introduced Biomass fuelled CHP plant.

distribution equipment probably accounted for 50% of the power decrease, server rack rearrangement in to hot and cold aisles 40%, and server decommissioning and replacement 10%

An estimated further potential saving of 775,000KWh per year (£79,000) has been identified once the first phase of our server virtualisation plan has been implemented during the next eighteen months. It is estimated that around 40% of this reduction will be as a result of consolidating servers and 60% due to reduced heat output and hence cooling required[3]. A similar amount could also be achieved if the remaining server stock is virtualised.

In addition another 275,000KWh (£28,000) will be also saved when the current UPS running at 70% efficiency in our older Computer Suite is replaced with a modern 90-95% efficient model. Subject to the business case being approved this would be done within the next eighteen months.

We have also identified other measures for generating additional savings which we will investigate and if appropriate implement, for example increasing the operating temperature of our Computer Suites (thus saving on cooling) and using natural ventilation in our older Computer Suite.

The project has also produced a framework to assist HEIs in conducting feasibility studies into hosting sustainable Data Centre services in a region. This framework has been used to conduct a feasibility study for implementing such at UEA and exploiting UEA's spare Data Centre capacity and on campus carbon lean power generation. UEA has yet to consider this feasibility study.

Desktop computer power savings

In student IT areas we achieved a reduction in average PC power consumption of 0.74KWh per PC per day, equivalent to 269KWh per PC per year (145kg CO_2, £27)[4]. This represented a 40% reduction in power consumption. The annual power saving totalled for all the power managed PCs in the project was 132,000KWh (£13,500). This saving was achieved by using Data Synergy's Powerman software to switch systems into 'sleep' mode (c.1W) when inactive out of hours and in some cases also when inactive for more than a 30 minute period during daytime hours. If applied across all student IT areas in the University[5] around 348,000KWh per year of power will be saved, equivalent to 188,000kg of CO_2 emissions and £35,500. As monitors are also put into sleep mode when Powerman switches the system unit to sleep, around another 80,000KWh would also be saved giving a total annual saving in excess of 400,000KWh (£40,000).

Some preliminary investigation using Powerman to put staff PCs into sleep mode when inactive out of hours has shown that this would be problematic. The project has therefore funded a study using the web based CRed system for implementing behavioural change, to determine the effect on energy consumption and CO2 emissions attributable to both IT and non-IT use[6]. Evidence from roll-out of this system in earlier trials at UEA and in local authorities indicates that CO2 emissions can be reduced by as much as 12-15% by using this system as part of a wider staff engagement programme to effect changes in behaviour.

Some piloting of thin client devices as student print stations and library information workstations was also undertaken. From this it was determined that there is an operational power saving to be achieved by using thin clients (225KWh per year for a student print station), but the saving is smaller than savings achievable using Powerman on fat clients. After considering implementation costs we found it would only be financially viable to replace the student print stations with thin clients and even then the financial saving achieved by replacing all of UEA's 37 student print stations with thin clients would only be £1,543 per year. If thin clients were deployed on a greater scale for a wider variety of applications then savings would be considerably greater, and there are other advantages associated with support costs to be gained. In light of this it has been recommended that investigation of using

[3] To calculate the cooling saving a rule of thumb calculation of 1.3W of cooling requirement for every 1W of server power was used. 'Calculating Total Cooling Requirements for Data Centers', Neil Rasmussen, APC, http://www.apcmedia.com/salestools/NRAN-5TE6HE_R2_EN.pdf .
[4] This does not include monitors.
[5] Currently the software is installed in all student IT areas under ITCS management and a few faculty managed student IT areas that were sampled in this project.
[6] At the time of writing this report, the study was still ongoing. When completed a report and other associated outputs will be available from the SISP project website.

thin clients on a wider basis be undertaken when UEA has a virtual server and virtual desktop infrastructure in place.

In addition to the above achievements the project has produced several reports and guidelines for use by other HEI/FECs and produced a video to aid in disseminating project findings. The video is available from the project's website.

Background

UEA has a strong track record in research into sustainability issues as witnessed by work in our Schools of Environmental Science and Development Studies, the Climatic Research Unit and inter disciplinary work between these and other schools. UK's first Strategic Carbon Management MBA has also been setup at UEA. The Low Carbon Innovation Centre (LCIC) has been created to effect knowledge transfer from UEA's sustainability research out to regional companies and employers. The CRed web based system for implementing behavioural change in sustainability, which has been used in this project, is being developed and marketed by LCIC. UEA's excellent record on carbon reduction has also been demonstrated by the construction and management of award-winning innovative and energy efficient buildings and there is already a significant measure of low carbon power generation and heating/cooling in place on campus enhanced by the recent introduction of a biomass fuelled combined heat and power generation plant. The recently revised Corporate Plan has also set the objective of the University becoming an exemplar of environmental good practice.

Information Services recently embarked on an intensive programme of ICT service improvements which included significant expansion of central data storage, corporate information and central services, high performance computing and a large increase in the number of servers used to support corporate, research and teaching applications. In order to support the additional infrastructure and improve resilience and business continuity, a second Computer Suite has also been built. Contrasts between the energy efficiency of the two Computer Suites, in particular their cooling, and concerns about rising energy consumption caused by increases in server numbers have resulted in senior management realising that improvements in energy consumption and sustainability are essential if ICT service development is to continue as planned.

Aims and Objectives

The project aimed to determine the sustainability of current University ICT services in terms of their energy consumption and CO_2 emissions and to investigate and implement strategies by which the sustainability could be significantly improved in a cost effective manner without compromising services. This has required a review of IT requirements for service and matching of these against the most appropriate technology as well as reviewing procurement, deployment and disposal policies for ICT. The project had two main areas of focus; the University's Data Centre operation (consisting of two Computer Suites) and its desktop provision for staff and students.

It was envisaged that the project would serve as a practical exemplar of how similar HE institutions can approach ICT sustainability issues and would produce guidelines that could aid other institutions in their ICT sustainability planning. It was intended that the project would make a very real impact on decision making about ICT procurement and deployment by demonstrating what had been achieved by the different measures implemented during the project.

The objectives of the project were to:

- Determine the impact on energy consumption and sustainability of the University's Data Centre operations and by comparing energy efficiencies of the old and new Computer Suites and conducting external research, determine and implement a strategy for sustainable expansion of University Data Centre operations and provide a model for other HE Data Centres.
- Develop and implement plans to improve energy efficiency of servers by using server virtualisation and 'self-regulating' blade/rack power management systems, measuring the effectiveness of this by monitoring power consumption 'before' and 'after'.

- Evaluate energy consumption and CO_2 emissions of current desktop systems in student IT areas, admin offices and academic/research offices and conduct pilots using alternative low energy consumption devices to explore the potential of these for improving sustainability.
- Conduct a feasibility study into use of DC power direct from photo- voltaic panels to end-user devices as a means of increasing energy utilisation from current UEA photovoltaic panels and exploring the potential for such in future building projects.
- Develop a business case for a hosted Data Centre service for regional HEI/FECs taking advantage of UEA's location and ability to generate green power.
- Review and revise UEA's ICT procurement and deployment policies based on work from the project.

Methodology

Whilst developing the project proposal it was recognised that sustainability issues had to be tackled across both Data Centre and desktop computer provisions as both significantly contribute to the University' s energy consumption and CO_2 emissions[7]. Although this strategy risked spreading effort too thinly and not achieving enough in an area, it was felt that the risk could be minimised by focussing on 'quick wins' and the overall benefit to the University would be greater than focussing in more detail on just one of the areas. We also considered this approach to be more useful to JISC and the HE/FE community as it would offer a range of measures across an IT provider's service provision that could be considered and if appropriate applied.

The project work was organised into five work packages, each one being further subdivided into discrete strands to aid planning and monitoring. A four phase approach was adopted within each work package as below. These followed the same principles as described in the original proposal, but the focus was adjusted to concentrate on reducing energy consumption from use of IT with an emphasis on cost savings.

1. Research and discovery - This involved research into related activities elsewhere (including other JISC funded 'green' ICT projects), attendance at appropriate conferences and learning from other exemplars of best practice. Some small scale testing was also done where applicable, power monitoring strategies agreed on and equipment procured where necessary. Energy saving measures previously identified were evaluated to ensure that they would fit in with the University's IT infrastructure and project timescales and would be likely to deliver the greatest benefits. Feedback from stakeholders was collected.
2. Implementation and evaluation – Selected energy saving measures were implemented and their effect on power consumption evaluated. Interim internal reports on the implementation, savings achieved, effect on service, issues etc were written for later checking, refinement and incorporation into project deliverables in phase 4.
3. Policy and guidelines development - ICT procurement and deployment policies were reviewed based on research and implementation work, and policy recommendations drafted ready for review and eventual approval by the University's Information Strategy and Services Committee (ISSC)[8]. This has involved communication with stakeholders groups and senior management which at project end was still ongoing. Recommendations from this work have been applied to development of an Invitation to Tender (ITT) for re-procurement of UEA's Managed PC Procurement Service.
4. Deliverables for JISC and HE – Reports and good practice guidelines have been derived from the internal reports produced during implementation. Short video clips highlighting key elements of the project have also been produced.

Summary details of the five work packages and the specific approach and methodology used are given below.

[7] It was estimated that UEA's Data Centre operation accounted for approximately 13% of the University's total power consumption and that due to UEA owned desktop systems(excluding student owned and printers) 5%.
[8] At the project end (31/3/2010) the recommendations had not yet been discussed by ISSC.

Work package 1: Monitoring and evaluation

The power consumption of both the Data Centre and desktop computer provision prior to any energy savings measures being implemented was determined using a combination of real-time measurement and estimation tools. CO_2 emissions attributable to the energy consumption were also calculated. The monitoring was then maintained throughout the project and 'before' and 'after' measurements used to determine the effect of each implemented measure on energy consumption. Some statistical analysis and data mining was also undertaken to identify patterns and relationships from gathered data.

Because of their different nature different power monitoring techniques were used for the Data Centre and the desktop computer provision.

Data Centre

The original intention was to use metering connected to the Estates managed Buildings Management System (BMS) to ascertain power consumption of the two Computer Suites (rooms) housing servers, storage and networking equipment. This proved to be impractical mainly due to differences between the time constraints of the project and Estates wider plans for introducing more metering within the University. Given the need to press on with implementation of energy saving measures it was decided to use a more manual approach by using Computer Suite operations staff to record power consumption measurements from power distribution equipment at regular intervals. The total power draw in amps of the whole Computer Suite was recorded (including air conditioning) and also the power draw on each of the three UPS phases delivering power to the equipment housed in the Computer Suite. From this we were able to determine the power draw attributable to IT equipment and to support services (air conditioning) and calculate the Power Usage Efficiency (PUE) now commonly used in Data Centre power studies. Power consumption in terms of KW was calculated and extrapolated to give an annual KWh figure, from which the annual cost and CO_2 emissions were also calculated.

Desktops

Owing to project time constraints, the large number of desktop computers (5,300) and the lack of room level electrical metering, it was decided early on to take an approach of structured sampling. Inventories of desktop computers (not printers) were created from an earlier survey of computers undertaken across departments and by conducting a separate more detailed survey of student IT areas. For the student IT areas the method of room temperature control (air conditioning or natural ventilation) and type of usage (science, non-science, mixed) was also recorded as well as type and age of the computers etc. This survey was done by circulating a questionnaire to departments' IT support staff and also by inspection by SISP project and Estates staff.

Staff and student profiling work was also undertaken to determine proportions of staff and students in science and non-science[9] schools and staff in business/administrative or academic/research roles.

A schematic showing the different types of users, and for students the different types of IT areas they used, was created as in figure 1. This was then used to develop a sampling rationale which would be representative of all the above types of use.

[9] Science schools included Chemistry and Pharmacy, Computer Science, Biology, Environmental Sciences and Mathematics; all others were categorised as non-science. It could be argued that this is too simplistic a split and that there are significant numbers of staff or students in for instance the Faculty of Health Schools who also undertake very computer intensive work, we felt that given the time and budget constraints it was a reasonable split.

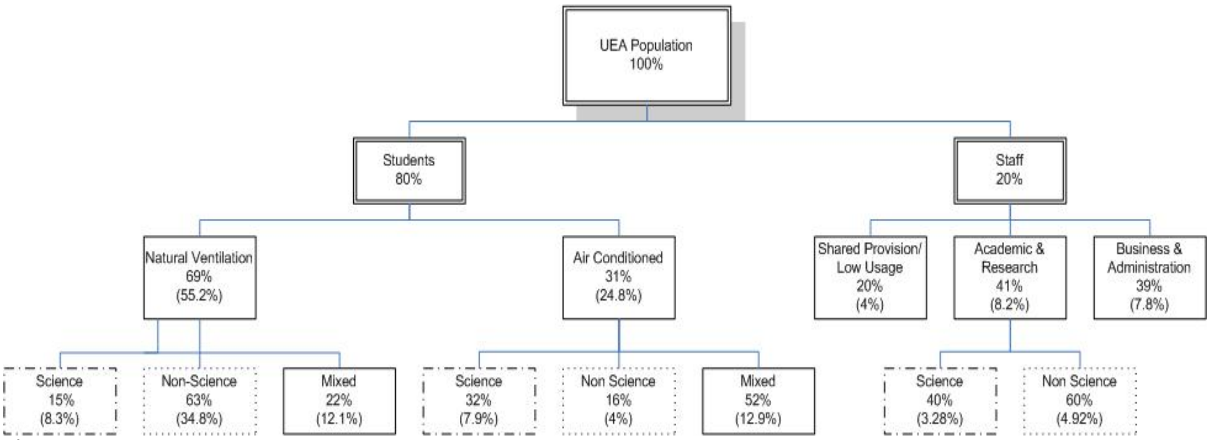

Figure 1

Because physical areas did not map in reality to the above and due to constraints of budget, building layouts, installation practicalities etc, the following sampling scheme of six student and three staff sample areas was arrived at.

Sample ID	Description	Location	No. of PCs in area
Stu - NV – S	Science students - Natural ventilation	CMP	16
Stu - NV – NS	Non-Science students - Natural ventilation	ARTS	67
Stu - NV – M	Mixed students - Natural ventilation	Library	15
Stu - AC – S	Science students - Air conditioning	CAP	50
Stu - AC – NS	Non-Science students - Air conditioning	AHP	26
Stu - AC – M	Mixed students - Air conditioning	ITCS	81
Sta - AR – S	Science Staff - Academic/research	CMP	5
Sta - AR – NS	Non-science staff - Academic/research	NAM	8
Sta – BA	Staff - Business/administration	Registry	240
Sta – SP	Staff - Shared provision	Dropped due to smallness of sample and disparate location making real-time monitoring impractical	

Figure 2

To monitor power usage in the above sample areas a two pronged approach was taken. After investigation of available real-time power monitoring systems a system from Green Energy Options (GEO) was chosen which was capable of measuring both the power consumption of the whole area, plus that of computer systems sampled within an area. Data Synergy's power management software, Powerman, was also installed both to monitor computer activity and inactivity, and in the student IT areas to be used to implement power management policies across all computers in that area. This software was also able to estimate power consumption of individual computers from activity/inactivity statistics.

In addition to the samples Powerman was also installed in LCIC offices, IT and Computing Service (ITCS) staff offices and all IS managed IT areas.

Work package 2: Data Centre power consumption

The power consumption of the University's Data Centre operation (two Computer Suites totalling 110 server racks and over 418m^2) was determined from outputs as described in Work package 1. Energy saving measures as identified in the original proposal were re-evaluated on their potential to save power, their impact on IT infrastructure and service, and also on whether they could actually be implemented during the project life cycle. The following were chosen for implementation: server decommissioning and replacement (with more power efficient models); re-arrangement of server racks and blades into hot and cold aisles for more efficient cooling; replacement of the old inefficient low voltage power distribution panel in the older Computer Suite. For each measure their effect on power consumption was determined by a combination of 'before' and 'after' measurements and some estimation.

In addition a comprehensive body of work was undertaken to develop a virtualisation plan for servers and from this estimates of the power savings that will be achieved when implemented were calculated. Some investigation into use of harmonic filters to smooth out the wave form of the power supply (and increase efficiency of utilisation of power) was also undertaken, but it was decided that there was little more that could be practically done in addition to the harmonic filters that had already been installed on Computer Suites' power supplies.

Further measures were also identified for future implementation after the project. Of these some are still being researched and some have already had business cases developed.

In the original project proposal Work package 2 included conducting a feasibility study into UEA hosting sustainable Data Centre services and also developing a framework for HEI/FECs to undertake their own studies. After some initial consideration and with the agreement of the JISC programme manager, it was decided that the best approach to this was to engage UEA's Low Carbon Innovation Centre (LCIC) to assist with the work. LCIC were thought well suited to undertake this work as they have considerable experience with green projects within the region and beyond, and also have more in depth business skills than could be provided within the core project team. To initiate this work it was decided to host an assembly consisting of UEA IS and Estates stakeholders and representatives from other 'green' projects, Janet, LCIC and an external Data Centre consultant commissioned by LCIC. The intention was to get a draft framework from this meeting which LCIC would then refine. This framework would then provide a template for the UEA feasibility study which the external consultant would undertake.

Work package 3: Desktop computer power consumption

The current energy consumption of University desktop computers was estimated from outputs of Work package 1. Previously identified energy saving measures (and some new ideas) were evaluated on their potential to save power, their impact on IT infrastructure and service, and also on whether they could actually be implemented during the project life cycle. Automated policy driven power management and a limited thin client pilot were chosen and implemented, and measurements recorded before and after to determine their effect.

Some preliminary study was undertaken with staff sample areas to determine whether a behavioural approach might deliver benefits and based on this and other research a study of using the CRed System carbon reduction tool was also commissioned. The web based CRed system records individuals' carbon saving actions in the form of pledges which the system then tracks and reports on, calculating the estimated carbon savings achieved. The system also provides a focal point and forum for ideas, bringing individuals together to build local identity and ownership for carbon reduction activities.[10]

Investigation into improved utilisation of DC power generated by photovoltaic panels (as already installed in one of the University's buildings) and incorporation into future building projects was started. However this was prematurely terminated because of lack of progress and the retirement of the principal investigator.

Work package 4: Policy review and development

Reviews of the University's ICT procurement and deployment policies were also undertaken in order to incorporate more sustainable practices, with the prime focus on ensuring that electricity consumption was properly considered as part of the total cost of ownership during procurement and deployment processes.

After research and review proposed modifications and additions to policies were discussed with the University's Purchasing Office and other stakeholders[11]. These proposals will be further refined after the SISP project ends and revised policies submitted to the University's Information Strategy and Services Committee (ISSC) for their approval and subsequent implementation.

[10] For more details of the CRed System see http://www.uea.ac.uk/lcic/cred .
[11] Proposed changes are still in draft form and require further consultation and discussion before proposed changes are submitted for University approval.

Work package 5: Dissemination

Dissemination of findings from the project was done via reports produced for the work packages which are published on the project website. Guidelines for other HEI/FECs were distilled from these reports and other research and again are published via the project website. Short video clips outlining key work of the project have been produced and are also available via the project website.

Implementation

Power monitoring

Data Centre

Monitoring the power consumption in UEA's two Computer Suites was initiated by first getting a clear picture of what equipment was in the suites and what methods of measuring power were already available. Estates help was also enlisted to better understand and document how power was delivered to the UPS and to equipment.

Prior to the project 'snapshots' of power consumption had been taken at infrequent intervals using readings from power distribution panels and clamp meters attached to air conditioning power circuits. This was somewhat error prone and the process was not systematically documented. There was also some environmental monitoring of individual server racks carried out using Jacarta boxes with sensors distributed throughout the rack, These boxes gave measurements at 15 min intervals of temperature, humidity, airflow, and amps (over two power feeds). However they were only installed in the newer Computer Suite (CS2), not installed in every rack and the resulting log files were never amalgamated together to get a picture of the total Computer Suite power consumption, or the consumption attributable to different types of equipment and services. There was also no central management program for analysing and reporting on data from across all of the monitoring boxes and consequently they were only checked infrequently and if there was a perceived problem with temperature etc in a rack.

Installation of power metering equipment that could be attached to the University's Building Management System (BMS) was discussed with Estates, but discounted because it could not be fitted within the project timescales. A low cost approach based on methods already at hand was chosen and it was decided to proceed with the 'snapshot' measurements taken from the UPS and power distribution panels, but to record them at more regular intervals than previously (now recording weekly) and using a fully documented process to avoid previous errors and inconsistencies. These measurements were incorporated into Computer Suite duty operator's weekly tasks and the power in both Computer Suites was monitored in this manner and recorded in a spreadsheet.

The collected data measured both the total power draw of each Computer Suite (excluding lighting) and that of the IT equipment in the suites. By difference of these two measurements the power draw of 'support services' (air conditioning) was also calculated. For each 'snapshot' the Power Usage Efficiency (PUE) ratio was also calculated[12].

In addition to the 'snapshot' measurements, previously planned installation of Jacarta monitoring boxes in all racks in both Computer Suites continued, and from May 2009 onwards it was possible to measure and record the power draw, temperature, airflow and humidity of the majority of server racks. Although we still lack a central console for analysing and reporting on the Jacarta data, it has been possible to amalgamate the data from all the boxes together and this has been analysed for significant patterns/trends and for correlations with other collected data. It has also been used to determine proportions of computer suite power consumed by major types of IT equipment (network, file store, High Performance Computing cluster etc).

[12] $$\text{PUE} = \frac{\text{Total power draw of Computer Suite}}{\text{Power draw of IT equipment}}$$
Where 1 is the theoretical maximum (i.e. all power used by IT equipment, non used by support services such as air conditioning.

In addition to the 'snapshot' measurements and Jacarta data, some investigation of using the Nagios alerting/monitoring system for measuring power consumption at blade, rack and UPS level was also undertaken. This was already being used to monitor server performance and issue alerts. At the blade level this data was incomplete because of dependencies on blade class and ILO (Intel Lights On) licensing and although some analysis of the Nagios data was carried out, it was decided not to use it to measure the effect of the various implemented measures on power consumption, instead sticking with the better understood 'snapshot' measurements.

Before the various power saving measures were implemented, the 'current' power consumption of the entire Data Centre operation was calculated, this being the 'baseline' or starting point for the project. The power consumption of specialist hardware was also estimated to better understand how these contributed to the total power consumption picture. Specialist hardware considered was network equipment, Storage Area Network (SAN) and an Escience High Performance Computing cluster .

Desktop computers

Because of the large volume and spread of desktop computers in the University it was not possible to monitor the power consumption of all these and a sampling approach was undertaken as described in the previous Methodology section. In total there were nine core sample areas of which six were student IT areas and three staff areas. In these areas two types of monitoring were installed

- A real-time power monitoring solution supplied by Green Energy Options (GEO) which was able to both measure the total power draw of IT equipment and also of selected sample systems within that area.
- Data Synergy Powerman software, which was installed on each desktop system in order to monitor computer activity and inactivity and from this estimate power consumption. This same software was also used to implement power management policies in student sample areas and one of the staff areas.

Data from the above two types of monitoring was used to derive average power consumption figures for computers in each area type and these coupled with sampling profiles used to extrapolate to the whole University and hence calculate the current ('baseline') power consumption of University desktop systems. Data from the GEO system was also compared with Powerman power estimates in order to estimate how far from 'reality' the latter estimates were[13]. When power saving measures were implemented 'before' and 'after' measurements from these two systems were then used to determine the power saving achieved.

Data Centre power saving measures

Taking account of the need to ensure that no services were compromised and that any implemented measures could be completed within project timescales, it was decided to focus on implementing three main measures in the Data Centre and evaluating their effect:

- Server de-commissioning and replacement - carried out mainly between January 2009 and June 2009.
- Re-organisation of racks into hot and cold aisles – carried out largely between January 2009 and June 2009, but with a small number of racks being re-positioned between June 2009 and September 2009. The objective of this exercise was to avoid mixing hot air out flows from racks with cool air intakes.
- Replacement of the ageing and very inefficient low voltage power distribution panel in the older Computer Suite (CS1) – carried out in July 2009.

Data Centre power consumption was calculated before implementation of each measure started and after implementation had been completed i.e. 'before' and 'after' measurements. However, because of the need to keep services running with as little downtime as possible, the re-organisation of racks was spread out over six months and did overlap with the other measures to a certain extent, making it

[13] Powerman estimates power consumption by applying a standard power draw for a PC. Real-time power measurements done on a range of UEA PCs of 1-5 years of age and taken from the GEO monitoring system indicated that the 'out of the box' Powerman estimates were twice as high as the actual consumption. Consequently the standard PC power draw defined in Powerman was re-configured to 80W which is more representative of the UEA PC infrastructure.

difficult to separate out effects. A power savings of 22% from the baseline was achieved after completion of the above measures, more details of which can be found in the Outputs and results section.

At the start of the project it had been the intention to also implement server virtualisation. After research and an assembly with the University of Hertfordshire RARE-IDC project, it became apparent that a complex mix of services such as we have at UEA would require substantial planning by ICT systems staff. It was agreed that development of a detailed implementation plan for agreement at senior management level was essential if appropriate budgets were to be made available and services not disrupted. An added complication was that the University embarked on a new venture, UEA London, which became the top priority during September 2009 to January 2010, leaving insufficient ICT Systems staff resource for undertaking virtualisation work. It was therefore decided to concentrate on developing an implementation plan during the project life cycle and from this estimate the potential power saving that would result when implemented. To assist with the planning a load assessment of servers was undertaken using external consultants and Platespin software. Based on the assessment and the consultant's report a phased virtualisation plan was developed and is undergoing final review before implementing over the next eighteen months after the SISP project ends.

Towards the end of the project other possibilities for reducing power consumption were identified. These were:

- Upgrading the UPS in the older Computer Suite. The current UPS is only c.75% efficient and newer models coupled with better harmonic filtering (smoothes out wave form of supply and improves energy utilisation) can now be purchased to operate at 95% efficiency.
- Raising the Computer Suite operating temperature (to save on cooling), improvements to cooling. Studies elsewhere[14] show that this is possible without significantly reducing reliability.
- Cooling of the older Computer Suite using natural ventilation. The location of this suite and its parent building indicate that it may be possible to provide much of the cooling cold air from the outside, only using traditional air conditioning in the warmer months of the year.

The above are being discussed with the ICT Systems team, Estates and external consultants and will all require business cases to be developed if sufficient funds are to be available.

Desktop computer power saving measures

Measures to reduce power consumption of desktop computers focussed on three main initiatives:

- Policy driven power management using Data Synergy Powerman software
- Piloting thin client alternatives to Fat clients for use as Library information workstations and student print servers.
- Roll out of the CRed System, a web based system for aiding behavioural change so that individuals would engage in more sustainable practices such as switching off PCs when not in use.

Powerman implementation

This software was installed in all previously identified project sample areas (both staff and student type) and used primarily to reduce power consumption in student IT areas where it was not practical to switch off machines 'out of hours' due to their large numbers. The software worked by putting computers into a sleep state where power consumption was very low (less than 1W for newer desktop models), but which could be awakened quickly by pressing a key or clicking the mouse, thus avoiding long start up times. Some limited use of it to control power consumption due to computer inactivity during core daytime hours was also undertaken and limited testing of using it to control 'out of hours' power consumption in a staff sample area was also undertaken.

Before and after power consumption measurements, both using Powerman estimates and real-time monitoring data from the GEO system enabled the effect of using Powerman to be measured. This proved very successful for reducing 'out of hours' power consumption achieving an average of 269

[14] One such study is '2008 ASHRAE Environmental Guidelines for Datacom Equipment-Expanding the Recommended Environmental Envelope',
http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf

KWh per PC per year (145kg CO_2, £27) saving in the student test areas and after initial teething problems had been resolved proved unproblematic. Using Powerman to reduce power consumption due to inactivity during core daytime hours on student systems also proved successful, although this had a more limited scope than for ‘out of hours’ power management because a large proportion of the student IT areas are used for scheduled teaching and it was felt that using this approach during teaching sessions would not be acceptable. Some testing of power management using Powerman was also started in a staff area (and which is still ongoing), but early indications were that savings were not that great. More details on power savings achieved using Powerman are in the Outputs and Results section.

Thin clients pilot

After some research, internal discussion and discussions with suppliers it was decided that any thin client pilot carried out within the project would have to focus on lightweight applications. This was because of time constraints and also because the teaching desktop installed across UEA IT areas contained some applications that were unlikely to be easily delivered by this approach e.g. Matlab and ArcGIS. To be successful in delivering more heavyweight applications via thin client type technology would require more investigation than the allocated time allowed for, time consuming packaging work and a significant investment in thin client and/or virtual desktop technology and skills.

Two lightweight applications were chosen for piloting thin clients; Library information workstations which have only Internet Explorer and some MS Office viewer applets installed and are used to access Library electronic resources (Library catalogue and electronic journals); and student print stations where most of the processing is already done on a central server. A server running Microsoft Terminal Services was setup and thin clients from three suppliers were in turn piloted in place of fat clients. Daily power measurements were taken and any problems/comment from students noted. Power measurements from ‘fat’ clients acting as a control were also recorded and client power savings calculated.

Power consumption of the server blade running Terminal Services (the only application on the blade) was also measured at regular intervals by using a clamp on power meter on the power cable. The server power consumption was then used to offset the thin client savings and arrive at a more realistic estimation of power savings that could be made by using thin clients.

Hosted regional Data Centre services – framework and feasibility study

The commissioning of LCIC to undertake this work proved to be a wise decision and the work progressed according to plan. A one day assembly of stakeholders (see Methodology) was held and a draft framework produced from this. LCIC in collaboration with the SISP project team then refined this framework. The external consultant undertook an inspection of UEA’s current Data Centre facilities and consulted with UEA IS and Estates stakeholders on their, then after conducting the necessary external research produced a draft feasibility study for UEA for review by LCIC, the SISP project team and IS management. A brief survey of potential customers for hosted Data Centre services in the region was also undertaken by the consultant and the completed feasibility study was submitted for consideration by UEA stakeholders and decision makers. At this point in time the feasibility study has not yet been fully considered by UEA and no decisions reached about execution of any of the options outlined in the study.

Behavioural change study using CRed system

LCIC were also commissioned to undertake a study of the UEA rollout of the CRed behavioural change system and to evaluate its impact on IT energy consumption and the University’s carbon footprint. Historical data from five years of previous regional CRed campaigns were analysed and this was compared with carbon savings and membership data from the UEA 2010 campaign. Data from the UEA campaign was also combined and compared with desktop power consumption data produced by the Powerman software. A report on the UEA CRed campaign including results of a user insight survey is awaiting preparation once UEA has launched its campaign. A best practice guide for running behaviour change campaigns within large institutions was also produced.

Outputs and Results

Data Centre power savings

The power consumption of UEA's Data Centre operations (two Computer Suites) was estimated at the start of the project to be 4,365,000 KWh per year, equivalent to 2,479,000kg of CO_2 emissions per year and a cost of £436,000. This represented 13% of UEA's electrical power consumption. The major components of this consumption were estimated and are shown in the pie chart in figure 3.

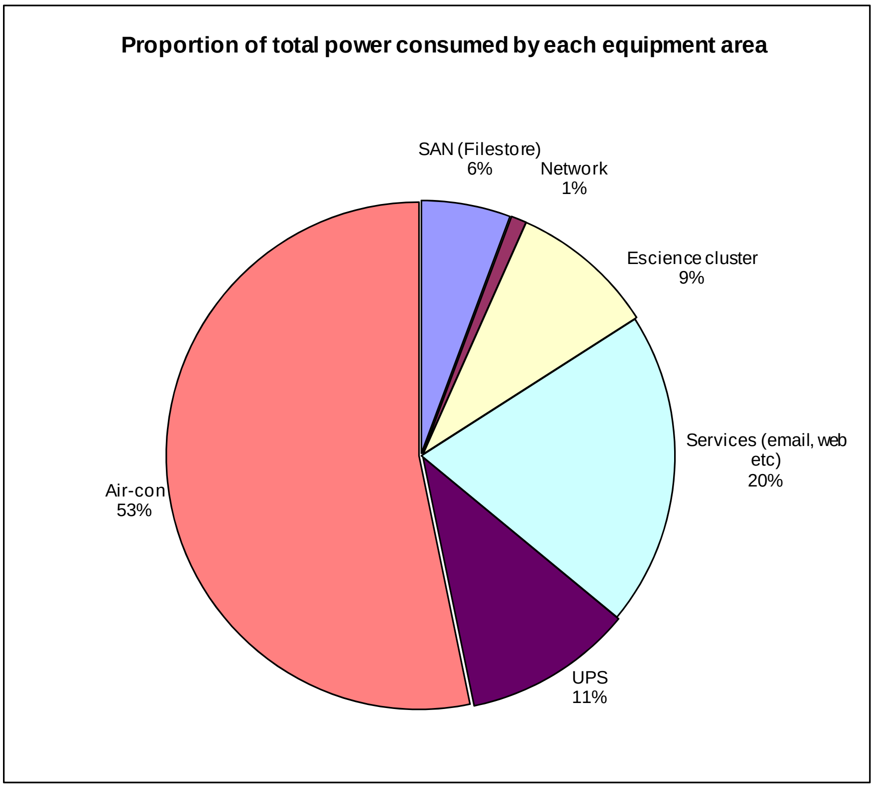

Figure 3

It is worth noting that the above is across the whole Data Centre operation and significant variation between the two Computer Suites was found, in particular regarding the proportions of electricity consumed by the air conditioning and by the UPS. More detail on this can be found in the Data Centre Power Management Report on the project's website.

During the course of the eighteen months of the project the power consumption was reduced by 22% to a projected 3,415,000KWh per year. This equates to a saving of 949,000KWh (949MWh) per year and a reduction in CO_2 emissions of 513,000 kg, representing a saving of £97,000. The saving was achieved mainly by server de-commissioning and replacement, re-organising server racks into a 'hot' and 'cold' aisle arrangement and by replacement of the grossly inefficient low voltage distribution panel in the older Computer Suite with a new more efficient one. The chart in figure 4 shows the drop in power consumption over the timeline of the project.

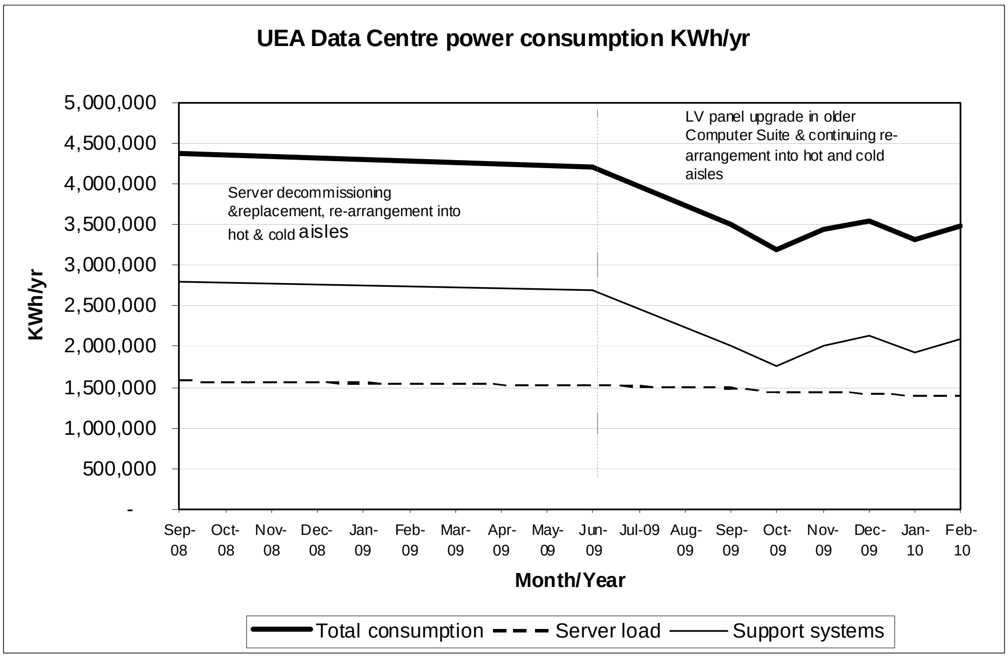

Figure 4

It is worth noting that the major proportion of this reduction (c.75%) occurred after June 09 coinciding with replacement of the low voltage power distribution panel in the older Computer Suite (CS1) in July 09. Although it was expected that this would have a significant effect as the old panel was very inefficient, the degree to which it appeared to have an effect was surprising. Unfortunately power measurements were not available immediately prior to and after the panel replacement and a small number of rack moves into hot and cold aisles also continued after June 09, so the effect of the panel cannot be determined precisely. However, it seems unlikely that the whole of the 75% decrease after June is attributable to the panel replacement. It is interesting to note that in 2006 when faced with reaching the load limit on the UPS in CS1, the load had been reduced very significantly by installing a relatively inexpensive harmonic filter on the power supply to smooth out the wave form of the supply and improve power utilisation. This had reduced the power draw by sixty amps on each of the three phases of the UPS (equivalent to 378,000KWh per year) again another large saving. Also, the general opinion amongst specialists in the power field seems to be that changes in efficiency of power distribution systems and UPS equipment do have a great effect. Taking these into account we think that replacement of the panel probably accounted for around 50% of the total power saving.

As server de-commissioning and replacement was occurring during the same time period as rack re-arrangement we cannot separate out these two effects with any great certainty, but our results suggest that 40% of the total power saving was due to rack re-arrangement into hot and cold aisles and the remaining 10% due to server de-commissioning and replacement.

Although we were not able to achieve any significant amount of server virtualisation within the project timescales, using the virtualisation plan that was developed further potential savings of 775,000KWh per year (£79,000) have been identified once the first phase of the plan has been implemented (over the course of the next 18 months). It is estimated that around 40% of this reduction will be as a result of consolidating servers and 60% due to reduced heat output and hence cooling required[15]. A similar amount could also be achieved when the remaining server stock is virtualised.

There is also a potential saving of 200,000-300,000KWh per year that should be realised when the upgrade of the UPS system in the older Computer Suite has been done. This again shows the importance of paying attention to efficiencies of the electrical distribution system.

[15] To calculate the cooling saving a rule of thumb calculation of 1.3W of cooling requirement for every 1W of server power was used. ‘Calculating Total Cooling Requirements for Data Centers’, Neil Rasmussen, APC, http://www.apcmedia.com/salestools/NRAN-5TE6HE_R2_EN.pdf .

A full report on the measures we have taken to reduce Data Centre power consumption and guidelines for other HEI/FECs are available on the project website at:
www.uea.ac.uk/is/sustainable-ict/outputs/datacentre .

Desktop computer power savings

Using Powerman

In student IT areas where we applied power management (491 PCs in total) we achieved a 40% saving in power consumption, equivalent to 132,000KWh per year and a financial saving of £13,464. This equates to an average annual saving per PC of 269KWh and a reduction in running costs of £27 per year[16]. This was achieved by using Data Synergy's Powerman software to put systems into 'sleep' mode (<1.5W) when inactive out of core hours and also in some IT areas[17] when inactive for more than a 30 minute period during daytime hours. The plot in figure 5 shows the drop in average PC power consumption as the power management policies were applied.

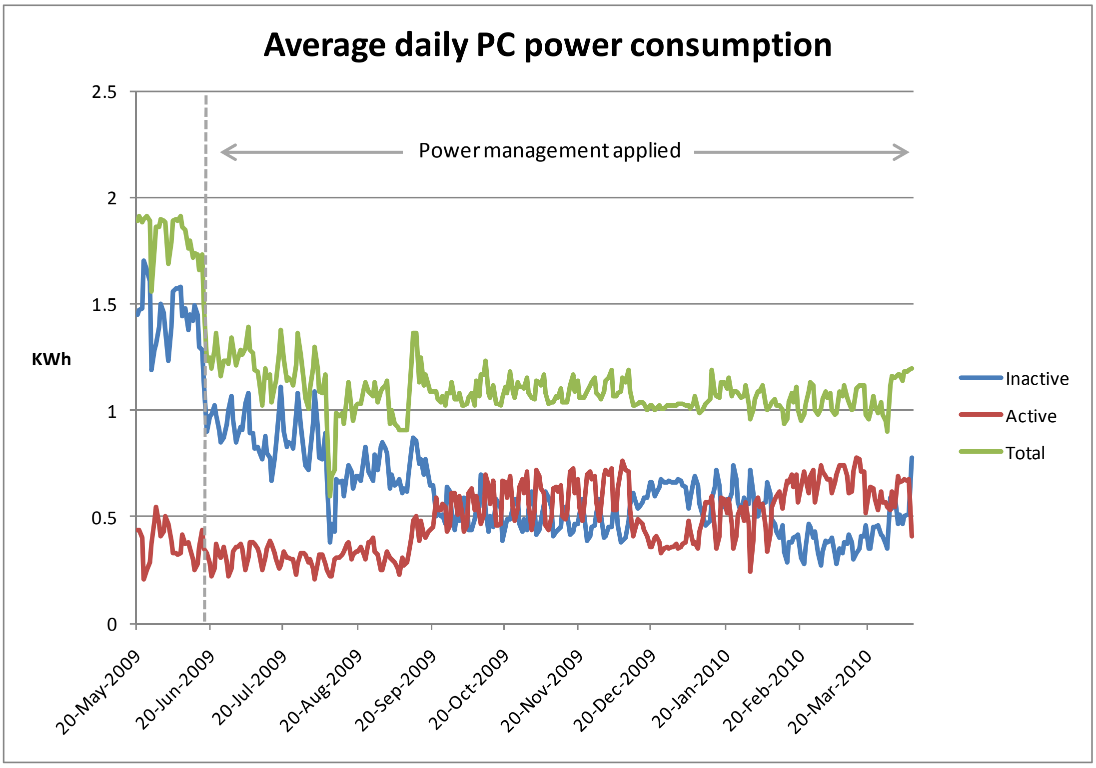

Figure 5

If this power management system is rolled out across all student IT areas it is estimated that a total saving of 348,000KWh per year will be achieved, thus reducing CO_2 emissions by 188,111kg and running costs by £35,500. Taking into account the cost of the Powerman software, the saving in operational costs would cover the cost of the software within approximately 2 months. Additional savings will accrue as we start to extend power management policies to reduce power wastage caused by daytime inactivity in student IT areas.

The savings to be achieved by using this approach on staff office machines are less clear. From our samples, many staff already switch of their PCs when leaving work (around 80%) and there are quite varied work patterns both across and within departments. Studies on staff samples within the project show that there are some issues related to staff working out of hours and also those that need to leave their machine on in order to be able to connect to it from home. The warning message and time

[16] This does not include monitors. At UEA, TFT monitors consume on average c.20-25W when in use. When Powerman puts computers into sleep mode, it also does this with the monitor (i.e. takes it to a state of c.1W).
[17] A faculty managed IT area and ITCS managed IT areas where no teaching took place. In areas where there is teaching, putting PCs into sleep mode when inactive during daytime hours was seen as likely to disrupt the teaching.

interval for cancelling sleep mode are quite limited within Powerman and it is felt that until more sophisticated features are enabled in this area, use of the software on staff machines may be limited. In addition, behavioural studies within the project also suggest that approaches to change the overall behaviour of staff regarding power saving may be a better approach and deliver wider benefits (see 'Savings by behavioural change').

A full report on the measures we have taken to reduce desktop computer power consumption and guidelines for other HEI/FECs are available on the project website at: www.uea.ac.uk/is/sustainable-ict/outputs/desktops .

Using thin clients

Our study of using 'thin clients' has been quite limited, choosing only to pilot thin clients in situations where little software was installed locally and where we were confident that there would be few software issues. We chose to use thin clients in two situations; as student print stations and as Library information workstations (used for searching the Library catalogue and electronic journals).

The student print stations required only a small applet in addition to the operating system to operate with the existing student network printing infrastructure. This applet could be easily installed into flash memory in the thin client, requiring no back end thin client infrastructure such as Terminal Services. It is realised that this would not be regarded by many as a true/typical thin client operation. Using thin clients as Library information workstations did however require an additional HP blade server running Microsoft Windows Server and Terminal services. This server had an average power consumption of 168W (1,472KWh per year).

Thin clients from three manufacturers (Wyse C90LE, Dell FX160 and HP T5730) were piloted in both situations. Measurements showed that the most power economical thin client was from Wyse which consumed 0.62KWh per day less power than the 'fat client' control when used as a student print workstation and 1.17KWh per day less when used as a library information workstation. Extrapolating from this to a year across the whole University and assuming each workstation is left switched on all the time (which they are), gives the annual savings as summarised in the table in figure 6 below.

Workstation	**Power consumption KWh/day**			**No. of stations**	**Total savings per year**		
	PC Fat client	WYSE Thin client	Saving		KWh	Kg CO_2	£
Student Print	0.764	0.149	0.615	37	8,306	4,490	£847
Library Information	1.293	0.122	1.171	10	4,274	2,310	£436

Figure 6 – Power consumption of machines in thin client pilot

The savings as presented above do not appear that great and might be considered marginal given other power saving measures that could be adopted. When implementation costs and a five year equipment replacement policy are also taken into account and combined with operational costs, a somewhat different picture emerges. The financial saving per year for 37 student print stations including both implementation and operational costs increases to £1,543 and for the 10 library information workstations there is an actual increase in costs of £224. This increase in costs for the library workstations is due to the purchase and running costs of the backend Terminal Services server and also the small scale of the operation.

It is also worth noting that because of their low wattage thin clients do produce less heat than fat clients and there would be some additional saving from reducing air conditioning requirements. However, it was not possible to quantify this with any degree of certainty in the UEA environment.

There were no service issues and no adverse comments from users during this pilot and power saving considerations aside, the smaller desktop footprint, less moving parts and ease of support for these thin clients suggest that there would be some value in deploying them more widely. However, wider use of thin clients in situations where more heavy weight applications are used does require more investigation. On our standard student desktop alone, we know of at least two items of software where we anticipate significant problems and where the software supplier does not support delivery via Microsoft Terminal Services or similar. Other thin client methods using newer virtual desktop technology might make use of this type of client more feasible, but there would have to be investment in different IT support skills to support this approach and power requirements at the Data Centre end would also be greater and would have to be investigated.

Further details about the project's thin client pilot are available in the Desktop Computer Power Management Report and in a separate report on the thin client pilot. Both of these are available from the project website at the URL below:
www.uea.ac.uk/is/sustainable-ict/outputs/desktops

Savings by behavioural change

Within this project, two studies were undertaken to determine the effect of behavioural change on power consumption from IT.

Firstly, it was noticed from our staff sample areas that there were several staff groups where initiatives to encourage more sustainable behaviour had been undertaken, for instance in the Registry building where there had been a concerted campaign to encourage people to switch off lights and switch off electrical equipment when leaving work each day. From the Powerman monitoring statistics obtained from our sample areas, those areas where such initiatives had been undertaken showed significantly less power consumption per PC and also significantly less attributed to inactivity (PC on but not being used). The 'well behaved' samples averaged only 14KWh power consumption per PC per week compared to 27KWh of the 'less well behaved' samples, and for power consumption attributable to inactivity 6KWh and 22KWh respectively. Although a seemingly large difference, the small number of sample areas and the small number of computers in some areas meant that extrapolating from this to the whole University could not be done with any great degree of statistical certainty. This along with perceived issues with implementing automated power management on staff computers led to thinking that we could do some work with LCIC and the UEA rollout of the CRed System[18] (online carbon reduction tool) to investigate using behavioural change measures to reduce power consumption.

Based on the above LCIC were commissioned in parallel with their rollout of the new CRed system[19] at UEA to look at the effect on IT use as well as overall effect on carbon footprint. Preliminary study of previous CRed roll-outs elsewhere suggest that significant reductions in power used by IT can be achieved by this approach. The approach is also 'less heavy handed' than imposing power management policies on staff machines as via Powerman and there are much wider benefits in sustainable behaviour to be had by this approach. At the heart of the system is a web based pledge system, so the system also provides an example of how IT can be used as a change agent. As the CRed System helps to raise awareness of issues such as power used by IT systems its lighter-touch approach can be used as a precursor to the introduction of more stringent power management software and other IT power reduction initiatives.

Full reports on the LCIC study and the smaller preliminary study are available on the project's website at:
www.uea.ac.uk/is/sustainable-ict/outputs/desktops

Hosted regional Data Centre services feasibility study

LCIC and an external Data Centre consultant were commissioned to undertake this study on behalf of the SISP project. The first phase of the work focussed on producing a framework for HEI/FECs considering offering hosted sustainable Data Centre services to others. The Framework that was developed adopts a seven phase approach:

- Phase One: Defining 'Green'
- Phase Two: Legal Operations
- Phase Three: Location
- Phase Four: Change Management
- Phase Five: Exit planning

[18] For more details of the CRed system see summary description and footnote under Methodology on page 9.
[19] The study is still ongoing at the time of this report.

- Phase Six: External Factors
- Phase Seven: Customer Analysis and Product Requirements

The feasibility study undertaken by the external consultant provides a sound basis for the University to start to discuss the future of its Data Centre operations and the possibility of hosting low carbon Data Centre services for the region. It highlights that there is significant spare capacity within UEA's current Data Centre operation that could be exploited to provide hosted services for other institutions, and that the Biomass combined heat and power plant could provide significant marketing advantage if used to contribute power and cooling. Although the study observed that there was a perceived market in East Anglia and the UK for high quality low carbon data centre space, a short market survey conducted in the region after the feasibility study, showed little appetite for hosted services at UEA apart from some demand for a specialist disaster recovery backup service. As the survey response rate was very low and we know that IT management in other institutions are likely to demonstrate some reluctance in seeing competitive institutions hosting services, it is difficult to draw substantial conclusions. There doesn't however seem to be any justification for a new green field data centre at UEA.

It is interesting to note that a recent Shared Service Data Centre requirements survey conducted by HEFCE and to which 65 HEIs responded, did demonstrate some evidence of a willingness to collaborate on shared service data centres during the next three to six years. However, the survey also highlighted that over half were planning to refit their existing data centres in the next two years and a third were planning to build a new data centre facility on site during the same period.

The Framework and UEA feasibility study are available on the project's website at:
www.uea.ac.uk/is/sustainable-ict/outputs/hostDCservs

Outcomes

The overall aim of the project was to determine the sustainability of UEA's ICT services in terms of their energy consumption and CO_2 emissions and to investigate and implement strategies by which the sustainability could be significantly improved in a cost effective manner without compromising services. From what we have said in previous sections and in particular in the Outputs and Results section with the power and CO2 emissions savings stated there, we feel that we have largely achieved this aim. As regards serving as a practical exemplar to other HEI/FECs, we hope that the reports and guidelines presented on our project website serve this aim, time will tell.

The table below summarises the original objectives and what has been achieved in order to meet these objectives. All deliverables/outputs referred to are available from the project's website at www.uea.ac.uk/is/sustainable-ict/outputs .

Original objective	Achievement
Determine the impact on energy consumption and sustainability of the University's Data Centre operations and by comparing energy efficiencies of the old and new Computer Suites and conducting external research, determine and implement a strategy for sustainable expansion of University Data Centre operations and provide a model for other HE Data Centres.	Work on power monitoring in the University's two Computer Suites and analysis of this data has resulted in a much clearer understanding of the amount of power being used (and hence CO_2 emissions) and the major elements of that power consumption. The power consumption has been significantly reduced (22%) and further measures have been identified for consideration and possible implementation. The following have been produced for use by other HE/FE establishments: • Data Centre Power Management Report and Guidelines
Develop and implement plans to improve energy efficiency of servers by using service	Considerable thought and research has

virtualisation and 'self-regulating' blade/rack power management systems, measuring the effectiveness of this by monitoring power consumption 'before' and 'after'.	been devoted to server virtualisation planning and a project Assembly organised with the University of Herts to benefit from their greater experience in this. Server load assessments have been undertaken and analysis done by external consultants, and this information has then been used to develop a phased implementation plan for virtualisation of UEA's servers. Potential power savings that will be delivered by the plan when implemented have been estimated. Note, no significant virtualisation was done within the project timescale.
Evaluate energy consumption and CO2 emissions of current desktop systems in student IT areas, admin offices and academic/research offices and conduct pilots using alternative low energy consumption devices to explore the potential of these for improving sustainability.	A sampling strategy was developed and power monitoring setup in sample areas. Using both real-time monitoring and estimates from power management software, power profiles for different types of use were built up and used to extrapolate to the whole desktop population. Pilots were conducted using power management software and thin client alternatives and by using 'before' and 'after' measurements the effects of these measures were evaluated. Some behavioural change studies involving staff groups were also conducted as an alternative to the power management software approach. The following have been produced for use by other HE/FE establishments: • Desktop power management report and guidelines. • Thin clients pilot report. • Behavioural change studies (including preliminary study and LCIC CRed system). Note, the focus changed from the original plan with more emphasis being put on use of policy driven power management software and the behavioural change studies, than alternative desktop devices.
Conduct a feasibility study into use of DC power direct from photo- voltaic panels to end-user devices as a means of increasing energy utilisation from current UEA photovoltaic panels and exploring the potential for such in future building projects.	This was terminated prematurely because of lack of progress and retirement of the researcher. Some preliminary measurement work was done which indicated that loss in power caused by inverting DC output from photo-voltaic panels and back again to DC via the computer's power supply was around 40%
Develop a business case for a hosted Data Centre service for regional HEI/FECs taking advantage of UEA's location and ability to generate green power.	A project Assembly was hosted to initiate this work and the University's Low Carbon Innovation Centre (LCIC) commissioned to produce a framework for UEA and other HEIs to use when undertaking feasibility studies in this area. The framework was then used by

	LCIC to produce a feasibility study for UEA. The following have been produced for use by other HE/FE establishments: • Framework for sustainable hosted Data Centre feasibility studies • Feasibility study for UEA.
Review and revise UEA's ICT procurement and deployment policies based on work from the project.	The University's Desktop Computer Procurement and Deployment policy was reviewed and proposed revisions are awaiting further consideration by the University. There was also some input into the Managed PC Procurement Service re-tendering process.

In addition to the original objectives, it was decided evaluate the effect of using the web based CRed behavioural change system on both IT energy consumption and the University's wider carbon footprint:

Evaluate the effect of the web based CRed behavioural change tool on IT energy consumption and the University's carbon footprint	The impact of the recent CRed campaign at UEA was evaluated, combining and comparing with energy consumption and activity/inactivity data from desktop computer power monitoring and also comparing with previous regional CRed campaigns. The following have been produced for use by other HE/FE establishments: • Report on the CRed UEA Campaign • Comparison with previous regional CRED campaigns • Results of UEA customer insight survey[20] • Best practice guide for running behaviour change campaigns within large institutions

Video clips describing key elements of the project work were produced and are available via the project website. It is hoped that these video clips will provide an alternative and quick summary of what was done in the project.

Conclusions

Data Centre

The main conclusions drawn from work in our Data Centre are summarised below:

- Significant Savings can be made over a relatively short period of time without a large capital investment or investment in new technology, by focussing on efficiency of power distribution equipment, separating hot and cold air flows and migrating to newer more power efficient servers.
- Inspecting the power distribution system including power distribution panels and UPS can reap significant benefits. Technology has become more efficient in this area and new power delivery

[20] At the time of this report only a draft CRed System Evaluation Report is available, which does not include a UEA customer insight survey owing to delays with the UEA rollout of the revised CRed System. When the rollout has been completed the report will be updated to include the UEA customer insight survey and it will be available from the SISP project website.

systems can be 20-25% more efficient thus saving considerable power. Good liaison with estates is essential if this is to be done thoroughly.

- Good housekeeping of IT equipment is essential. In large Data Centres containing a complex mix of services and where a significant number of staff have access, it is all too easy to lose control over what equipment is being installed and what is being removed. At UEA we do have fairly strict controls on access to the Computer Suites and all new servers are recorded in an inventory maintained by the Computer Suite team. However other equipment such as for network and SAN are recorded separately under the care of the respective service teams. This means that quality and scope of the data does vary and there have been cases of equipment being installed and de-commissioned without full details being recorded. This makes it more difficult to keep track of changing power requirements and consumption etc
- Controlling air conditioning costs is key and as can be seen from the SISP project can be the largest component of power consumption. Many Data Centres operate with air conditioning systems that are designed to operate on a whole room basis and as virtualisation reduces server numbers, under capacity can become an issue with disproportionately more being spent on cooling than is necessary. In UEA's newer Computer Suite this is a problem even before a virtualisation plan has been implemented as the computer suite has been built with capacity for growth.
- Server virtualisation isn't easy for a complex mix of services. This needs much planning effort and good consultation with system owners, suppliers and other stakeholders. External consultants and server load assessment software can help, but much internal staff input will be required before signoff of the plan by senior management. With system owners in different service teams the 'politics' and communication can be a very time consuming process. This added to the technical complexities and a technical landscape that is constantly in flux means that good project management is essential.

Desktops

The main conclusions drawn from work on desktop computer power saving are:

- Understanding what you have (inventories) and having procurement policies in place to control the frequency of replacement, number of suppliers and different models is important. The greater the number of suppliers and models the harder it will be to track whether an institution is purchasing and deploying power efficient models. If there is no policy in place to ensure that power consumption is considered in the total cost of ownership, then the need to minimise capital cost and the desire for more processing power (whether required or not), may lead to increased power consumption.
- The tension between keeping for longer (saving on embedded carbon in manufacture) and purchasing newer more power efficient models needs to be properly considered and managed. It is not a simple decision. Old kit can consume considerably more power than new kit, so a well thought out rolling replacement policy with a 'maximum life' which is reviewed annually to take account of technical developments would seem to be the most balanced approach. It is interesting to note that at UEA, which has had a five year replacement policy in place for some time, the average power consumption of a standard staff or student IT area PC is now around 80W (excluding monitor) which is probably half the consumption of a similar, or even lower spec machine of five years ago.
- Policy driven automated sleep (to 1.5W or less) of PCs in student IT areas overnight is a quick win and appreciable power savings can be achieved. The ROI is good and savings quickly offset the cost of the software. Using this to decrease power consumption from inactive machines during the daytime is also worth considering, but may not be appropriate where scheduled teaching is undertaken.
- Policy driven power management on staff PCs can be difficult owing to differences in working behaviour. It can also be seen as a very authoritarian approach. Behavioural approaches may well be better for staff machines and there are additional benefits in other areas (changes their thinking generally)
- Thin client technology can make a difference, but won't be suitable for all applications and needs to be coupled with virtual desktop work to implement widely across the organisation. It should also be borne in mind that there doesn't appear to be an easy automated way of putting

thin clients into sleep mode like there is with PCs (e.g. using Powerman), so where thin clients cannot be switched off at night, modern power efficient Fat clients with power management applied out of hours could give similar power saving results.

Hosted Data Centre services

It is hard to draw conclusions based on the work we have done. Hosted Data Centre services serving HE/FE and built on low carbon principles are likely to happen as energy and manpower costs rise and the economies of scale increasingly look more attractive. There is also a requirement for Disaster Recovery backup data to be stored off-site which may well lead to HE collaboration and co-hosting of data. However, national coordination will be required if this is to be driven along more rapidly and 'political' and ownership barriers overcome. The impact of the CRC[21] (Carbon Reduction Commitment) on this also needs to be investigated.

Implications

This project demonstrates that significant energy savings can be made across both the Data Centre and desktop computer provision in a relatively short period of time and with relatively small capital investment by focussing on the 'quick win' measures that we have employed in this project. These measures have also been well documented in projects elsewhere.

As partly referred to in the Conclusions section on desktops, there are tensions between using IT equipment for longer and saving on embedded carbon, or purchasing newer more power efficient equipment and saving on carbon emissions from use. The impact of CRC on this also needs to be taken into account. Work to better understand this and to develop guidelines could save HEI/FECs much time and energy.

We have started in this project to consider how UEA's green field site and sustainable power generation could be put to good effect to host low carbon Data Centre services for others and achieve some economies of scale and savings in power consumption and CO2 emissions. What decisions UEA will take in regard to this and whether other institutions will see such as an efficient pooling of resources, or unwelcome competition, remains to be seen. This also needs to be considered alongside commercial cloud computing service offerings where vendor's large scale Data Centre operations are perhaps better placed to achieve power efficiency owing to their greater capital resources.

References

Desktop power management
University of Oxford, Low Carbon ICT 'Green desktop computing' resource - http://www.oucs.ox.ac.uk/greenit/desktop.xml . Contains power consumption estimates for PC and monitors, modelled scenarios (always on cf. switched off evenings/weekends/holidays) and green tips and links to other resources.

Thin client pilot
Power to the People: Comparing Power Usage for PCs and Thin Clients in an Office Network Environment; Stephen Greenberg, Christa Anderson, Jennifer Mitchell-Jackson; Thin Client Computing, Scottsdale, AZ; August, 2001. http://www.hsp-central.net/Power_Study.pdf . Results from this study broadly comparable to the SISP thin client pilot and confirms the fact that power and monetary savings are proportionately greater the larger the network.

Thin client presentation from Fraser Muir, Queen Margaret University.
http://qmu.academia.edu/FraserMuir/attachment/154651/full/The-QMU-thin-client-project
Comparison table of thin client and PC on slide 20 broadly in line with findings from the SISP pilot.

Data Centre power management

[21] Recently renamed CRC Energy Efficiency Scheme, see: http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/crc/crc.aspx

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http://tc99.ashraetcs.org/documents/ASHRAE_Extended_Environmental_Envelope_Final_Aug_1_2008.pdf

Appendix

Project Definitions

- Sustainability is determined as the measurements of energy consumption in kWh and CO_2 emissions in kgs. There is a recognised relationship between these two metrics.
- The scope of the monitoring of this project is limited to University owned desktop computers, desktop monitors and Data Centre IT equipment including servers, network (incl. telephony) and SAN, and air conditioning.
- Data Centre refers to Computer Suites (machine rooms) housing servers, network, SAN and air conditioning equipment.
- The term ‘students’ refers to taught undergraduates.
- Science schools are in the set {CMP, CAP, BIO, ENV, and MTH}.
- ‘Staff’ refers to all regularly paid employees of UEA who have the entitlement to PC access for email & intranet use (as per conditions of employment).
- A thin client is a computer which depends heavily on a server to provide processing power.
- A Fat client is a computer on which the majority of application processing is undertaken independently of a server.

Glossary of terms & acronyms

BIO	School of Biological Sciences, UEA.
CAP	School of Chemistry and Pharmacy, UEA.
CHP	Combined Heat and Power, used in reference to Biomass CHP (Biomass fuelled gasification combined heat and power).
CMP	School of Computer Science, UEA.
ENV	School of Environmental Sciences, UEA.
EST	Estates Division, UEA
IS	Information Services UEA, director of which was SISP Project Director.
ITCS	IT and Computing Service, UEA. Part of Information Services.
MTH	School of Mathematics, UEA
SAN	Storage Area Network
SUSTE-IT	Sustainable Information Technology In Tertiary Education, http://www.susteit.org.uk/ . A JISC funded initiative which reviews the environmental and social impacts of IT in further and higher education, and identifies and disseminates examples of good practice within it.
UEA	University of East Anglia, sometimes referred to as “the University”.