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Sustainable IT

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Capstone V600

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Capstone Roster

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Executive Summary

Introduction

Indiana University's Sustainable Computing Working Group commissioned a study from Dr. Barry Rubin and the School of Environmental Affairs to gather information on current IT sustainability practices, analyze these practices with respects to other institutions and make recommendations for future action. This project was undertaken as a SPEA "capstone" project, where 27 second-year Masters of Public Affairs (MPA) candidates divided into five teams to tackle a separate dimension of Sustainable Information Technology at IU. These teams looked at e-waste, the efficiency of the new data center, printing standards, how the University is using IT to promote sustainable behaviors, and best practices in the field.

E-Waste

Creating a convenient, financially viable system to recycle e-waste is vital to IU sustainability efforts and has the potential to raise revenue for schools and departments through sales at the IU Surplus Store. In addition, e-waste created by the student body should be considered when developing a university-wide electronic recycling program. To confront both of these issues, the team interviewed professionals involved in the electronic reselling and recycling chains, surveyed the student body, and undertook a case study of one school's recycling practices.

After conducting a survey of 1,902 Bloomington students, the team found that over half of students store their unused electronic waste and that a majority of students are interested in electronic recycling opportunities on campus. There are very few options outside of Electronic Waste Collection Days, which happen in the summer after the majority of the students have left campus, and a cell phone recycling bin in the Indiana Memorial Union that receives very little traffic.

To assist students in electronic recycling, we recommend implementing computer recycling services at both the UITS Help Desk in the Herman B Wells Library and the Computer Connection Store in the IMU. These locations may also offer assistance with wiping hard drives clean and work with the Serve IT Clinic to donate electronics to local nonprofits. The team also recommends solidifying overlapping opportunities with the Hoosier-to-Hoosier sale and E-Waste Days including promotion and collection efforts.

To increase the efficiency of the University e-waste recycling program and reduce lost revenue due to hoarding, we have identified both organizational changes needed and opportunities available. First, to make the system easier for IT professionals to navigate, we recommend regular communications between relevant departments to make sure e-waste policies meet the needs of the University. We also advise that the University reconsider the data-wiping policy to reduce redundancies, and that the e-waste process on IU Surplus forms be simplified. Electronic recycling can also be encouraged by automatically reminding purchasers how to dispose of old equipment, and by affixing e-waste stickers to electronic equipment that contain policy and avenues by which to access information about e-waste.

Data Center and Server Management

With sustainability among its core values, the new Indiana University Data Center has made great strides with respect to sustainable IT. Continued collaboration with campus departments outside the data center coupled with innovation inside presents opportunities for the Data Center to go further still.

One recent trend in the IT industry to reduce carbon emissions and save money is a method known as server virtualization which allows IT managers to fully utilize the potential of each server by consolidating workloads of several machines. Indiana University has embraced this technology by constructing UITS II and the new IU Data Center, allowing IT departments to virtually locate their servers in an energy efficient system.

We recommend that IU consider pursuing Energy Star certification from the EPA for our IU Data Center; analyze the airflow within the center and consider feasible partial-aisle containment configurations which may allow for material energy and cost savings; increase the relative advantage of UITS II to IT managers by offering more affordable storage packages and exploring intangible savings such as dependability and staff time use; and invest in consensus building with IT departments, aligning organizational incentives and goals between the data center and autonomous IT departments. These recommendations were formed as a result of an analysis that focused on the IT department level, including a random sample of interviews and surveys.

Duplex Printing

The Duplex Printing Group was tasked with determining steps the University could take to reduce paper consumption, shift printing culture on campus, and save money. Based on our research, students prefer printing duplex and when given an easy option to make their printing preference reality, do so. This simple, user-selected printing system (piloted in Business/SPEA Information Commons in the spring of 2011) should be permanently expanded to all Bloomington's STCs and computer labs. Additionally, the University's quota system does not appear to be in-line with actual student printing on campus. Students print, on average, well below their allotment, and the current system does not encourage paper conservation. It is our belief that IUB should follow the lead of other Big Ten universities and lower the print quota in the short term, with an eventual plan to phase it out completely in coming years.

Furthermore, the University should consider new and emerging technologies that move our campus into the digital age, providing software like Adobe Acrobat Pro X for digital note taking as opposed to traditional, paper notes. Other technologies should be researched to determine if they are right for some or all IUB departments – Ecofont and solid ink technology are two examples. We believe that new programs and policies aimed at sustainable computing will reduce the University's carbon footprint as a result of the savings generated from a more aware community *and* could potentially save the University money.

Sustainability in IT

To examine the scope of which IT is utilized at the University, we needed to look for initiatives not covered by other teams. We therefore designated a team to look for new ideas and current ways in which IT is used to increase sustainability on campus. We first catalogued current efforts including

ways in which IT is encouraging public transportation and reducing paper consumption with online document management.

We then looked at some ongoing initiatives, including paperless ticketing for events, enhancing green team communication, online teacher evaluations, and dissemination of the GoGreen Gadget. We found progress in all of these areas. Athletics is already using electronic ticketing for football games, the green teams have made use of an online blog, and a university-wide task force has been put in place to implement teacher evaluations. In the full report, we list challenges related to implementing the GoGreen Gadget and recommend appealing to administration, creating partnerships with department IT managers, and creating positive support for the initiative with students and faculty. Finally we investigated a new initiative: the use of QR codes as a method of reporting water wastage in IU facilities. For the purpose of a short trial, we created a prototype reporting system, which can be used to widen the scope of the trial in future studies.

Best Practices

The final group looked for best practices to compare IU policy and practices with private and public sector IT sustainability efforts. Best practices in e-waste include virtual desktops, clear electronic disposal instructions, specific purchasing standards, and creative locations of cell phone recycling receptors. Best practices in duplex printing include using duplex as a default printer setting, but we found no conclusive evidence about the toxins in liquid printing ink. For data centers we recommend looking at the EPA Energy Star Program, specifically in the categories of server consolidation, elimination of unused equipment, power management and improved airflow.

When examining the public sector, we encourage professionals to consider the U.S. Department of Commerce's Green IT To-Do List, which names basic sustainable IT practices. At the state level, the past several Indiana state administrations have encouraged the ongoing efforts of the Greening the Government plan which encompasses many of the best practices supported by the Best Practices' literature review which include creating a sustainable purchasing plan and addressing energy efficiency and the greening of state buildings (IDOA, 2011[2]). The Indiana Office of Technology also offers a unique program to incentivize employees by including metrics for greening in performance-based pay, and it produces a monthly newsletter highlighting its sustainable activity (Id.). The City of Bloomington also uses virtualization and efficient LCD screens, participates with IU in Electronic Waste Collection Days, and is drafting a sustainable purchase policy.

Though IUB is not yet "the best it can be" regarding its ratings in the STARS and CSRC systems, we were pleased and encouraged by the results of research and comparisons to higher-rated universities. The best practices identified in STARS were common to both systems – a fact which serves to emphasize the importance of IUB's implementation of a formal sustainable purchasing plan for computers and electronics and improved recycling options for e-waste. It is our impression that due to LEED requirements, the University's green building and renovations mandate help improve the scores related to energy efficiency. Our observations of the high usage of dashboards, water conservation technologies, and other energy efficient practices lead us to recommend efforts at implementation for IUB. Underlying all these technological recommendations is the realization that ultimately the most important purpose for which we will use this sustainable technology is to change is the way people think. By promoting use of virtual workspaces like Oncourse, changing of printing settings from simplex to duplex, and promoting the green office certification program, the University can reduce its

carbon footprint and cause a fundamental shift in the collective campus consciousness regarding IT sustainability.

Conclusion

We believe the Sustainable Computing Working Group has the opportunity to provide leadership in interdepartmental communication, establish official purchasing plan guidelines, tie energy savings to money savings by promoting direct energy billing to departments, and provide support to department IT managers as they try to navigate these sustainable initiatives. By implementing these recommendations, we believe Indiana University Bloomington can be a leader in sustainable IT.

Stakeholder Summary

Introduction

Indiana University commissioned a group of SPEA Master's students to examine the state of the University's computing system and determine where the University could make gains in its sustainability practices. The semester-long study included a thorough investigation of IU's practices and policies in regards to the operation of the data center, the disposal of electronic waste, its use of paper and printing policies, a review of potential new uses of IT to promote sustainability, and a best practices section.

The project culminated with the issuance of a final report and a presentation of findings to staff, professors and other interested parties. The following document contains an explanation of each working group's actions, and it highlights each groups findings. For a more detailed breakdown of a group's actions or findings please reference the final report.

Electronic Waste

Creating a systemized electronic waste disposal system on Indiana University's campus is important at both the micro and macro level. Although our report focuses on how electronic recycling can benefit the Bloomington campus, the positive effects extend to the national and even international level. Currently university policy requires all IT managers to send unwanted electronics to IU Surplus for resale or recycling, though research indicates electronic waste hoarding poses a serious threat and continues to cost the university and departments money. Additionally, there are currently no on campus computer-recycling options for student-owned items. These issues pose a significant problem for the university if it wishes to promote sustainability and reduce the harmful effects of improper electronic waste disposal.

According to the Environmental Protection Agency, discarded electronics make up around two percent of the municipal solid waste stream, and this number is quickly growing (U.S. Environmental Protection Agency, 2011). Alarmingly, only 18 percent of TVs and computers are reported as being recycled and only ten percent of cell phones (Id.). The toxic material mix found within these products is of particular concern. Cathode ray tubes and circuit boards contain lead, a heavy metal that can impair neurological function and fetal development. Mercury is used in the lamps that light flat-panel display screens, including laptops, new desktops and thin televisions as well as cell phones, circuit boards, and digital cameras. Mercury can cause similar problems as lead- neurological, kidney, and reproductive damage. Cadmium, a known carcinogen, is found in circuit boards (Grossman, 2007:7).

These compounds have the potential to leach into the water table and soil, which may eventually affect humans. According to a study that researched leaching of heavy metals in electronics, lead in cathode ray tubes leached at 70 times over the U.S. EPA limit. Further results revealed that circuit boards leached lead at approximately five times the U.S. EPA limit, mobile phones sixteen times the limit, and TV remotes nine times the limit (Keith et al., 2008).

In addition to the domestic risks associated with improper e-waste disposal, improper recycling techniques pose a significant health and environmental threat across the globe. The process of e-waste

recycling is highly labor- and energy-intensive and provides only marginal returns. The United States has comparatively restrictive processing regulations, which in turn, increase marginal costs. However, the United States is not a party to the Basel Convention, which bans international trade of toxic wastes (Basel Action Network and Silicon Valley Toxics Coalition, 2002; Carroll, 2008). Consequently, approximately 80 percent of the e-waste that is to be recycled in the United States is shipped overseas to China, South Asia, or one of several African nations (Chea, 2007).

These countries do not have the necessary domestic policies or infrastructure to ensure proper recycling. Many of the major e-waste recycling areas in these countries use rudimentary processes to extract the valuable metals. Often piles of broken electronics are burned in order to remove the plastics and unwanted metals, enabling the individuals to pick-out the valuable components in the remnants. This process releases significant amount of toxic fumes into the air and causes contamination of surface and ground water as well. Research indicates dangerously high levels of lead and other contaminants in both the children who work in metal extraction and those who live near processing areas (Carroll, 2008).

The team undertook an extensive analysis of the University's programs and policies regarding electronic waste in order to determine the current situation and remedy any identified problems.   The project included numerous interviews, the administration of two surveys – one to a random sample of students and the other to a sample of IT managers, the creation of a case study highlighting the consequences of e-waste hoarding. The surveys provided the primary source of data in determining current program usage, student perceptions, willingness to participate and recommendations on how to expand/improve participation among IT managers and students.

The group's interviews included the following:

1. Matt Hottell – *Director of the Serve IT Clinic*
2. Steve Akers – *Associate Director of Environmental Operations for Residential Programs and Services*
3. Bill Brown – *Director of Sustainability*
4. Susan Coleman Morse – *Senior Communications and Sustainability Specialist at University Information Technology Services*
5. Representatives from the Student Sustainability Council
6. Jim McAuley – *Manager of the University Surplus Store*
7. Craig Porritt – *Administrative Manager of University Surplus Store*

The final student survey results contained the contributions of 1,902 participants, and they clearly demonstrate the need for and interest in an on campus electronic waste-recycling program for students. Currently, 57 percent (1,087) of respondents reported currently storing unwanted electronics because they are unaware of responsible disposal options on campus. In contrast, only 28 percent (534) of respondents currently recycle their unused electronics, and 27 percent (519) reported donating their unwanted electronics to charity.

One positive survey result was that only six percent (112) of students admitted to throwing away their electronic waste (See Chart 1). Furthermore, 76 percent (1,444) of the respondents perceived electronic waste recycling as being either an important or very important issue, and an overwhelming 83 percent (1,557) of respondents indicated their willingness to participate in an on campus electronic recycling

program. These data clearly indicate unmet demand and the need for student recycling opportunities and form the basis of our recommended actions.

Student opinions on where recycling options should be located on campus were quite varied; however, the Herman B Wells Library and the Indiana University Memorial Union received the strongest support, with 31.9 percent and 34.7 percent respectively. There was also significant interest in having electronic waste-recycling options in the dormitories; however, the implementation costs and the difficulty associated with coordinating the program in each of the dorms likely outweigh the benefits. There was also interest in having recycling services in the large academic buildings, namely the Kelley School and Ballantine Hall, but this would require the creation of a more extensive pick-up program and surveillance of security at multiple building sites.

Based on the interviews, survey results, and other research, the team developed the following recommendations on how to best systemize electronic recycling efforts on campus.

Student Recycling Program Recommendations

1. Provide computer-recycling services at the UITS Help Desk in the Herman B Wells Library. This is the point on campus where most students interact with UITS staff on personal computer issues, and the staff would be a critical stakeholder in educating students on the availability of the recycling program when their computers are broken or in need of replacement. In order to accomplish this goal we foresee the following necessary steps:

    a. Have an IUOS intern teach student UITS workers how to wipe student computer hard drives. This is critical for data safety and the protection of private information.

    b. Determine a location for secure storage of donated electronics. There is a need to protect the donated electronics from theft until they are disposed of or arrangements are made with Matt Hottell from the Serve IT Clinic.

    c. Arrange a partnership with Matt Hottell from the Serve IT Clinic (http://serveit.soic.indiana.edu). He can be reached at (812) 856-1096 or mhottell@indiana.edu. He has been notified about the possibility of receiving donated student computers and would be able to make use of any donated machines, either as parts or as complete machines if they function properly.

2. Provide computer recycling services at the Computer Connection store in the IMU. The Computer Connection is the university bookstore's technology store, and it is consequently the logical location for recycling services within the IMU. It is likely the staff will have the skills necessary to assist students in wiping their hard drive and will require only minimal training on the new service. However, it will be necessary to for an IU Sustainability Intern to setup the program and ensure the staff is adequately prepared.

3. Relocate the Eco-Cell phone-recycling bin to the Herman B Wells Library or a more central location in the Indiana Memorial Union.

4. Combine the collection for E-Waste Collection Days with the Hoosier-to-Hoosier event in order to increase participation among students and simplify the message and develop communication plan between key administrators to help implement this collection.

5. Educate the students on the E-Waste Collection Days during dorm move-out and allow students to donate their unwanted electronics at this time. (See "Marketing Plan" in following section)

6. Schedule the E-Waste Collection Days event prior to the end of the school year in 2012 in order to increase donations and facilitate recycling.

7. Change the Hoosier-to-Hoosier program to accept and store unwanted electronics, which will be disposed of through the E-Waste Collection Days.

University E-Waste Recycling Recommendations

1. Develop channels of regular communication among the three major e-waste stakeholders (the Office of Sustainability, IU Surplus, and UITS) to ensure that e-waste policies and practices are up to date and the most appropriate for current needs.

2. Reexamine the data wiping policy in order to minimize the dampening effect current data wiping practices have on the adoption of ideal e-waste disposal methods.

3. Create an automated message system triggered by the purchase of electronic products that reminds local support providers about the available resources and recommended protocol for removing unused equipment.

4. Establish a designated "e-waste sticker" to adhere to electronic equipment that informs staff and faculty in all capacities within departments of the university's commitment to responsible disposal.

5. Standardize an e-waste logo on Website, e-mails and equipment stickers to provide a universal symbol that will be easily recognized.

6. To promote widespread inter-departmental adoption of timely and proper removal of electronic items from offices, distribute informational flyers to be displayed in high traffic areas that inform faculty and staff of the importance of not throwing away or hoarding e-waste.

7. Initialize conversations with other IU campuses to share lessons learned, opportunities for improvement, and establishing standardization of practices.

8. Clarify information about e-waste processes on the IU Surplus forms to eliminate misconceptions about costs to departments, re-sale revenues, and collection procedure.

9. Develop a communication schedule for IT Managers to remind them to schedule e-waste collection and to clarify policies.

10. Develop alternative means for IT administrators to transport large quantities of equipment to Surplus.

Data Center and Server Management

With sustainability among its core values, the new Indiana University Data Center has made great strides in sustainable IT. Continued collaboration with campus departments outside the Data Center coupled with internal innovation presents a number of opportunities for the Data Center to go further still. During the last 14 weeks, our team conducted a broad review of sustainable IT industry standards and methods, interviewed IU department IT managers and conducted cost analyses to identify these opportunities. The goals of our analysis were to:

1. Assess and report on advances in data center energy efficiency measurements.
2. Explore practices to increase energy efficiency within the IU Data Center, namely hot/cold aisle containment.
3. Estimate the energy and cost effectiveness of virtualizing department server applications within the Data Center through UITS Intelligent Infrastructure.
4. Provide insight on overcoming institutional hurdles, thereby positioning Indiana University to better realize its Data Center's environmentally sustainable potential.

Recent trends in the IT industry are transforming once bulky and power hungry systems into lean machines which reduce carbon emissions and save money. Among these advances is a method known as server virtualization, which allows IT managers to fully utilize the potential of each server by consolidating workloads of several machines. Indiana University has already embraced many of these advances and is eager to make additional gains in sustainable IT. A few such opportunities are outlined in the contents of this analysis. In line with the stated goals, our team recommends the following actions:

1. Consider pursuing the Energy Star certification from the EPA for the IU Data Center.

An extensive review of industry energy efficiency reports demonstrated the potential of the IU Data Center to accomplish its strategic sustainability goal of achieving a boastful 1.67 and 1.59 Power Usage Effectiveness in the enterprise and research pods respectively. Our research uncovered many shortcomings to this metric and we ultimately recommend the IU Data Center consider pursuing an EPA Energy Star rating, which we believe to be obtainable in the near future. Earning an Energy Star rating may increase Indiana University's status among academic institutions while providing the data center with a more representative signal of its accomplishments to the IT industry overall.

2. Analyze the airflow within the data center and consider the feasibility of partial-aisle containment configurations, which may allow for material, energy and cost savings.

One championed method of increasing data center cooling efficiency involves partitioning data centers into "hot" and "cold" aisles. Aisles alternate as cold air comes in one side of the servers and exits the other. Hot aisles, then, are aisles where servers face back-to-back emitting hot air. Aisle containment furthers this practice by containing the aisles while strategically directing the flow of air. This method varies in complexity and can be especially difficult if not implemented during the original design of the data center.

While the IU Data Center organized server aisles by temperature, there is currently no containment to prevent air of different temperatures from spilling into counterpart aisles and mixing temperatures. Such mixing may reduce the overall efficiency of the IU Data Center's cooling efforts. Our team recommends the IU Data Center first conduct an analysis to examine the extent to which temperatures are mixing. If deemed beneficial we should then consider aisle containment methods, which are compatible with the data center's existing fire protection system, such as the one proposed in our final report.

3. Increase the relative advantage of UITS II to IT managers by offering affordable storage packages and exploring intangible savings such as dependability and staff time use.

Decision makers must exercise their understanding of the cost and energy effectiveness of different virtualization scenarios in order to make sustainable choices. Therefore, it is crucial to conduct comprehensive calculations that spread beyond departments. This portion of the analysis reviews what estimations have already been published concerning the costs and benefits of virtualization UITS Intelligent Infrastructure, specifically a graduate report from the Kelley School of Business.

Graduate students with limited resources and short deadlines similarly conducted the Kelley report, and as a consequence, it needs to be expanded upon. The discussion on their report includes many recommendations that Indiana University may implement to obtain more informative calculations.

Our findings demonstrate that the intelligent infrastructure is attractive to server applications with low resource requirements or CPU intensive tasks. The intelligent infrastructure is currently more costly for tasks with high storage or memory requirements. To increase the relative advantage of UITS II for certain applications we recommend the IU Data Center considers more affordable storage systems which may offer IT departments a better value.

When introducing the intelligent infrastructure, it may be more effective to market based on hard-to-quantify benefits rather than cost alone. Additionally, these benefits, such as IT administrator's opportunity costs, reduced maintenance headaches, secure stationary and off-site backups, and other data center features, may be the unique strengths the data center has to offer.

4. Invest in consensuses building with IT departments, aligning organizational incentives and goals between the data center and autonomous IT departments.

The professional autonomy of IT staff, faculty, and individual departments (and the inevitable conflicts of interest) will make implementation of green technology challenging. UITS would be well served by redoubling its efforts to reach out to individual departments to address their idiosyncratic needs and concerns. In the process of addressing contentious issues, (for example, uncertainty regarding budget and personnel allocation) UITS could partner with the central administration to reassure staff and faculty of the great care will be taken not to penalize departments for implementing sustainable technologies.

Our survey of IT managers identified three specific areas of department IT needs: technical demands and impacts on staff and budget. These recommendations are based upon an IT departmental level analysis, which included a random sample of interviews and surveys.

Duplex Printing

The Duplex Printing Group throughout our research have found a number of opportunities for Indiana University-Bloomington (IUB) to reduce paper consumption, shift printing culture on campus, and save money. The following pages offer an overview of our findings and recommendations of the following: purchasing, user printing preference at IUB, default printing settings, print quotas and allotments, and alternative inks and other emerging technologies.

Purchasing at Indiana University

While the purchase of recycled content paper (the total of thirty percent, fifty percent, and one-hundred percent recycled content) has increased from $5,637.05 in 2005 to $270,709.93 in 2010, this number still only represents 23.57 percent of the total paper purchased for all eight Indiana University campuses (2009). That means that the remaining 76.43 percent of paper purchased is produced entirely of virgin trees.[1] We believe that the upward trend in the University's purchase of recycled content paper is promising, but we believe the University can improve on these numbers by developing a recycled paper-purchasing plan with the input of the Office of Sustainability that includes, as one of its main goal or objectives, to reduce the University's carbon footprint.

Printing Preferences at Indiana University

Based on the over 1,900 student responses to the survey distributed to nearly 10,000 random IUB students, students prefer duplex defaults (Figure 1). The most common reason students do not currently print duplex is that they do not know how to change the setting. Of the 830 respondents who said they do not currently print duplex, eighty percent said they would change to printing double-sided, if instructions were posted on or near Student Technology Center (STC) computers. Because of this, we believe posting instructions in computer workstations,[2] much like the instructions currently affixed to STC scanners, will boost the amount of users who print double-sided, thus reducing paper consumption on campus and alleviating the University's carbon footprint. As IUB's own Marc Wagner noted, a 1.56 percent reduction in paper used on campus represents a savings equivalent to the cost of ten computer workstations
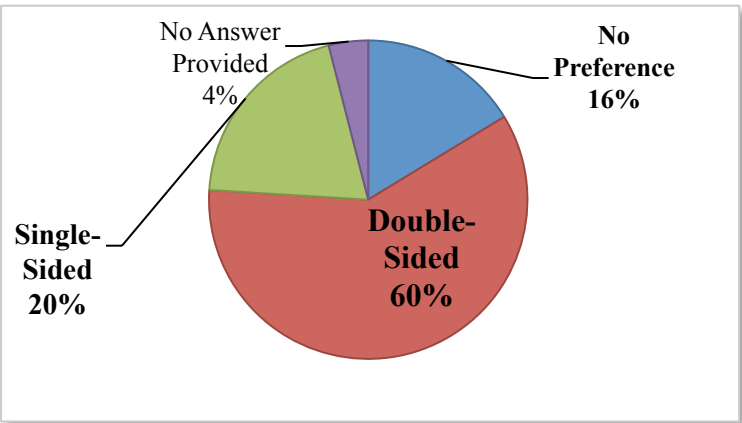
Figure 1. Student printing preference ratios at Indiana University-Bloomington (n=1,902).

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[1] The number is even higher when we consider that 70 percent of 30-percent-recycled content paper comes from virgin trees.

[2] And, digitizing the instructions with screen shots and then housing the instructions on computer desktops

One key finding affecting our recommendations is that many students indicated that specific documents had to be printed single-sided either by a professor's request or because of the nature of the document (e.g., music). Thus, we recommend that IUB expand the Duplex Printing Study conducted from January to March 2011 in the Business/SPEA Information Commons (BSIC) that allowed users to easily choose their print setting when logging in (Figure 2). Lastly, we believe default margins within Microsoft Office should be decreased from one inch all around to ¾ of an inch. This simple adjustment saved this research paper six pages.
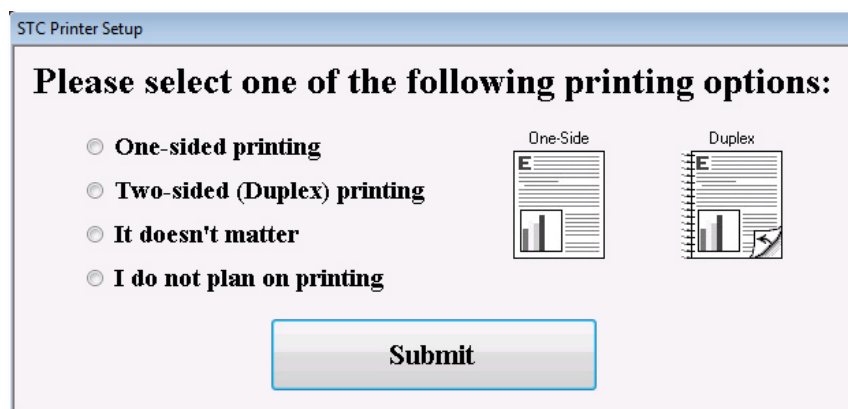
Figure 2. STC printer setup menu seen when users logged in to BSIC computers from January to March 2011.

Default Printing Settings

One of the more important issues we learned from researching the default printer settings of machines in IU Athletics, IU Chemistry, and BSIC is the central role a formal test structure could play in future studies and settings on campus. We believe that duplex printing may not be the best default setting for all IUB machines such as for older machines with large page printed counts, and therefore departments should test their machines. It is important to note that we do not believe the HP 4515s in IUB STCs are one of those machines (i.e, the HP4515 machines reliability is not compromised when printing double-sided). Our proposed formalized structure (Table 5 and 6, Duplex Printing section of research document) benefits from an exemplary research team / end user relationship like the one fostered between this research team and IU Chemistry. Both the research team and end users have information that benefits the other, and thus an open, trusting partnership is the cornerstone for successful projects.

One way departments like IU Athletics, BSIC, and IU Chemistry can benefit is by communicating and sharing information. Throughout the process we were continually reminded of the need for departments to reach out to one another. We believe that formalized test structures and general sustainability-related prompts or savings tips housed and distributed by UITS could go a long way to reducing costs through smart, "green" practices.

Print Quotas and Allotments

One of our more troubling findings was that, come the end of each semester, a small minority of survey respondents indicated that they would print all the remaining pages from their print quota, because they

had "paid for them." That is, students with an additional 100 pages of quota would visit an IUB STC and print 100 blank sheets of paper. This is the wasteful type of behavior IUB should strive to eliminate. On average, undergraduate students print 359 pages per semester, while graduates print 581 pages per semester. Only about fifteen percent of undergraduate (14.6%) and graduate (15.1%) students exceed their print quota, yet these users account for nearly forty percent of all student pages printed. We believe we should re-shape printing culture on campus by encouraging a reduction in printing in the most visible way possible – by reducing and eventually eliminating the print quota system.

We found that institutions within the Big Ten that set printers to the duplex default setting and have a strict pay-as-you-go (or, pay-per-page) system have decreased on-campus printing. We recommend that IUB let users choose their printing setting with a simple menu at log-in (as seen above in Figure 2) and incrementally phase out the print quota system beginning as soon as possible with an updated allotment of 400 pages per undergraduate student and 600 pages per graduate student. Students who exceed this limit should be charged a five cent-per-page fee and the additional money generated from this one-cent increase (currently additional pages cost four cents) should be reinvested in 100 percent recycled content paper. These quota numbers should be reassessed and reduced over time with the goal of a pure pay-as-you-go (or, pay-per-page) system in the future. We believe a reduction in the short-term may be more feasible given the logistical hurdles associated with a completely new system.

Other Study Areas: Alternative Inks, Adobe Acrobat Pro X, Ecofont

Based on research conducted in IU Chemistry and the review of solid ink technology, we believe it to be worthwhile for departments to conduct cost analyses on departmental printers currently in use and compare those numbers to newer technologies. We believe that for some departments Solid Ink is not only a good environmental or sustainable choice, but also a good economic choice.

Also, we believe that, as part of re-shaping printing culture on campus, emphasis should be placed on technology (like Acrobat Pro X) that reduces the need for printing and mitigates toner consumption ("greener" fonts like Century Gothic and possibly Ecofont). This focus on emerging technologies should be done through the Office of First Year Experience, the Office of Sustainability, and by IUB faculty.

IT and Sustainability

Catalog of Present Initiatives at Indiana University

There are currently a number of green initiatives at IU. For example, the Green Team certificate program is intended to promote ever-increasing sustainability (including the area of computing) in campus departments and offices. IU also provides a wide variety of online services to reduce paper usage and increase convenience and efficiency. For instance, employees can utilize many online services such as ePTO. All students use Oncourse and OneStart to perform a variety of activities such as registering for class, viewing assignment, grades, and announcements, and paying tuition and fees. Transportation is another area with online services. With ZipCar and Zimride, people can find cars near them online, and either rent the car or share ride with others. The campus bus system also provides live maps of bus routes.

A campus-level implementation of online course evaluations is currently underway. From a sustainable computing perspective, online course evaluations will improve resource management and conserve

paper. Conducting course evaluations electronically will result in significant cost savings and has the potential to help IU move toward standardizing evaluations.

The IU President's Office created a task force to implement online course evaluations by 2013. The unit is responsible for determining the evaluation's content and format, as well as choosing a vendor, security provisions, data management, and troubleshooting. The task force will conduct a pilot test, interviews, and then present recommendations to the President's Office in 2012.

Electronic Ticketing

There are various methods of electronic ticketing. Student IDs, credit cards, or bar codes downloaded on mobile phones can be scanned to enter events. Currently three major departments at Indiana University utilize large ticketing systems – the Jacobs School of Music, the Department of Theatre and Drama, and IU Athletics. Only IU Athletics has a partial electronic ticketing system for football student season ticket-holders. Other departments do not possess electronic systems primarily because of the capital and implementation costs. Nevertheless, in a student survey, two-thirds of the respondents supported e-ticketing. Although IU outsources all its ticketing business to Ticketmaster, IU maintains authority on the method of delivery.

Recommendations

1. Continue to experiment with the IU Athletics electronic student ticketing system.

2. As technology improves to meet needs and costs fall, consider integrating electronic ticketing where possible.

Green Teams

Green Teams are informal groups that exist in many departments across campus and work collectively to promote environmentally sustainable practices on campus. The group created a blog that contains information on upcoming events and a discussion section on "Best Green Team Practices" in order to promote efficient communication. Although the Green Teams intern acts as the administrator and sole publisher of posts, any Green Team member may participate by submitting a post to the intern or commenting on existing posts.

Recommendations

1. Continue to update the blog and encourage participation by all Green Team members.

2. Increase functionality by adding a calendar widget to inform members and the public about upcoming events.

3. Include discussion forums for to each Green Team to enhance visibility and participation.

Energy Dashboards

Energy dashboards are a creative way to use IT to promote sustainability. By providing user-friendly graphics, they increase awareness about energy usage and thus reduce consumption. Commercial

vendors of energy dashboards, such as Lucid Design Group, offer interactive graphs that allow user to view data in different ways, see historical trends, and compare energy consumption by building or by end use. These dashboards also provide real-time data and have the capability to connect to social media.

Rather than purchase dashboard software from commercial vendors, some universities have built their own. These institutions include Purdue University, the University of Iowa, and the University of California San Diego. Although not as versatile as commercial dashboards, these versions provide similar graphs and data on energy usage.

Recommendations

1. IU should conduct an analysis comparing the costs of purchasing a suitable vendor-provided energy dashboard with the costs of building a dashboard in-house.

2. Install energy dashboards in all major buildings on campus, including dormitories, academic buildings, the Wells Library, and the IMU.

3. Dashboards should be automated, updated continuously to report real-time data and highly visible, placed in a prominent location in high-traffic areas.

GoGreen Gadget

The GoGreen Gadget has the potential to save the university between $300,000 and $500,000 in energy costs and reduce carbon dioxide emissions by putting desktop computers in a deep sleep. An administrator must install the gadget, and although the School of Education and HPER have implemented it department-wide, other departments have not done so. When speaking with IT managers, we learned they believed that installation was somewhat daunting, and it was difficult to see the Gadget as a priority, though most of them were receptive to the idea in theory and knew that they needed to reduce energy usage. We believe that since the university as a whole will realize the savings in energy, it is important to get support from the larger university administration. We also believe it will be useful to create a positive image of the GoGreen Gadget by marketing it in traditional channels to students and faculty.

Recommendations

1. Pursue the possibility of an STC/Chemistry collaboration.

2. Clearly communicate ways for technical support, and any resolved issues that may contribute to the perception that the GoGreen Gadget is bugged.

3. Talk to individual IT managers to understand their concerns and offer them help for their specific circumstances.

4. Use basic marketing channels to increase awareness of the GoGreen Gadget on campus.

5. Seek support from higher levels of University administration.

Using Smartphones to Conserve Energy and Water

The pilot project is intended to enable students to report leaky faucets and running toilets from their mobile phones. Smartphones can read barcodes and the square "Quick Response," or QR codes allow phones quick access to a phone number or Website, which appears on the screen once the QR code is successfully scanned.

Fliers containing QR codes were placed in bathrooms in the School of Informatics and Computing. The fliers contained a short amount of text letting visitors know they can report issues by scanning the QR code with their smartphone. Once scanned, the user is presented with a link to a short form that asks what they would like to report, where they are, and for additional comments. An additional choice stating that the user has nothing to report but likes the idea was included on the form and the flier. Although there were only three responses during the three-week trial, all had nothing to report but were supportive of the concept.

Recommendation

1. Pilot project should be scaled up to include multiple buildings across campus to more thoroughly evaluate its feasibility and utility.

Best Practices

The Best Practices committee conceptualized our research plan as having three primary goals:

Goal 1: Establish the "key" sustainable IT practices that are used in business, governmental, and
            academic settings.
Goal 2: Determine whether these practices have been or could be implemented at IU.
Goal 3: Identify best practices applicable to IU in the areas of e-waste, duplex and reduction in
            printing, and data center energy use. Through the data gathered and here reported, the best
            practices group hopes to provide IUB with the means to improve its STARS and Campus
            Sustainability Report Card scores and effectively utilize information technology to achieve
            some of its sustainability goals (as stated in the Office of Sustainability's 2020 Master Plan).

Best Practices in E-Waste

There are several best practices in electronic waste that IU could implement. The first is virtual desktops. Virtual desktops are stored on an off-site server, which reduces the need for internal computing power at the workstation. Servers last longer than individual computers and require little maintenance, which minimizes the creation of e-waste. Additionally, virtual desktops create gains in efficiency, as housing the computing power on servers is more efficient than in individual CPUs. A second best practice comes from the University of Michigan and is a guide to their departmental "Green Clean Day." The guide is distributed among departments, and it outlines how to properly dispose of e-waste and other materials from offices and other locations within the building. The creation of purchasing standards is another possible best practice. Purchasing machines with long lifespans that contain fewer toxins, reusable parts and meet energy standards will help minimize the volume of e-waste the university creates. A final best practice comes from Ohio University. Ohio University takes old file

cabinets and turns them into secure e-waste bins. The file cabinets are located throughout campus and have slots to dispose of cell phones, CDs, flash drives, batteries, and other e-waste. IU spent $450 on a single cell phone disposal bin. This best practice not only allows for an easy way to dispose of e-waste but it also saves cost and finds a new use for old file cabinets.

Best Practices in Duplex Printing

Extensive research of duplex printing and the related facets of sustainable computing demonstrate the considerable benefits of duplex printing far outweigh the associated costs. Therefore, duplex should be the default printer setting. Duplex printing reduces paper consumption, which results in both financial and environmental savings: Decreasing paper consumption at IU will lead to cost savings from reduced purchases and a reduction in waste disposal costs, all while lowering paper production and CO_2 emissions. Additionally, research indicates liquid printing ink has various toxins detrimental to the environment and personal health, but solid ink may be more health and environmentally friendly. However, no conclusion can be drawn on the threat these toxins carry, and it is recommended a cost-effectiveness or cost-benefit analysis be conducted on the printing-ink alternatives in the duplex printing section.

Best Practices in Data Centers

Within a large computing network, the data center is the largest and most important component. At the most basic level, a data center stores the system's backup power, along with security filters, cooling systems for the processors, and large amounts of data and secure information. The United States Environmental Protection Agency (EPA) and Energy Star Program spearheaded a joint study to compile information on the best practices to increase energy efficiency within data centers (U.S. Environmental Protection Agency, 2007). This study concluded by identifying three areas of opportunity: improved operations, best practices, and state-of-the-art technology. Suggested actions under this category are server consolidation, elimination of unused equipment, power management and improved airflow. Ultimately, this could save $1.6 billion dollars (2005) across all three sectors (Energy Star, 2011).

Best Practices in the Public Sector

Federal

In October 2009, President Obama passed Executive Order 13514, stating, "In order to create a clean energy economy that will increase our Nation's prosperity, promote energy security, protect the interests of taxpayers, and safeguard the health of our environment, the Federal Government must lead by example" (Exec. Order No. 13514, 2009). This order mandated that the federal government and its agencies pursue energy efficient practices and create agency-specific strategic sustainability performance plans. One way that the government has responded is through the Office of Technology and Electronic Commerce in the U.S. Department of Commerce's International Trade Administration. The department published a Green IT To-Do List, listing ten easy, low/no cost ways to save IT energy and cut CO_2 emissions. The list included simple ways to begin the process of greening IT, including basic practices such as unplugging chargers, and turning off PCs and monitors when not in use. They have made this list accessible to their employees and published as an easy reminder.

State

At the state level, the past several Indiana state administrations have encouraged the ongoing efforts of the Greening the Government plan. The state's Greening the Government Plan includes five major categories: (1) Employee Education; (2) Source Reduction and Recycling Collection; (3) Environmentally Preferable Purchasing; (4) Pollution Prevention and Energy Efficiency; and (5) Employee Transportation. This plan encompasses many of the best practices supported by the Best Practices' literature review including: a sustainable purchasing plan and addressing energy efficiency and the greening of state buildings (IDOA, 2011[2]).

The State of Indiana has been applauded for its greening efforts. The Indiana Office of Technology was founded with three goals in mind: (1) improve IT service, (2) reduce costs, and (3) employ green initiatives wherever possible (Brandel, 2009). The IOT has made progress in terms of sustainable IT is the use of best practices in the consolidation of seven data centers into one and the reduction of servers by one-third through virtualization (Brandel, 2009). By 2009, IOT upgraded 30,000 desktops to Dell machines using Intel Corp.'s vPro chip, which resulted in $400,000 in savings, a reduction in electricity use and CO_2 emissions, and an increase in productivity (Id.). The IOT offers a unique program to incentivize employees by including metrics for greening in performance-based pay, and it produces a monthly newsletter highlighting its sustainable activity (Id.). The efforts of IOT have been so successful, that they have been encouraged to start a pilot program in which other governments might take part in an effort to reduce inefficiencies and equipment in other areas (Id.).

Local

At the local level, the City of Bloomington (COB) is pursuing many best practices in terms of sustainable computing. The COB is currently in the process of virtualizing as much of their system as possible. Because of the nature of some of the city's systems, virtualization is not possible for everything. For example, the utilities department's system is too integrated and complex for virtualization. The ITS department has replaced all the computer's supply bricks with more energy efficient options, an alternate means of addressing sustainability through power management. The city has also switched all CRT screens to the more efficient LCD screens. The city has collaborated on community E-Waste Days. The ITS department also has its own policies in place for dealing with e-waste. The COB replaces about one-fourth of its computer equipment each year to keep up with new technology and registered 501(c)(3) non-profit organizations can apply to receive this equipment free of charge. The City of Bloomington is currently drafting a sustainable purchasing plan. The proposed plan encourages the purchase of Energy Star electronics when available, which will reduce energy usage in city departments.

Best Practices in the Academic Sector

The academic sector's best practices were compiled using data taken from the Campus Sustainability Report Card (CSRC) and AASHE's STARS (Sustainability Tracking Assessment & Rating System). Through our examination of data submitted by highly rated schools, it is our intention to support IUB's independent commitment to environmental progress as well as to provide recommendations that would raise the school's scores in each of these rating systems. The best practices common to both systems were the need for a formal sustainable purchasing plan for computers and electronics and improved recycling options for e-waste.

Though IUB reported specific information regarding its many sustainable IT practices, programs, and technologies, STARS generally allows discretionary reporting of these initiatives, as participating universities have the freedom to provide as much or as little information as desired. As a result, STARS is somewhat difficult to utilize and hindered our ability to compare IT practices and programs across institutions. However, there were a few specific areas in which sustainable information technology solutions were obviously applicable. The category identified as being the most relevant to sustainable IT was coincidentally, the category in which IU received the lowest of its STARS scores: the "Operations" category. The subcategories of Waste and Purchasing were appropriate for examination as well.

For a breakdown of IU's scores in relevant categories on both the STARS and CSRC examinations as well as recommendations on how to improve performance see the Best Practices section in the Final Report.

Conclusion

Overall, the research from each of teams indicates that there are number of opportunities for Indiana University to improve IT Sustainability on campus. By developing a systemized electronic waste system on campus, promoting duplex and sustainable printing, encouraging new ideas such as the Go-Green Gadget, improving data center efficiency and staying up-to-date on best practices, the University can serve as a model for sustainability around the country. We hope that these recommendations and the following detailed report provide IU with useful and attainable ideas and programs.

Introduction

The Indiana University Sustainable Computing Working Group, which is part of the Campus Sustainability Advisory Board, commissioned a group of graduate students from the School of Public and Environmental Affairs to conduct a study to determine the best means for the University to improve sustainable information technology systems on Indiana University's Bloomington campus. Sustainable information technology systems are a key component of the University's mission to promote environmental stewardship, and the practice provided students with an opportunity to design models of sustainability for Indiana University that could serve as examples to other institutions within the state, nation, and abroad.

The graduate students conducted the study over the course of the spring 2011 semester and focused on five specific areas of concern and opportunity including the following: E-waste Collection, Data Center Energy Usage and Disposal, Duplex Printing, the Use of Information Technology to Enhance Sustainability, and a Best Practices Document. The study focused on how to best accomplish the University's goals of improving sustainable practices in information technology. Students separated themselves into groups focusing on each topic with the responsibility of learning the intricacies of the issue, engaging all relevant stakeholders, and making recommendations.

Sustainability issues are a priority for Indiana University's administration, and sustainable information technology systems play a critical role in the overall approach to the topic. By tackling sustainability issues early, the University has the opportunity to lead the nation, a position that will not only attract positive press but will also create an incentive for other universities to follow suit. Students applied knowledge obtained in their graduate study to analyze and develop proposals for sustainable computing practices at the University and the following sections summarize their methods, results, and analysis of each topic. It is the ultimate goal of the class that this document serve as a blueprint for the University as it plans to enhance sustainable information technology systems.

Organizational Structure

The division of labor primarily focused on five groups, with each class member belonging to one. In order to organize and communicate properly, one member from each group served on the Coordination Committee. This committee met on a regular basis to update each other on the progress of respective projects. They also determined the nature of the deliverables and communicated with the Sustainable IT Working Group. Ginger Simpson, who served as a student representative on the Working Group, acted as a liaison between the Working Group and the Coordination Committee.

In anticipation of possible redundancies between working groups and the Best Practices group, a member of the Best Practices group acted as a liaison to each of the other groups. This person served as another form of checks and balances, by keeping assessed of the groups' progress and ensuring that the research and findings of the group corresponded with the findings of the Best Practices group.

E-Waste Collection and Disposal

Introduction

Creating a systemized electronic waste collection and disposal system on Indiana University's campus is important at both the micro and macro level. Although our report focuses on how electronic recycling can benefit the Bloomington campus, the positive effects extend to the national and even international level. To better understand the environmental impact of electronic waste, it is essential to understand the size of the waste stream and the chemicals released one the electronics are disposed. It is also helpful to gain perspective on what happens to the millions of tons of electronic waste that American companies "recycle," and to better understand the decentralized supply chain of electronic waste.

According to the Environmental Protection Agency, discarded electronics make up around two percent of the municipal solid waste stream, and this number is quickly growing (U.S. Environmental Protection Agency, 2011). Between 2003 and 2005 the landfills received the following volumes of electronics: 180.9 thousand tons of desktop computers, 19.3 thousands of tons of laptop computers, 291.6 thousands of tons of CRT monitors, 709.1 thousands of tons of televisions, and 7.9 thousands of tons of cell phones (U.S. Environmental Protection Agency, 2011). In addition, 157 million computer products were discarded including CPUs, monitors, notebooks, keyboards, mice, printers, faxes, and copiers. Twenty million televisions and 26 million cell phones were thrown away. Alarmingly, only 18 percent of TVs and computers are reported as being recycled and only ten percent of cell phones (U.S. Environmental Protection Agency, 2011). This means that a large bulk of electronic waste is going into landfills.

Based on estimates, the approximate 290 million Americans in our county own over two billion pieces of high-tech consumer electronics (Grossman, 2007:5). Because of the high replacement rate of electronics, this means that five to seven tons of electronics become obsolete each year (Grossman, 2007:5). The fact that the majority of electronics are disposed of in landfills is of particular concern because of the toxic material mix found within these products. Cathode ray tubes and circuit boards contain lead, a heavy metal that can impair neurological function and fetal development. Mercury is used in the lamps that light flat-panel display screens including on laptops, newer desktops, and thin televisions as well as cell phones, circuit boards, and digital cameras. This is dangerous because mercury can cause similar problems as lead- neurological, kidney, and reproductive damage. Cadmium, a known carcinogen, is found in circuit boards. Electronics also contain a variety of plastics included polystyrene (HIPS), acrylonitrile butadiene styrene (ABS), and polyvinyl chloride (PVC). Other elements contained in electronics include copper, antimony, beryllium, barium, zinc, chromium, silver, nickel, gold, and PCBs (Grossman, 2007:7). There are also subtler dangers found in the chemical nature of electronic equipment. For example, some circuit boards use beryllium elements as insulators, and if released during disposal beryllium is known to cause severe lunge disease (Grossman, 2007:18).

The danger in these chemicals ending up in landfills is that they have the potential to leach into the water table and soil causing ingestion by aquatic creatures that may work themselves up into human diet. According to a study that researched leaching of heavy metals in electronics, lead in cathode ray tubes leached at 70 times over the U.S. EPA limit. Further results revealed that circuit boards leached lead at approximately five times the U.S. EPA limit, mobile phones sixteen times the limit, and TV

remotes nine times the limit (Keith et al.., 2008). If these electronics are left to decompose in landfills, they pose a significant environmental and public health threat.

It is evident that the proper disposal of electronic waste extends beyond the desire to be a good environmental steward. By not properly recycling electronic waste, we risk contaminating the water table and endangering public health. These public health issues range from local to international and encompass everything from production of electronics to disposal. For examples of environmental impact during production of electronic equipment, one only need to think of the amount of mining that occurs to excavate the metals used in machinery. It is estimated there is 1.3 billion pounds of copper in computers alone, namely because it is one of the most popular metals used in high tech equipment because of its superior conductivity of electricity (Grossman, 2007:23). Mining copper consumes a large amount of energy; in fact, it is estimated 7 to ten percent of the world's energy consumption is derived from mining (Grossman, 2007:276).

In addition to the environmental costs of mining and excavating raw materials, there is also an environmental toll during production. For example, producing a semiconductor involves over 250 steps of chemical layering and etching. By the end of production the .07 ounce microchip will have generated almost 57.2 pounds of waste (Grossman, 2007:60). This example is extremely difficult to extrapolate to all electronic materials, and therefore the ecological footprint from production to disposal of electronic waste is yet to be determined.

One of the more politicized concerns regarding electronic waste is the exporting of it to different countries. In addition to the domestic risks associated with improper e-waste disposal, improper recycling techniques pose a significant health and environmental threat across the globe. The process of e-waste recycling is highly labor and energy intensive and provides only marginal returns. The United States has comparatively restrictive processing regulations, which in turn, increase marginal costs. However, the United States is not a party to the Basel Convention, which bans international trade of toxic wastes (Basel Action Network and Silicon Valley Toxics Coalition, 2002; Carroll, 2008). Consequently, approximately 80 percent of the e-waste that is to be recycled in the United States is instead shipped overseas to China, South Asia or several African nations (Chea, 2007).

These countries do not have the necessary domestic policies or infrastructure to ensure proper recycling. Many of the major e-waste recycling areas in these countries use rudimentary processes to extract the valuable metals. Often, piles of broken electronics are burned in order to remove the plastics and unwanted metals, enabling the individuals to pick-out the valuable components in the remnants. This process releases significant amount of toxic fumes into the air and causes contamination of surface and ground water as well. Research indicates dangerously high levels of lead and other contaminants in both the children who work in metal extraction and those who live near processing areas (Carroll, 2008).

E-Waste and University Property

Indiana University has a well-noted stewardship and responsibility to minimize the previously explored environmental and resource problems associated with mismanaged e-waste. Additionally, the university has a significant financial stake in the timely collection of electronic equipment as many functional or repairable items can be resold at a percentage of the purchase price. When e-waste is stored, neglected, or disposed of improperly, the university loses a revenue opportunity. This analysis, therefore, addresses the issues associated with timely e-waste collection to prevent dumping and to increase the financial

gains of saleable equipment. Most electronic equipment used on campus has a useful life of 3-4 years; it is estimated that the resale value of a 3-4 year old computer, for example, decreases 50 percent when sold one year after being cycled out compared to being sold immediately. These powerful depreciation rates raise questions about how and how often e-waste is exported from departments throughout the university.

To assess the current e-waste situation and practices at IU, we conducted research regarding the relevant institutional policies and conducted a series of interviews and surveys with relevant stakeholders. Our initial investigation presented the possibility that there is substantial E-waste "hoarding" occurring throughout departments and business units. In defining the scope this research, we identified the following stakeholders whom have a vested interest or role in the E-waste processes on campus:

- UITS
- IT Managers (Local Support Providers)
- IU Surplus Stores
- IU Office of Sustainability
- Apple/Sims Recycling
- Purchasing/Procurement
- Individual IU Departments

The Disposal & Redistribution of University Property (http://www.indiana.edu/~purchase/policies/14_0.shtml) and Sale of Computing Equipment (http://www.indiana.edu/~purchase/policies/14_1.shtml) policies of the Office of Procurement Services offer the primary institutional policy on the disposal of unused or expired electronic equipment. These policies require departmental and institutional tracking, data wiping, and resale of electronic equipment.

With this massive volume of electronic equipment cycling through a large number of separate departments and units, the details of such a policy are easily overlooked or weakened as they pass through multiple channels and levels of communication. Understanding the reality of e-waste practices will enable UITS and the Office of Sustainability to formulate the most effective mechanisms for responsibly collecting e-waste. We sought out the opinions of generous and obliging institutional employees to help us detail the common practices and problems faced when dealing with electronic waste.

IT Local Support Managers

The purpose of the IT survey was to collect information about the equipment inventory and e-waste removal practices of IT managers across the Bloomington campus. These individuals play a key role in the flow of electronic equipment through the school, particularly in determining the life cycle of machines and making the final decision to send them to surplus. To communicate with IT managers, we coordinated with the Data Center working group to create a survey which would incorporate both group's questions and then be distributed to the IT managers at the Bloomington campus. After input from VP of Information Technology Todd Herring, we removed some questions and split our combined survey into two shorter surveys. Our hope was to increase participation by distributing a smaller, quicker survey. To not overburden managers with too many surveys, we split the IT manager group with the Data Center Group and only surveyed our half of the managers. All responses were confidential to encourage accurate reporting of less desirable e-waste practices. However, we did collect

the e-mail addresses of the IT managers, for the purpose of verifying that they were from the Bloomington campus and also so that we could ask follow-up questions of managers with interesting responses. These are not included in the final data set to preserve anonymity.

The survey collected data on the life cycle of electronic equipment which is displayed as Figure 1.

Figure 1.   Average Equipment Life Cycle Measured in Years
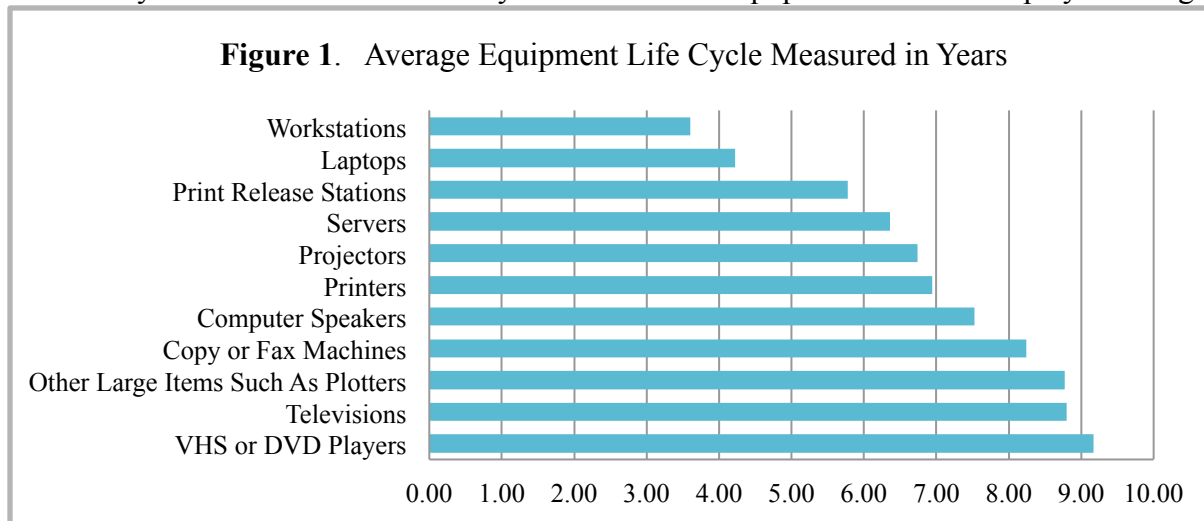
gure 1.
On average, computers and laptops are replaced every three to four years. Servers and printers have a longer useful life and can last up to seven years, and most other equipment remains in use either for very long periods of time, over eight years, or until it breaks. Because computers and laptops will depreciate in value less over the course of their shorter life cycles, they are the most important component of the e-waste disposal process from a purely monetary standpoint.

After equipment is sent to Surplus, only 19 percent of IT managers reported receiving money back during 2010 from the sale of their equipment as seen in Figure 2. Beyond the fact that some managers may not have had any e-waste to send to Surplus in that time period, there are two reasons that some managers may not receive money back. First,

Figure 2. IT Managers Reporting Reimbursement from IU Surplus

some managers retain equipment beyond the point where it has resale value, in which case IU Surplus can only send it for recycling. Second, sale receipts are placed in whichever account number is specified on the Surplus pick-up form. In some departments, building managers are responsible for the pick-up of e-waste items and may receive the resale funds into their account.

Figure 3. Stated Awareness of Policies

Our survey revealed a high level of confusion about e-waste policies among IT managers. Though most managers state that they are aware of current policies,

5

53 percent of respondents revealed substantial lack of knowledge about proper procedures. These numbers are displayed in Figure 3. Additionally, our case study results reveal significant hoarding on the part of at least one department. Overall however, most managers appear to be keeping only a small number of machines in storage. Of their total volume of electronic equipment, items in storage account for 13 percent, as shown in Figure 4. In an interview with the IT Manager of one school (which is summarized in Appendix EW-1), we learned of several reasons for IT managers to keep this equipment in house for a while before sending to Surplus. The IT needs of departments fluctuate throughout the year, with different professors and different office or lab spaces having different needs. Unexpected breakdowns need temporary replacements and sometimes an emerging computer need can be met with old hardware. For this reason, IT managers keep small amounts of old hardware on hand, to offer increased response time to changes in equipment needs and also to control costs.

Figure 4.
Average Equipment Inventory
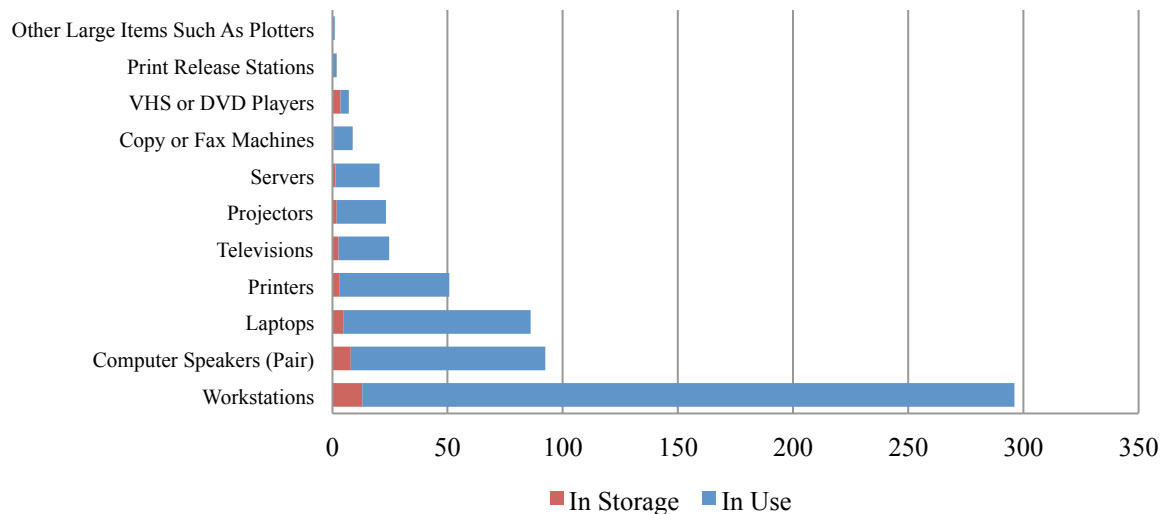
Despite this information, we also know that some IT managers have simply been too busy to send stuff to storage, with 67 percent of IT managers reporting that some of their items are still around simply because they have not found the time to send them on to storage yet. Five admit to simply throwing old equipment away. Reasons for keeping equipment in storage are reported in Figure 5 and disposal methods are reported in Figure 6.

Four main barriers to proper e-waste disposal were identified in the survey results. First, the time cost to IT managers is prohibitive. Any computer sent to Surplus must first have its hard drive wiped clean of any university data using the most current Department of Defense standard for data deletion. The time to do this for any one computer varies depending on hardware capabilities and the amount of data being stored, but on average is two hours. Time savings do occur if conducting this procedure on more than one machine at once. However, one manager reports that this means that he waits until he has at least ten machines ready for Surplus before he cleans their hard drives. During this wait time, all of the equipment value continues to depreciate. For items without data storage, such as printers or projectors, the time taken to prepare an item for Surplus is much shorter at about 20 minutes.

Many managers report frustration with this time intensive process, especially since IU Surplus conducts a second wipe of all drives once they arrive at the warehouse. External hard drive erasing services are available, but only at additional cost. One manager reports simply removing the hard drives from machines and keeping them in their office to avoid the data deletion task. According to Surplus, it is difficult to resell a machine without a hard drive and most machines received in this state are simply sent to recycling, with no revenues accruing to the IT department. Surplus has recently purchase a hard drive shredder, and may change to a system where all hard drives are shredded at no cost and replaced with purchased refurbished drives.

Another barrier is transportation. Surplus will supply one man and one truck to collect equipment. For large volumes of equipment, or for especially heavy items, this is not sufficient to load the truck. Surplus asks IT managers to provide their own labor to assist in this process or to contract with IU Moving and Set-up to have the materials delivered for them. Since some managers are sitting on large quantities of equipment, transportation to the Surplus Stores can be a daunting task.

Figure 5.
Disposal of Used Equipment

Figure 6.
Reasons for Storing Equipment
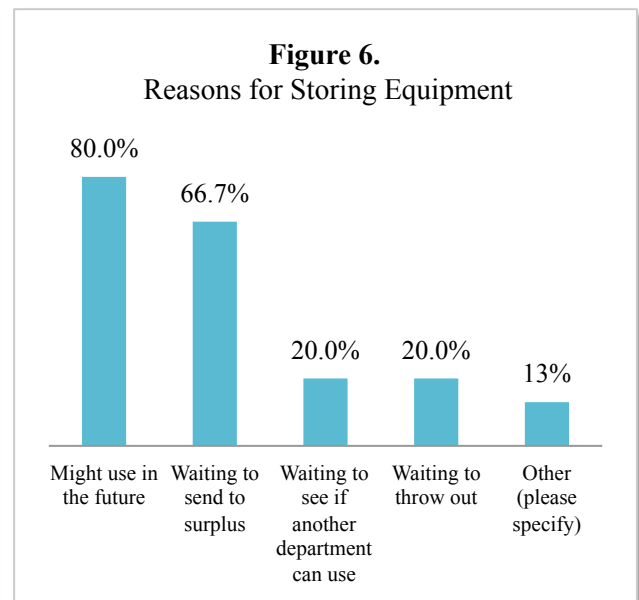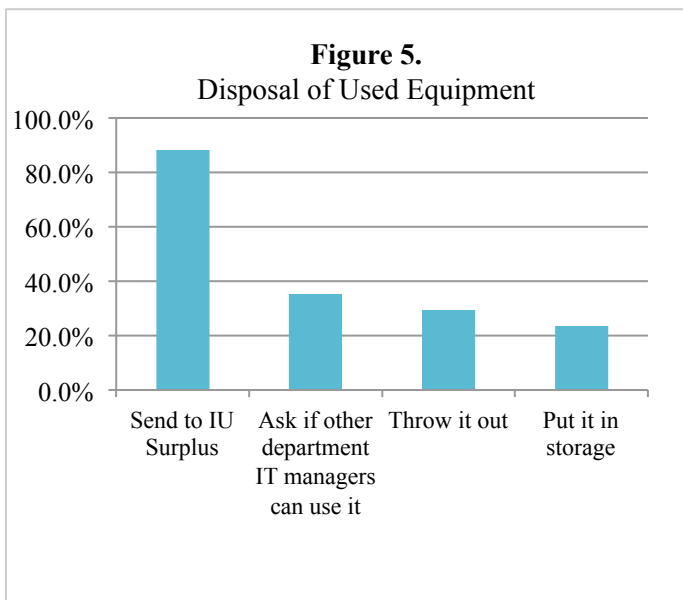
There is also a general lack of awareness about the services offered by IU Surplus. Some managers commented that they would like regular equipment pick-ups, though they seem unaware that pick-ups may be scheduled at any time. Once this information is broadly disseminated, the primary benefit from regular pick-ups would be motivation for each manager to send equipment to Surplus on a more regular schedule.

IU Surplus Stores

On February 18, 2011, the E-waste Group members Katrina Saucier, Brice Crozier, and Caleb Baker met with Craig Porritt and Jim McAuley. Jim McAuley is the manager of the university Surplus Stores and has worked in Surplus for over 25 years. Craig Porritt is the administrative manager of the university Surplus Stores and began working in this position within the last six months. The interview lasted for about an hour and followed a question/answer format with frequent discussions surrounding

certain procedures and common practices. A summary of the information discussed during this interview is detailed below. An outline format of the questions and answers are provided in the Appendix EW-2.

The current system for electronic equipment pick-up involves filling out a pick-up form that is located on the Surplus Website (Appendix EW-3) and sending the form to the Surplus Store. Pick-ups do not cost anything, and there is no minimum volume needed. There is one full-time driver with a truck who is available during Surplus' open hours. The only restriction surrounding the pick-up is Surplus' manpower because the only person going to the pick-up is the driver. Therefore, if items are large, he needs assistance moving the material. Also, there are departments that hire outside vendors (moving companies) to truck items to Surplus. Mr. McAuley and Mr. Porritt could not speculate on why departments choose this option.

At this time, the Surplus Store is in a period of transition and updating. The Website is being redesigned and Mr. McAuley and Mr. Porritt feel advertisement of the current system is needed before considering a monthly e-waste pick-up. On one hand, they thought a regular monthly pick-up may help move item quicker and gave Surplus the change to be proactive rather than reactive. On the other hand, it may cause problems on the handling side since large amounts of electronic would arrive at once. Given new space and manpower limitations, these large fluxes of items could cause a number of logistical problems.

In general, Mr. McAuley and Mr. Porritt feel strongly that departments are following disposal protocol and are not throwing items out. They feel one of the reasons IT may not quickly move electronics is due to wiping the hard-drive and the extra time required if the computer is not functioning. There also appear to be departments that are better about bringing electronic items to Surplus in a timely fashion than others. The incentive to quickly bring items to Surplus would appear to be substantial; the departments whose items are sold at Surplus receive 50 percent of resale value. Over the fiscal year, $95,000 has been remitted to all of the departments combined for all items (furniture, computer, etc.) sold by Surplus. These profits are forwarded to the account number provided for the items.

Over the past two years, Mr. McAuley has noticed that incoming items are getting older. He thinks this may be due to tightened budgets and departments extending the life of electronics to reduce expenditures. Therefore, incoming items are worth less than incoming items from years past. Even with this obstacle, about 85 percent of electronic products can be sold with a ratio of 3:1 of electronic items that go into a "lot" rather than sold on shelf. "Lots" are pallets of like material that may or may not work and that are sold in an auction. Buyers of "lot" items sign an agreement to properly dispose of e-waste (see Appendix EW-4). Shelf items are priced and sold to the general public. "Lot" items are worth about ½ value of same item sold on shelves. About 50 systems per month (on shelves) are sold at IU Surplus and about three times that many are sold in lots (about 150 items).

There are no set guidelines for discount rates or a depreciation rubric used to price electronic items, and Mr. McAuley prices item based on what an individual will pay. Sometimes he uses E-Bay pricing on Apple products as a guideline for a reasonable price. The depreciation rate for an electronic item is quite steep; Mr.McAuley estimated there is a 50 percent depreciation for each year an electronic items is stored in storages. For example, a computer this year can be sold for $300, next year is it worth $150. Currently, Apple picks up the e-waste from Surplus and there is a plan in process to make these pick-ups more regular and to coordinate with other Indiana University campuses.

All of these figures from this interview were based on reasonable estimates by Mr.McAuley. Due to his 25 years at Surplus, the E-waste Group feels confident that these figures are accurate and provide the best information concerning electronics and the IU Surplus Stores. At this time, there is neither an accounting system nor a robust inventory system to provide equivalent information.

Based on the information shared by Mr. McAuley, Mr. Porritt and IT managers, Figure 7 shows the flow of electronic material through Indiana University's current system.
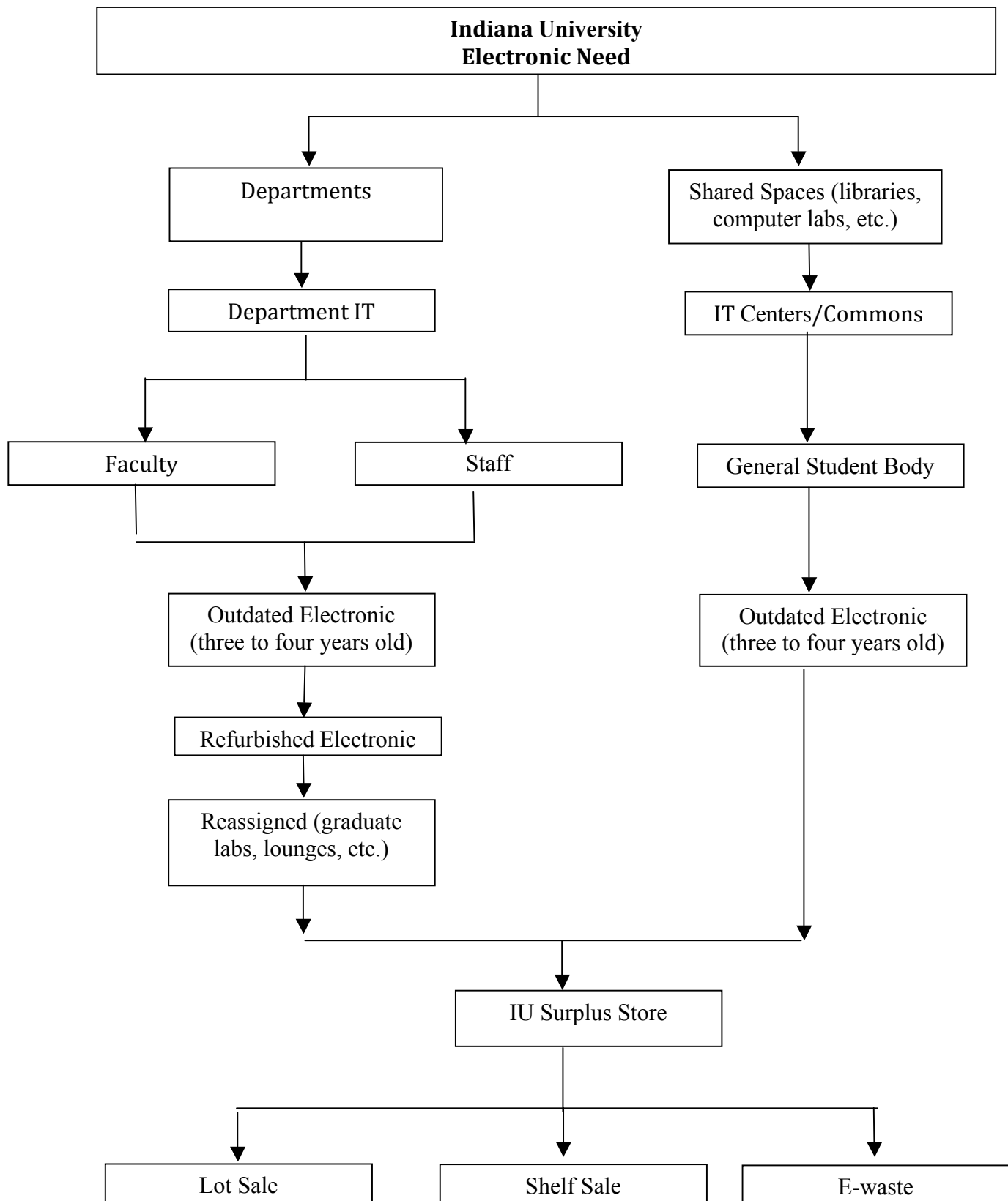
Figure 7. Flow chart of electronic items through the Indiana University system.

Case Studies and Findings

On March 9, 2011, two members of the E-waste Group, Katrina Saucier and Susanna Foxworthy, visited a building on campus that was reported to have a large amount of electronic material in the hallways and stairwells. The E-waste Group wanted to visit a department at Indiana University to create a case study surrounding the electronic material that is stored for long periods of time. The purpose of this visit was to take an inventory of stored items and create a case study of the stored electronic material.

When entering the building, there was a great deal of equipment in the entry way; some of the items had exposed circuitry (Figure 8).

Figure 8. E-waste with exposed circuitry found in the entry way of a building on campus (4/9/11)

We also found a large number of electronic items stashed in the hallways on the top floor of the building (Figure 9).

Figure 9. Items stored in the halls (4/9/11)

We took pictures of electronic waste found in the building. These items were unsecured, lying on benches along the length of the entire hallway (Figure 10).
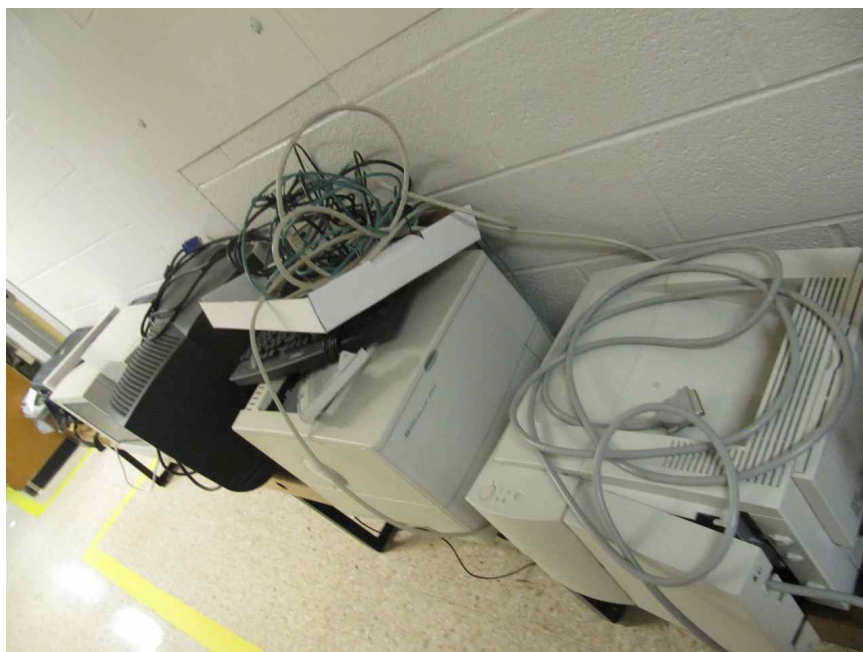
Figure 10. Electronic items along length of hallway (4/9/11)

We also saw a great number of specialized devices throughout the building (Figure 11).

Figure 11. Unsecured specialized electronic devices (4/9/11)

12

This field trip brought up the question concerning these devices since we were not sure if Surplus collected and sold these items. After discussing this issue with the Surplus Store, we discovered that the IU Surplus does collect and sell some of these devices. However, since a number of these items are commonly donated, the respective department usually handles the decommissioning of the donated item.

Due to the age of the electronics, there seemed to be a lag time in decommissioning of items and bringing it to IU Surplus. Therefore, we spoke with a building employee who said the common practice was to allow the items to build up in the stairwells and hallways until there was no room left, and then the building manager called Surplus for a pick-up. The employee estimated these pick-ups occur every six weeks, and he did not know what happened to the specialized equipment.

During the visit, we collected a summary of items in the building by volume and type, and calculated an estimate of how much money the department lost by not submitting these items to the surplus store as soon as they were decommissioned. We took an inventory of the items found in these areas (Table 1).

Electronic Equipment Found	Model	Quantity	Approximate Value at Age 4	Total Value
Printers	HP Laser Jet 4050	3	$ 300.00	$ 900.00
Desktops	Dell	3	$ 150.00	$ 450.00
	Power Mac 8600/200	1	$ 200.00	$ 200.00
Monitors	View Sonic E75	5	$ 75.00	$ 375.00
	Mac	1	$ 75.00	$ 75.00
Laptop	Dell	1	$ 75.00	$ 75.00
Keyboards	Dell	2	$ 4.00	$ 8.00
	Mac	1	$ 4.00	$ 4.00
Adding Machine	Unknown	5	$ 5.00	$ 25.00
Surge Protector Power Strip	Unknown	1	$ 4.00	$ 4.00
Cables (about 25 ft.)	Unknown	5	$ 1.00	$ 5.00
Mini Fridge	Kenmore	1	$ 25.00	$ 25.00
Total				**$ 2,146.00**
Department Reimbursement				**$ 1,073.00**
Lost Revenue over 10 years				**$ 21,460.00**
Specialized Equipment				
Mechanical Chairs	Unknown	4	Unknown	
Unknown Electronic Devices		3	Unknown	

Table 1. Inventory of out-of-service electronics found in a building at Indiana University on April 9, 2011 with assessed value included.

With the help of IU Surplus, we assigned values to all of the electronic equipment. The assessed value is based on the price the item could have been sold for at age four or five years old. This value is meant to parallel the worth of the item when it was decommissioned and simulate how much the Surplus Store could have sold the items for after they were taken out of service. Using this assessment, the values of lost revenues due to postponing the Surplus pick up was calculated using the below assumptions:

1. Cables are five feet each.
2. Prices are for top-quality resale items
    a. Working condition
    b. Shelf sale
3. Amount of equipment occurs every six months.
4. IU Surplus reimburses depart 50 percent of sale price.
5. All items are currently valued at $0.00.

According to this case study with the above assumptions, this department lost about $21,460.00 over the last ten years due to long lag times from decommissioning to resale. This evaluation only includes actual monetary losses due to depreciation of the items but additional factors that would quickly inflate this loss include real-estate value of building space items took over year and inconvenience of items consuming student's bench space.

Recommendations

After reviewing all aspect from the stakeholders, we identified the main issues with proper e-waste disposal and present the following recommendations.

1. Develop channels of regular communication among the three major e-waste stakeholders (the Office of Sustainability, IU Surplus, and UITS) to ensure that e-waste policies and practices are up to date and the most appropriate for current needs.
    Stakeholders should maintain open and regular communication about departments' needs to ensure that current policy and procedures are most fitting and efficient. Periodic check-ins with IT managers will ensure that the processes and methods for promoting responsible e-waste disposal are realistic and in-line with current technology trends. Incorporating Surplus leadership is critical to ensure that policy decisions will be plausible and successful from the stock, resale, and recycle part of the process. Open communication among the policy and logistic providers is important to establishing a responsive e-waste system on campus.

2. Reexamine the data wiping policy in order to minimize the dampening effect current data wiping practices have on the adoption of ideal e-waste disposal methods.
    Investigation into the obstacles that local support providers face in regards to proper collection and removal of e-waste reveals that the time required to satisfactorily clear hard drives is inhibitive, especially since the drives are wiped a second time upon arrival at IU Surplus. Moving to a system where drives are only cleaned at Surplus may remove barriers to proper e-waste recycling. Now is an excellent time to challenge this policy, as it will be reevaluated anyway as Surplus begins the use of the hard drive shredder.

3. Create an automated message system triggered by the purchase of electronic products that reminds local support providers about the available resources and recommended protocol for removing unused equipment.

   Installation of new equipment is an ideal time to remind local support providers of the avenues in place to dispose of e-waste, as the purchase of new equipment likely indicates that older items will be cycled out of use. An automatic message sent to IT managers should restate the e-waste policy and provide links and contact information to ensure that departments are fully informed.

4. Establish a designated "e-waste sticker" to adhere to electronic equipment that informs staff and faculty in all capacities within departments of the university's commitment to responsible disposal.

   The decentralized nature of information technology management and equipment on campus requires proactive methods for promoting awareness in all levels of departments. Placing an easily understood, symbolic e-waste sticker directly on the equipment may remind users not to store or throw away items. There is evidence that some faculty and staff members with their own space and equipment may be retaining items or possibly even throwing them away. Denoting the e-waste policy through a symbol or sticker will increase the likelihood that non-IT employees adhere to the university's adopted method of proper disposal.

5. Standardize an e-waste logo on university Websites, e-mails and equipment stickers to provide a universal symbol that will be easily recognized.

   An example of a possible logo:

6. To promote widespread inter-departmental adoption of timely and proper removal of electronic items from offices, distribute informational flyers to be displayed in high traffic areas that inform faculty and staff of the importance of not throwing away or hoarding e-waste.

   Similar to the e-waste sticker recommendation, promoting awareness of e-waste problems and policies among all employees is critical to ensuring widespread adoption of clean e-waste practices. Once campus Green Teams are more widely established, distributing this information may be an impactful task. Information flyers should describe what e-waste is, why it is important to resell or recycle e-waste, the financial and spatial advantages of collection, and who to contact within the building to have e-waste removed.

7. Start conversations with other IU campuses to share lessons learned, discuss opportunities for improvement, and to establish standard practices.

An assessment of e-waste practices at IU revealed surprising information from non-Bloomington campuses. One campus reported that they generally throw away unused or non-working electronic equipment all together, while another reported extremely successful collection of refunds from used computer sales. Central leadership as well as campus management can benefit from discussing best practices and established standards throughout the state.

8. Clarify information about e-waste processes that is contained on IU Surplus forms to eliminate misconceptions about costs to departments, re-sale revenues, and collection procedure.

There is a current disconnect between policy and messaging on IU Surplus forms that all electronics must go to Surplus and that Surplus will only take "sellable items." Survey results show that some administrators are not aware that all equipment must go through Surplus and others are not aware of, or are not receiving, money from equipment resale. Some administrators admit to throwing away electronics because they are not aware of current policy. The pick-up form for electronic waste should eliminate misleading language that electronics must have resale value in order to be picked up. Instead it should clearly state that all items must go through Surplus regardless of their age or condition. As the first point of contact between IT administrators and the Surplus Store, this form would also be a valuable place to advertise that half of all resale revenue is returned to the department

9. Develop a communication schedule for IT managers to remind them to schedule e-waste collection and to clarify policies.

A large obstacle for prompt e-waste collection appears to be motivation of individual administrators. In the survey, a number of administrators requested regular pick-ups of materials. Many of these administrators however, do not appear to be aware that IU Surplus will schedule a pick-up of electronic materials at any time, free of charge. Because this service exists, the benefit of a regular pick-up would largely be the motivating effect it has on individual administrators to get equipment out the door once or twice a year. Each month, a number of departments would be contacted by Surplus reminding them to schedule E-waste collection and supplying them with the necessary forms and information. A sample communication is included as Appendix EW-5. These communications would be staggered so that all departments would receive a reminder every six months. Most departments report having enough material ready roughly every six months to a year.

10. Develop alternative means for IT administrators to transport large quantities of equipment to Surplus.

While IU Surplus will collect materials for free, it will only provide a truck and one driver/mover. IT administrators report frustration that the collection cannot always handle their collection needs and that they must instead spend money on moving services to transport their equipment. Much of this problem should be ameliorated by having regular E-waste pickups. Large volumes of e-waste usually mean that a department has been sitting on materials for some time. For especially large requests that still occur however, IT administrators should contact Green Teams to take advantage of volunteer assistance with truck loading.

E-Waste and IU Student Property

As discussed in the previous section, all University-owned electronics must pass through the Surplus Stores, and materials and equipment that cannot be sold are recycled through an Apple Inc. sponsored partnership with Sims Recycling. Apple Inc. provides this service free of charge to the University, and Sims is known to be one of the most responsible e-waste recycling companies in the country. Although University IT managers have the opportunity to utilize these methods for disposing of electronic waste, there are few such options for students in terms of proper e-waste disposal. The following section analyzes the current situation regarding student electronics and proposes potential solutions to increase the amount collected for proper recycling

Currently there is one cell phone recycling bin operated by Eco-Cell on the Bloomington campus. The bin is relatively hidden in a corner of the Indiana Memorial Union, which decreases its overall utility and the likelihood students will use the service. The bin accepts only cell phones, and the company provides a portion of the revenue generated by their sale back to the university. However, each bin costs $450, and our interview with Steve Akers indicated students are not taking advantage of this opportunity. Additionally, many of the campus dormitories have other cell phone recycling options in the lobbies that are operated by student groups and campus organizations. These recycling boxes generate revenue for the respective organizations, and are likely too numerous to justify the expense of adding an Eco-Cell recycling bin to dorm lobbies.

There are currently no regular computer or other electronic recycling services for students on campus. As is the case with university-owned computers, the need to wipe the hard drive for any computer that is to be recycled prior to its disposal is a critical obstacle that must be addressed. Additionally, any on-campus drop area or bins must be secure and able to prevent theft. Though the university is prevented from donating unwanted electronics to charity by Indiana law, student-owned computers are not subject to the same restrictions. This freedom presents an opportunity for local charities and community organizations in need of new equipment or components, and students or their parents could receive a tax write-off if the organization is a registered charity. Matt Hottell from the School of Informatics runs an organization called the Serve IT Clinic, which restores and donates unwanted electronics to local charities in order to help them meet their IT and computing needs. There is a significant potential benefit to the Bloomington community if students regularly donate their computers to local charitable organizations.

In addition, The Hoosier-to-Hoosier event would serve as a suitable means for preventing unwanted student electronics from being thrown away. A partnership is beginning between Hoosier-to-Hoosier collection efforts and E-waste Days collection efforts. This is in the beginning stages and needs formalization to ensure that students receive a unified message regarding collection of unwanted items.

Currently, the biggest event that has the potential to involve students is the Electronic Waste Collection Days. This event involves citizens of Bloomington as well as IU students and employees who can donate their unwanted electronics by driving them to the football stadium for drop-off. This year, the event takes place on May 12th – 14th and the first two days are reserved for IU-affiliated individuals. During the final day, IU accepts donations from anyone in the community. Last year was the first time the event was held, but data indicated the community was the primary source of unwanted electronics. Apple Inc. pays the recycling costs for all donated items, and SIMS Recycling in Illinois actually processes the materials. Holding the event after the end of the school year likely prevented many

students from donating their unwanted electronics and is a missed opportunity for preventing large amount of electronic waste that are likely improperly disposed.

To summarize, students on campus have the following options for recycling electronic waste on campus:

1. Recycle any material, small and large capital waste, at the annual Electronic Waste Collection Days hosted by Indiana University and Apple Computers. The scheduled public day for the 2011 drop-off is May 14th from 9am-2pm.

2. Recycle toner cartridges and cell phones in the residence halls. There are multiple bins at these sites sometimes sponsored by outside organizations such as the Sierra Club.

3. Recycle cell phones in the IMU at an Eco-Cell bin.

4. Donate privately owned electronic equipment to the newly founded Serve IT clinic. This is a relatively new venture, and there is no evidence that many students have participated or know about this program.

Based on these options, it is clear that there is no systemized method of recycling electronic waste for students on Indiana University's campus. The following section summarizes findings and offers recommendations. The overall takeaway from the current situation is that Indiana University is in the prime position to synthesize these individual efforts into a streamlined program that will provide students with an easier way of properly recycling electronic waste.

Methodology: Student Electronic Recycling

The team administered a survey in order to determine the demand for an on-campus electronic waste recycling program for students and non-university-owned electronics. The student survey (Appendix EW-6) provided the primary source of data collection for determining student actions and perceptions of electronic waste. Administered in conjunction with several other working groups, the survey used a random sample of 10,000 students from across the University, 1,902 which responded, including undergraduate, graduate and PhD students. The survey was distributed through Survey Monkey and was open for three weeks. The questions were intended to determine how often students dispose of their various electronic devices, namely cell phones and computers, as well as their attitudes regarding the importance of electronic waste recycling, their willingness to participate in a University-sponsored program and where they believe the most convenient on campus donation locations to be.

In addition, the team conducted interviews with key constituents to better assess the current situation. In the following section, these results are summarized followed by recommendations and analysis.

Survey Results: Student Electronic Recycling

The final survey results contained the contributions of 1,900 participants, and they clearly demonstrate the need for and interest in an on campus electronic waste-recycling program for students. Of the 1,900 total respondents, 68 percent (1,300) were undergraduate students, 21 percent (386) were graduate students and 11 percent (214) were PhD students. The survey results indicate 59 percent (1,121) of students dispose of their cell phones every two years; however, according to the survey, 66 percent (1,271) of respondents replace their computer only every five to six years. Additionally, 57 percent (1,087)

Chart 1. Current Electronic Waste Disposal Methods

Sell, 2%
Throw Away, 5%
Recycle , 23%
Storage/ Hoarding, 47%
Donation, 23%

reported currently storing unwanted electronics because they are unaware of responsible disposal options on campus. In contrast, only 23 percent (534) of respondent currently recycle their unused electronics, and 23 percent (519) reported donating their unwanted electronics. As previously stated, the high depreciation rate for electronics makes hoarding a particularly costly activity, especially when the unwanted devices could be donated to the Serve IT Clinic. (Recommendations can be found in the following section).

Chart 2 . Percentage of Students Willing to Participate in Campus Electronic Waste Recycling

No, 17%
Yes, 83%
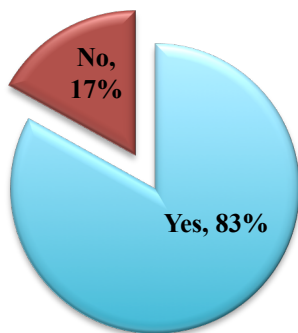
One positive survey result was that only 6 percent (112) of students admitted to throwing away their electronic waste (See Chart 1). Furthermore, 76 percent (1,444) of the respondents perceived electronic waste recycling as being either an important or very important issue (See Chart 2), and an overwhelming 83 percent (1,557) of respondents indicated their willingness to participate in an on campus electronic recycling program (See Chart 3). These data clearly indicate the unmet demand and the significant need for student recycling opportunities and form the basis of our recommended actions.

Chart 3. Perceived Importance of Electronic Waste Recycling

Total Respondents

Extremely Unimportant	Unimportant	Neither Unimportant or Important	Important	Extremely Important
130	41	235	830	614

Student opinions on where recycling options should be located on campus were quite varied; however, the Herman B Wells Library and the Indiana University Memorial Union received the strongest support, with 31.9 percent and 34.7 percent respectively. There was also significant interest in having electronic waste-recycling options in the dormitories; however, the implementation costs and the difficulty associated with coordinating the program in each of the dorms likely outweigh the benefits. There was also interest in having recycling services in the large academic buildings, namely the Kelley School and Ballantine Hall, but this would require the creation of a more extensive pick-up program and surveillance of security at multiple building sites.

Chart 4. Student Preference for Electronic Recycling Locations
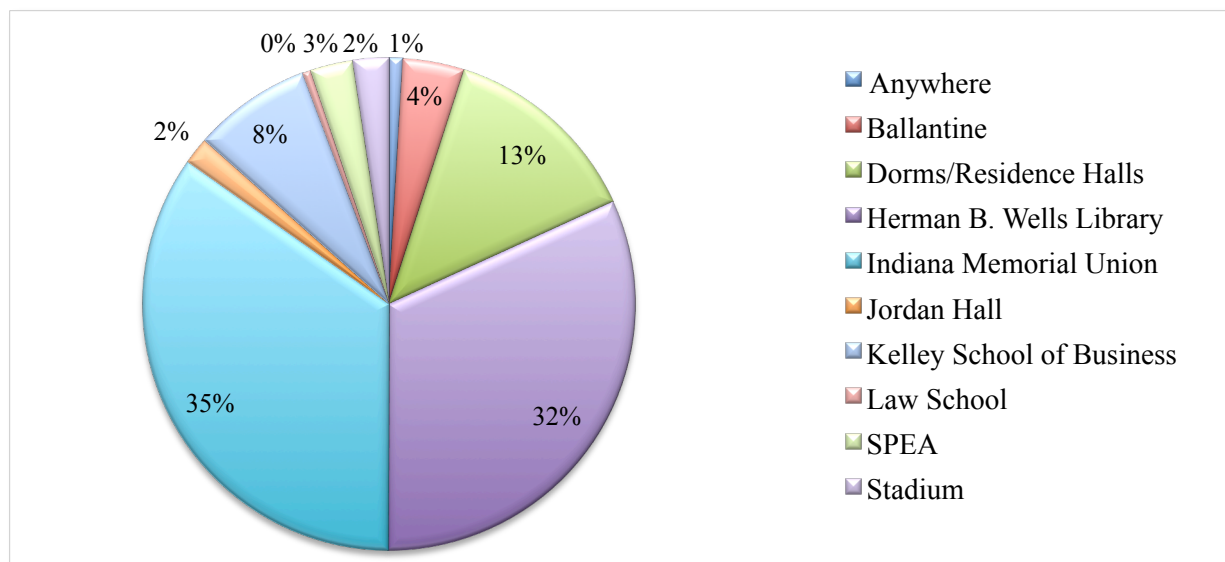
Graphical representations of all survey results are contained in Appendix EW-6.

Interviews: Student Electronic Recycling

Interviews with the following constituents provided a better perspective of the current situation and how to handle student electronic waste on campus. From the information provided by these, the team was better able to develop a communication and marketing plan.

1. Matt Hottell – *Director of the Serve IT Clinic, Senior Lecturer in School of Informatics*

The School of Informatics and Computing started the Serve IT Community IT Clinic in 2010 and chose Matt Hottell to lead the formation and management of the venture. The mission of this clinic is to "provide real-world, team-based learning opportunities for IU students that focus on helping nonprofit organizations solve IT-related problems" (Indiana University School of Informatics and Computing, 2011). According to Hottell, this clinic accepts only privately-owned electronics because Indiana University material is publicly-owned and cannot be donated or sold to nonprofits. The majority of donations come from community members and students are not actively engaged in donating used equipment to the IT clinic.

The Serve IT Clinic is a new venture, and Indiana University's First Lady Laurie Burns McRobbie was chosen to head the Advisory Board. Currently, the IT clinic is scheduled to help five nonprofit clients including Christole, Inc., Sycamore Land Trust, Boys and Girls Club, and Middle Way House. Hottell expressed interest in informing students about the potential of donating their equipment for use. He said they always need more equipment and that he had the capacity to sort through it.

2. Steve Akers – *Associate Director of Environmental Operations for Residential Programs and Services*

Steve Akers oversees environmental operations in residential halls and serves on the Resource Use and Recycling Working group, whose mission is to raise awareness, implement strategies, and promote responsible resource use of waste and recycling (Indiana University Office of Sustainability, 2009). According to him, there are various bins in the halls, including for ink jets and cell phones. He said that multiple vendors bring in cell phone recycling bins including Sierra Club and that Indiana University is hesitant to claim responsibility over the disposal of electronic items.

Akers also said that the residential halls do not wish to put more bins in the residential halls because the administration feels there are too many already. He would be happy to help in any way, however, to establish a more unified system of electronic waste bins throughout campus and especially the residence halls.

In addition to the information provided about electronic waste, Aker's said that each year, room space is set aside in the residence halls to allow for donations to the annual "Hoosier to Hoosier" sale. He expressed interest in collection both items for Hoosier-to-Hoosier and E-Waste Collection Days to be stored in the same place until a pick-up for the electronics could be arranged.

3. Bill Brown – *Director of Sustainability*

Bill Brown is Indiana University's first sustainability director, and his specialty is in architecture and green buildings. His knowledge regarding electronic cycling on Indian University's campus involved the EcoCell bin initiative completed by a student intern According to Brown, this is the only electronic cycling bin on campus outside of residential halls. Unfortunately, the bin required an initial investment, and students have not enough cell phones to pay off the cost of purchasing. Because the EcoCell bins are expensive to purchase, this makes them cost prohibitive for residential halls.

4**.** Susan Coleman Morse – *Senior Communications and Sustainability Specialist at University Information Technology Services, Indiana University*

Susan Coleman is familiar with the Surplus Store operations and IT staff side of electronic waste recycling. However, she did feel that students should become more engaged in the Electronic Waste Collection Days, and that as of now no systematic methods have been made to educate students on recycling electronic waste.

5. Student Sustainability Council

This council's mission is to "promote communication and collaboration among member organizations, to advise the Indiana University Office of Sustainability from the perspective of the students, to reduce

the negative effects of the University on the natural environment, to promote social and economic justice, and to engage the Indiana University student body in these issues" (Indiana University Student Sustainability Council, 2010). Organizations involved include Greeks Go Green, Environmental Law Society, Environmental Management Association, and the Sustainable Development Association. The E-waste Group presented at a member meeting to attain information on current efforts made my any of these organizations to address electronic waste.

None of the associations expressed any knowledge of electronic waste nor did they think that any major efforts had been made on campus to educate students regarding E-Waste Collections Days. One of the organizations, the Indiana University Student Association, was in the process of planning an e-waste drive of cell phones to commence in April. On April 4th, 2011 they launched the drive to collect cell phones and electronics to donate to Cell Phones for Cancer, a company started by IU graduate RJ Campbell.

The rest of the group representatives seemed quite receptive to educating students on electronic waste. They offered the following suggestions:

   1. Make students feel as if they are expected to recycle electronic waste.
   2. Make memory erasing easy-to-understand and accessible.
   3. Use shame to make students feel like if they don't do it, they will be hurting the planet, society, etc.

The council volunteered that if they were asked to help promote this initiative, they would disseminate the message to their constituents. In addition to these recommendations, the Sustainability Council organizes a Sustain IU week each year that has a theme; this year the theme is waste. Events will take place throughout campus to promote awareness and action on recycling of all types of waste. Currently, electronic waste is not being addressed during this week.

6. Christopher Craig – *Waste Tracking Coordinator, Stanford University*

To gain a better perspective of what is going on at campuses around the country, the researchers conducted an interview with Christopher Craig who works at Stanford University in California. California has different laws regarding electronic waste than Indiana, and because of this, its system of recycling items is structured differently.

In California, an organization must register to become a collector. Stanford uses on an on-site recycler to collect the materials. Students have two options of recycling waste. First, they can drop cell phones, mice, circuit boards, and other small items in five-gallon pails distributed throughout student housing. There are 150 total pails on campus, 50 of which are in residential halls. It is important to note that these pails are not secure. Hypothetically, a student could steal a disposed cell phone. However, Chris noted that campus security surveys these locations. Technicians go to each location once a month to pick up e-waste. For larger items, students can dispose of waste at the campus recycling center. Since the beginning of their program seven years ago, Stanford has collected 425,000 pounds of electronic waste. This is at both the university and student level.

Recommendations

Based on the interviews, survey results, and other research, the team developed the following recommendations on how to best systemize student electronic recycling efforts on campus.

1. Provide computer-recycling services at the UITS Help Desk in the Herman B Wells Library. This is the point on campus where most students interact with UITS staff on personal computer issues, and the staff would be a critical stakeholder in educating students on the availability of the recycling program when their computers are broken or in need of replacement. In order to accomplish this goal we foresee the following necessary steps:

   a. Have an IU Sustainability intern teach student UITS workers how to wipe student computer hard drives. This is critical for data safety and the protection of private information.

   b. Determine a location for secure storage of donated electronics. There is a need to protect the donated electronics from theft until they are disposed of or arrangements are made with Matt Hottell from the Serve IT Clinic.

   c. Arrange a partnership with Matt Hottell from the Serve IT Clinic (http://serveit.soic.indiana.edu). He can be reached at (812) 856-1096 or mhottell@indiana.edu. He has been notified about the possibility of receiving donated student computers and would be able to make use of any donated machines, either as parts or as complete machines if they function properly.

2. Provide computer-recycling services at the Computer Connection store in the IMU. The Computer Connection is the University Bookstore's technology store, and it is consequently the logical location for recycling services within the IMU. It is likely the staff will have the skills necessary to assist students in wiping their hard drive and will require only minimal training on the new service. However, it will be necessary to for an IU Sustainability Intern to setup the program and ensure the staff is adequately prepared.

3. Relocate the Eco-Cell phone-recycling bin to the Herman B Wells Library or a more central location in the Indiana Memorial Union.

4. Combine the collection for E-Waste Collection Days with the Hoosier-to-Hoosier event in order to increase participation among students and simplify the message and develop communication plan between key administrators to help implement this collection.

5. Educate the students on E- Waste Collection Days during dorm move out and allow students to donate their unwanted electronics at this time. (See "Marketing Plan" in following section)

6. Schedule the E-Waste Collection Days event prior to the end of the school year in 2012 in order to increase donations and facilitate recycling.

7. Change the Hoosier-to-Hoosier program to accept and store unwanted electronics, which will be disposed of through the E-Waste Days.

Based on these recommendations, the team developed more in-depth implementation plans for the communication plan and marketing scheme. The following section explains how to move from recommendations to action.

Communication Plan

A communication line needs to be established between Steve Akers, Susan Coleman Morse, the current electronic waste intern, and Matt Hottell. The diagram on the following page summarizes this communication and action plan in a flow chart.

This communication plan summarizes the steps needed at the administrative level to collect electronic waste before the annual E- Waste Collection Days. Because the event occurs after students leave, there is a need for administrative involvement to coordinate the collection. This method provides dorm residents a venue through which they can donate their electronic waste; usable waste will be filtered to the IT clinic for use in nonprofits and unusable waste will go toward E-Waste Collection Days.

Steve Akers

- Inform students about collecting items for E-Waste Days and Serve IT Clinic during the last two weeks of school.
- Collect items and store in same room/s used for Hoosier-to-Hoosier.
- Inventory number and type of items collected.
- Inform Matt Hottell of inventory for use in IT Clinic following student graduation on May 6th.
- Inform Susan and e-waste intern of leftover items for E-Waste Days after Matt investigates items. Ideally this would happen at least three days before the E-Waste Days on May 12th.

Matt Hottell

- Make site visit to dorm location to survey electronic materials for use by IT clinic within 24 hours of notification by Steve Akers.
- Take materials that are still working and usable to Serve IT Clinic for use and leave leftovers for E-Waste Days.

Susan Coleman/ E-Waste Intern

- Visit dorms within 24 hours of notification by Steve Akers.
- Document rough estimate of placement and volume of student waste collected in dorms.
- Schedule pick-up of items before E-Waste Days.
- Inform Steve of plan to pick up materials for E-Waste Days for recycling and make sure all entrances will be unlocked and enough people volunteer to pick it up.

Figure 12: Communication flow chart for organizing movement of student e-waste to the Serve IT Clinic and E-Waste Collection Days 2011.

Marketing Plan

Indiana University does not currently have a method of educating students on electronic waste disposal, and before developing a marketing plan, it is important to understand the demographic and psychographic profile of the student body. The following table summarizes the student demographics based on geographic origin.

Table 2: Students by Geographic Region at Indiana University Bloomington, Fall 2009

Geographic Origin	Number	Percentage
Foreign	5,192	12.3%
United State	36,026	85.1%
Unknown	1,129	2.7%
Total	42,347	100%

Source: (IU Enrollment Database, 2011)

Students in the foreign category of geographic origin come from 136 countries. Although the student population is diverse, a majority of the student population is from the United States. Bloomington's campus alone has 42,347 students. The following table breaks these students down by level of education and gender.

Table 3: Enrollment by Course load, Gender, and Level, Fall 2009-2010

	Full-time		Part-Time		Total
Level	Men	Women	Men	Women	
Undergraduates	15,566	15,417	561	456	32,000
Special Undergraduates	38	40	207	205	490
Graduates	2,884	2,545	1,465	1,566	8,460
Special Graduates	52	42	129	259	482
Professionals	467	421	11	16	915
Total	**19,007**	**18,465**	**2,373**	**2,502**	**42,347**

Source: (IU Enrollment Database, 2011)

From this table, one sees that that the majority of students are full-time undergraduates, and that men and women are almost evenly split with 50.4 percent males and 49.5 percent females.
To better understand the psychographic profile of these 42,347 students regarding their opinion on electronic waste, the researchers distributed a survey to 10,000 students, and 1,900 or 19 percent responded. Of these survey participants 83.05 percent said they would participate in electronic recycling if provided free of cost by the university, and 44.9 percent thought it was important to recycle electronic waste. Only 7 percent thought it was not important at all. From this data, one sees that the students are not opposed to recycling their electronics and feel it is important. The missing component seems to be a streamlined program provided by the university.

Situation SWOT Analysis

A SWOT analysis provides a schematic to better understand how to develop a comprehensive marketing plan. Environmental factors *internal* to the student body and campus are classified as Strengths, Weaknesses, Opportunities, or Threats, and those *external* to the campus are classified as Opportunities or Threats (see Figure 13).

Strengths

-Indiana University Bloomington has active Office of Sustainability, Green Teams, and Student Sustainability Council.

-The Office of Sustainability already has an intern focusing on e-waste.

-The campus organizes E-Waste Collection Days, which currently attracts large community involvement.

-The Serve IT Clinic recently began to encourage the reuse of technological equipment from private establishments.

-IU's School of Public and Environmental Affairs has faculty that undergo current and award-winning research regarding sustainability.

-Independent student efforts have begun regarding recycling including the Eco-Cell bin and IUSA E-Waste Drive.

Weaknesses

-There are multiple projects going on with no systematic form of communication.

-There is not one consistent message for students regarding electronic waste.

-The E-Waste Collection Days occur after students leave campus.

-Indiana University is reluctant to claim responsibility for disposing of electronic waste on a regular basis.

-Students self-organize e-waste efforts, leading to a muddling of the message or so many messages that students become confused and then apathetic.

-Challenge to create unified message for a large and diverse student body.

-Campus is spread-out thus making a location for electronic waste difficult to choose.

-Students from different countries may not understand message.

Opportunities

-Awareness around the country is rising regarding electronic waste disposal as evidenced by increase in companies and standards for the industry.

-Other campuses are beginning to establish electronic waste programs that IU can learn from including Stanford and the University of Michigan.

-States are passing laws that push manufacturers to force certain percentages of their products; IU's e-waste partnership with Apple Computers is a result of this.

-With increased technology, it is easier to see our waste impact through documentaries, pictures, and blogs.

-IU has an incentive to improve waste disposal so it compares well to other universities.

-According to Bill Brown, students are increasingly looking at sustainability as one of their factors for choosing a university.

Threats

-Because the electronic waste regulations and industry is so new, systems may change quickly as new information is discovered.

-Students are flooded with messages every day about social causes, and this may result in numbing or non-action.

-Disposing of electronic waste is tedious and students worry about confidentiality. Performing a DOD wipe and taking electronics to a location may be viewed as "too much work."

-Because state laws are different, students from different states may become confused as to what they should do.

- There is not a national awareness of the toxic chemicals found in electronic waste, and this is a barrier to moving students from awareness to action.

Figure 13. SWOT Analysis

Opportunity Statement

Indiana University has the opportunity increase the amount of e-waste donated from students to both the Serve IT Clinic and E-Waste Collection Days by increasing awareness and easing the barriers that exist to proper electronic waste disposal.

Goal

Indiana University's goal is to increase the amount of electronic waste recycled by students on campus. (Percentage of increase is difficult to put here since there is no original percentage from which we are working.)

Objectives

1. Restructure Website to better educate students on how they can dispose of electronic waste.
2. Distribute campus-wide or resident hall-wide e-mail that explains how to donate/recycle electronics before the public E-Waste Days on May 14th (or day of event in 2012).
3. Place educational flyers in key places throughout the IMU, Herman B Wells Library, SRSC, and resident halls.
4. Inform IT helpers of the plan and ask them to encourage students to donate old or unusable equipment.
5. Inform key stakeholders to spread the word including the Indiana Student Association, Student Sustainability Council, Greeks Go Green, Environmental Law Society, Environmental Management Association, Graduate and Professional Student Organization, Net Impact, Residence Halls Association, Sustainable Development Association, Volunteers in Sustainability, and Green Teams.
6. Table throughout campus to raise awareness of donation drive and inform students how to dispose of electronic waste at their resident halls or IMU.
7. Engage resident hall directors to help encourage students to donate their electronics at the same time as they donate items to the Hoosier-to-Hoosier sale.

Key Publics, Message, Tactics and Strategies

Full-Time Undergraduates

The full-time undergraduate students at Indiana University number 30,983. Of these, many live in university dorms. Others, however, live in off-campus housing either through Greek housing or independent apartments. Because students living off-campus are harder to target, it is essential to market most heavily to the incoming freshmen that have the easiest access to recycling electronic waste through their dorms. The undergraduate group represents the largest portion of students at Indiana University Bloomington, and there are also the most diverse. They are also the group of students that receive the most messages from a variety of sources including the school, organizations, friends, and parents. Therefore a message to them must truly stand out for this demographic to pay any attention.

Primary Message

Properly recycling electronic waste is the simple and right thing to do instead of hoarding it or throwing it away. Let us (the university) take care of it for you so you don't have to worry about it.
Secondary Messages

- On average, students replace their cell phones every two years and their computers every four to five years. This means that in the undergraduate population alone, if every student threw away two cell phones and one computer, it would equal 61,966 phones and 30,983 computers.
- Even if students recycle their electronic waste, if they do not research the company, it could end up in another country and taken apart by children or underpaid laborers.

Strategy

Raise awareness of proper recycling of electronic waste and increase student participation in the annual E-Waste Collection Days through collections in residence halls.

Tactics

1. Place flyers on every floor of dormitory. (See Appendix EW-7)
2. Restructure Website to easily explain to students how to recycle electronic waste.
3. Send out e-mails during the week of collection.

Part-Time Undergraduates, Full and Part-Time Graduate Students

This section of student life may be more disconnected from the campus activities either because they are spending less time on campus or because their graduate programs demand more time and academic rigor. Marketing to this group will most likely be effective if it takes place within the students' academic buildings or online. It may also appeal to this group if combined with their professional associations, commuter groups, or academic programs.

Primary Message

As busy people, you need an easy and sustainable to way to recycle your e-waste. Let the University help you de-clutter and help the environment.

Secondary Messages

- This group of students, along with the undergraduates, are transitory, and the thought of hauling around unused electronic equipment from apartment to apartment is unappealing.
- These students may have recently updated their electronics or be planning to upon graduation. Providing a yearly method of disposal eases their decision on what to do with old electronics.

Strategy

Raise awareness of busy students who may not spend much time on campus and increase participation in the annual E-Waste Collection Days.

Tactics

1. Utilize professional associations or academic societies for graduate students and commuter organizations to advertise the E-Waste Days and donating to the Serve IT Clinic.
2. Restructure Website to easily explain to students how to recycle electronic waste.
3. Utilize Green Teams, program offices, and student associations to collect items at their academic building for pick-up by IU Surplus or the Serve IT Clinic.

Residence Hall Assistants

This is a key group that can help facilitate action between freshman and other students living in dorms during the e-waste collection period at the end of the year. Thirteen percent of students preferred electronic waste pick up at their dorms, making this a key place to target for marketing. The assistants should be educated on the opportunity and encouraged to put up a sign in their hallway or send out an e-mail to their resident hall students.

Primary Message

As a resident hall assistant, you can help your students donate items for Hoosier-to-Hoosier and E-Waste Day. This helps promote sustainability on campus and reduces the junk left in your hallway or rooms after students leave.

Secondary Messages

- As resident hall assistants, it is your job to inform students about the opportunities on campus.
- You can participate as well to serve as an example for the students in the residence halls.

Strategy

Educate resident hall assistants and increase their participation in promoting recycling e-waste to dorm residents.

Tactics

1. Train resident hall assistant in how to promote electronic recycling at a group meeting.
2. Provide resident hall assistants with ample promotional material, and check residence halls to make sure they are promoting the effort.

Greek Houses

Because the Greek system sponsors an organization called Greeks Go Green, this is an ideal public to target for the collection of electronic waste for recycling. Marketing to the Greek system may be more effective if done through a competition because of the many point-based activities the fraternities and sororities organize. In addition, it may be a strong recruiting tool to say that their house is one of the "most sustainable" on campus. Fraternities and sororities typically have mandatory volunteer hours, and collecting items for E-Waste Collection Days can serve as a volunteer opportunity.

Primary Message

Become the most sustainable house on campus and donate your electronic waste to E-Waste Collection Days. The winning house will receive recognition.

Secondary Messages

- Fraternities and sororities are places to build leadership skills, and this is the perfect opportunity to organize a wide-scale collection drive for a good cause.
- This is a prime opportunity to give more visibility to Greeks Go Green, and it can be done in conjunction with the event they organize each year through the Student Sustainability Council.

Strategy

Engage Greek houses and increase participation in E-Waste Collection Days by using Greeks Go Green and competition.

Tactics

1. Advertise to Greeks through Greeks Go Green and ask about possibilities of making collection a competition.
2. Emphasize the philanthropic component with Serve IT as well as the recognition the house will receive if they donate the most.

Indiana University Student Association

Because this organization has already organized a student e-waste drive, it would be a key public to disseminate information to the rest of the student body regarding electronic waste and recycling. They represent the entire student body and have the largest number of constituents to circulate information. In addition, the IUSA is an advocate for students and can push for higher electronic waste participation and opportunities.

Primary Message

As the primary representative for IU's student body, and as a promoter of electronic waste recycling already, you can play a key role in establishing our university as a model for student recycling.

Secondary Messages

- IUSA has a history of advocating and lobbying for policy changes IU administration. Adding E-waste to this list would demonstrate student support and convince the university to do more about proper electronic recycling.
- IUSA is currently operating an e-waste drive. Instead of organizing it all on their own, they could partner with an already established program and simply serve as a communication liaison.

Strategy

Convince IUSA that this is an important legislative initiative for the student body and that they should increase awareness among constituents.

Tactics

1. Present to the IUSA or approach an executive member about electronic waste recycling.
2. Ask them to participate in E-Waste Collection Days or in the Serve-IT Clinic initiative.
3. Provide with marketing materials to give to their constituents.

Implementation

By implementing these strategies and tactics, Indiana University can increase its collection of electronic waste recycling from students on campus. This can be implemented in the 2012 year with strategies beginning in early April before move-out in May. The IUOS e-waste intern would serve as an ideal representative to carry out this plan. Appendix EW-7 includes sample flyers to post around campus.

Conclusions

Based on interviews, the student survey, and research, it is clear that Indiana University is in a prime position to mobilize resources and implement a more systemized method to collect student electronic waste on campus. This can be done through educating IT workers who help students, developing a drop-off point once a year for students, and implementing a campus-wide awareness marketing campaign.

In addition, the University can better handle university-owned electronic equipment through education, streamlining, and emphasizing the monetary benefit departments can receive by moving unused to equipment to IU Surplus as soon as possible. Through these measures, we hope that the university can greatly improve e-waste recycling efforts on campus.

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Data Center and Server Management

Introduction

With sustainability among its core values, the new Indiana University Data Center has made great strides in university sustainable IT. Continued collaboration with campus departments outside the data center coupled with innovation inside presents opportunities for the data center to go further still. During the last 14 weeks our team has conducted a broad analysis reviewing sustainable IT industry standards and methods, surveying and interviewing IU department IT managers, and conducting cost analyses to identify these opportunities. The goals of our analysis were the following:

1. Assess and report on advances in data center energy efficiency measurements.

2. Explore practices to increase energy efficiency within the data center, namely hot/cold aisle containment.

3. Estimate the energy and cost effectiveness of virtualizing department server applications within the data center through UITS Intelligent Infrastructure.

4. Provide insight on overcoming institutional hurdles to better position Indiana University in realizing the Data Center's environmentally sustainable potential.

Recent trends in the IT industry are transforming once bulky and power-hungry IT systems into lean machines which reduce carbon emissions and save money. These trends stem not only from emerging environmental awareness, but also from technological advances which allow an industry historically know for disregarding power effectiveness for the sake of high performance to accomplish both for the first time. Among these advances is a method known as server virtualization which allows IT managers to fully utilize the potential of each server by consolidating workloads of several machines together. Reducing the number of physical machines needed to accomplish fragmented tasks.

Indiana University has embraced these advances, and President Michael McRobbie has set a high bar for sustainable IT moving forward (McRobbie, 2008). In order to achieve its potential as a role model of sustainability, Indiana University's IT community and the IU Data Center must constantly evaluate their practices and culture to find opportunities for progress. A few such opportunities have been outlined in the contents of this analysis. In line with the stated goals, our team recommends that the IU Data Center take the following actions:

1. Consider pursuing the Energy Star certification from the Environmental Protection Agency (EPA).

2. Revisit hot aisle containment as feasible configurations may allow for material energy and cost savings resulting from improved temperature and air current control.

3. Increase the relative advantage of UITS II by offering more affordable storage packages and exploring intangible savings such as dependability and staff time use.

4. Invest in consensuses building with IT departments, aligning organizational incentives and goals between the data center and autonomous IT departments.

Virtualization and Departmental Survey

One primary focus of our analysis is virtualization. As discussed before, this advanced software enabled practice allows IT administrators to greatly decrease the number of physical servers needed. Virtualization is especially useful in the context of large data centers because managers can move virtualized applications across large numbers of physical servers as the applications workload demands change. Data centers leverage these economies of scale to save energy by further consolidating applications when workloads are down and fully utilizing the expertise of staff trained in virtual server management. The IU Data Center in partnership with the IUPUI data center plays host to approximately 1,700 virtual applications from IU departments via UITS Intelligent Infrastructure, a fee-for-service virtualization package.

Much analysis and rhetoric prior to this report has consequently centered on the IU Data Center and the movement of IT department server applications into UITS Intelligent Infrastructure. This includes a graduate report by the Kelley School of Business which will be referenced later. By including a departmental focus we hope to provide decision makers with a more holistic understanding of sustainable IT at Indiana University.

One way our analysis included IT departments was through an extensive system of surveys and interviews. Twenty-five departments were randomly sampled from the 75 Indiana University Bloomington departments, which employed ten or fewer employees. These relatively smaller departments were representative of the majority of Indiana University Bloomington's 85 total departments. 56 percent of the 25 IT departments responded to our information requests, which came in the form of phone interviews and online surveys. Two of these departments did not manage servers virtually or physically and were removed from our sample. The table below is one example of the knowledge gained from this effort. Additionally, our team worked closely with Indiana University Bloomington IT administrators who were introduced to us by the Office of Sustainability.

Figure 1: IT Departments at Indiana University Bloomington on Virtualization
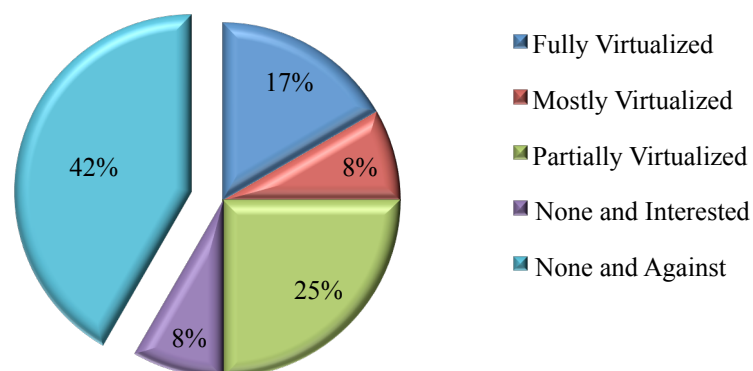
Goal 1: Assess and Report on Advances in Data Center Energy Efficiency Measurements

An extensive review of industry calculations of energy efficiency reports demonstrated the potential of the IU Data Center to accomplish its strategic sustainability goals achieving a boastful 1.67 and 1.59 Power Usage Effectiveness in the enterprise and research pod effectively. Our research also uncovered many shortcomings to this metric and ultimately recommends that the IU Data Center considers pursuing an EPA Energy Star rating with we believe to be obtainable in the near future. Successful awarding of an Energy Star rating may increase Indiana University's presence as a role model of sustainability among academic institutions by providing the data center with a more representative signal of its accomplishments to the IT industry.

PUE Measurement and Shortcomings

The most commonly used measurement for determining energy efficiency in a data center is Power Usage Effectiveness (PUE). PUE is calculated by adding up the total power used by the data center - including energy used by servers, fans, lighting, power loss from uninterruptible power supplies (UPS), and computer room air conditioner units (CRAC units), and any other sources of power use. This number is divided by the amount of power used by the IT equipment, primarily servers. This measurement was proposed in 2007 in a white paper by several authors at "The Green Grid," an association of IT professionals seeking to raise the energy efficiency of data centers (Rawson et al., 2007).

To make this concrete, a data center that uses 100 kWh of energy per month, with 75 kWh of that going to servers, would have a PUE of 1.33. The reciprocal of PUE, Data Center Infrastructure Efficiency (DCiE), shows what fraction of total power is dissipated compared to that used to power servers. In our example, the DCiE measure would be .75, suggesting that 75 percent of the consumed power is going to IT infrastructure and 25 percent to supporting that infrastructure.

Like any metric, PUE has its limitations. First, some data centers will have better PUE scores due to environment. In consistently-temperate environments, cool air could be pumped in from the outside, and data centers would absorb less heat from outside during summer months. Second, PUE is vulnerable to gaming. Manipulating what counts as IT equipment, intentionally or unintentionally, will skew results. For example, moving fans from inside servers to the racks may be more efficient, but rack fans may not count as "IT equipment," like internal fans. Choosing whether total power is measured before or after voltages are stepped down will also make a big difference in the PUE calculation, particularly when power is measured before or after PSU losses, the voltage regulator down (VRD), and/or voltage regulator modules (VRM).

A number of alternative measures have been developed to address these shortcomings. Data Center Productivity is calculated by dividing "useful work" by Total Facility Power. This eliminates a lot of the loopholes, although it retains differences due to climate. However, determining what power consumption counts as "useful work" is difficult. Even if everyone agrees to a clear definition, actually measuring this quantity is challenging as well. For example, if cooling fans don't count as "useful work," how do you measure a server's actual power consumption if it has several internal fans?

For now, PUE seems to be both industry standard and the lowest cost measure to collect. The Environmental Protection Agency uses a modified version PUE to determine qualification for their

Energy Star program. The modifications do not address the "gaming" problems of the PUE measure, but they do address inherent regional differences among others.

The data center currently measures the PUE of the enterprise pod at 1.67 and the research pod's PUE at 1.59. This number has been falling since the data center was opened, when PUE values were 2.28 and 1.78 for the enterprise and research pods respectively. Although many data centers do not share information about their energy consumption, the Uptime Institute approximates an industry average PUE to be about 2.5. If true, the IU data center compares very favorably to average data centers. Although some large Internet companies have claimed much lower PUE values--Google claims a PUE value of 1.21, Microsoft 1.22, and Facebook 1.15--the IU Data Center's PUE is impressive given the resources these firms have to spend on efficiency.

EPA's Energy Star Portfolio Manager and Certification

The Environmental Protection Agency's Energy Star program rates building energy efficiency. Through the "portfolio manager" at https://www.energystar.gov/istar/pmpam/ anyone can enter energy use information to determine the building's energy efficiency rating, as measured by Energy Star.   This benchmark rating is determined by comparing a particular building against similar buildings nationwide using EPA's "national energy performance rating system." The benchmark rating is based on a facility's energy use, level of business activity, and geographical location. Although this rating has built in a PUE measurement, adjustments for geographical location and business activity are attractive because they suggest a comparison that is fairer than a simple PUE where data centers in consistently temperate climates have a natural advantage.

The portfolio manager calculates both a baseline rating, which is the average rating over the last 12 months, and a current rating for the last month. Buildings with an efficiency rating at or above 75/100 qualify the building for energy star certification. Buildings rated below 75 would receive suggestions for efficiency improvements. By keeping information current in the portfolio manager, a building administrator can track energy use and efficiency over time, which may help evaluate where energy savings are available.

We have entered the energy use information into the portfolio manager for the enterprise pod of the Data Center. The enterprise pod has a current rating of 83/100, qualifying it for Energy Star certification. From the internal calculations provided by Dennis Cromwell, the research pod has an even lower PUE measurement than the enterprise pod, suggesting the research pod may also be eligible for Energy Star certification.

An Energy Star certification does not bring tangible benefits by itself. However, the certification may be useful for marketing purposes. According to IU's director of sustainability Bill Brown, incoming students have said sustainability is a significant factor when choosing schools. University admissions or departmental admissions and recruiting efforts may find such a certification useful to attracting high quality students. Additionally, IT managers considering virtualization may be interested to know the IU Data Center has been certified by the EPA as efficient.

If administrators of the data center are interested in pursuing Energy Star certification, they would need to create a login at the portfolio manager. The building can be transferred from our account to the

administrators account. Alternately, the power use information can be re-input into the portfolio manager. The following steps are required:

1. Generate an eligible **Statement of Energy Performance (SEP)**. This can be done from within the portfolio manager.
2. Obtain a **stamp and signature on the SEP** from a Licensed Professional (i.e. Engineer or Registered Architect).
3. Obtain a **signature on the Data Checklist** from the Licensed Professional who verified your SEP (required for all applications).
4. Complete the **ENERGY STAR Recognition form**.
5. Download and sign a copy of the **Letter of Agreement**.
6. Mail the following documents to EPA:
   o Signed **Letter of Agreement**
   o Stamped and signed **SEP**
   o Signed **Data Checklist** by the Licensed Professional who verified the SEP

Certification is not a trivial matter and would take some time from a "licensed professional." We cannot say whether the process is worthwhile and have not attempted to compare the costs of certifying with potential benefits. Instead, we leave this as an opportunity that may merit consideration.

Goal 2: Explore Practices to Increase Energy Efficiency within the Data Center

One championed method of increasing data center cooling efficiency involves partitioning data centers into contained hot and cold aisles. This method varies in complexity and can be especially difficult if not implemented during the original design of the data center. While the IU Data Center has organized server aisles by temperature, there is currently no containment to prevent air spillover. Our team recommends that the IU Data Center considers containment methods which are compatible with the data center's existing fire protection system.

Aisle Containment Opportunities for Cost and Energy Savings to the Data Center

It is a widely accepted truth in the data center industry that aisle containment will improve the efficiency of computer room air-conditioning systems. The majority of the commercially recognizable names in the IT industry utilize various aisle containment designs. Firms such as Google, eBay and Yahoo all practice aisle containment and all three have a different design approach suited to their individual needs and the design of their data center.

The continuing debate in the field of aisle containment is whether hot aisle containment (HAC) or cold aisle containment (CAC) is superior. Currently, there is no clear consensus among practitioners about which method is more efficient when measured in energy savings. However, either model offers different factors for consideration. When a center's cold aisles are contained the hot air expelled by the servers collects in the server room, increasing the ambient temperature and making it an unpleasant working environment. Alternatively, when the hot aisles are contained additional ventilation systems are required to extract the hot air from the sealed aisle.

Ideally, if a data center is to take advantage of aisle containment the cold/hot issue should be resolved before construction begins and the appropriate ventilation included in the original design. It is still

perfectly feasible to retro-fit an existing data center with aisle containment but given the 'always-on' nature of most data centers, certain large scale modifications are unfeasible.

In the case of the IU Data Center, we would recommend a variant of HAC which will require limited modification to the computer room structure. The Data Center could enclose the ends of its hot aisles with plastic curtaining, not unlike that found in meat lockers. This form of enclosure is cheap and easy to install without disrupting the operation of the servers (Miller, 2010).

This analysis also recommends the installation of a returning air plenum to improve the flow of hot air in the server room. The data center currently has a false floor under which the cold air flows to the vents in the cold aisles. The returning air plenum acts in the same manner by creating a false ceiling with vents above the hot aisles and enclosing the intakes of the computer room air conditioners (CRACs).

Furthermore, by installing a false ceiling the overall volume of the computer room is reduced, thereby reducing the space in which the temperature must be controlled (Costello and Gray, 2006). This method is recommended for the IU Data Center because, like the plastic curtaining, it is cheap and easy to install.
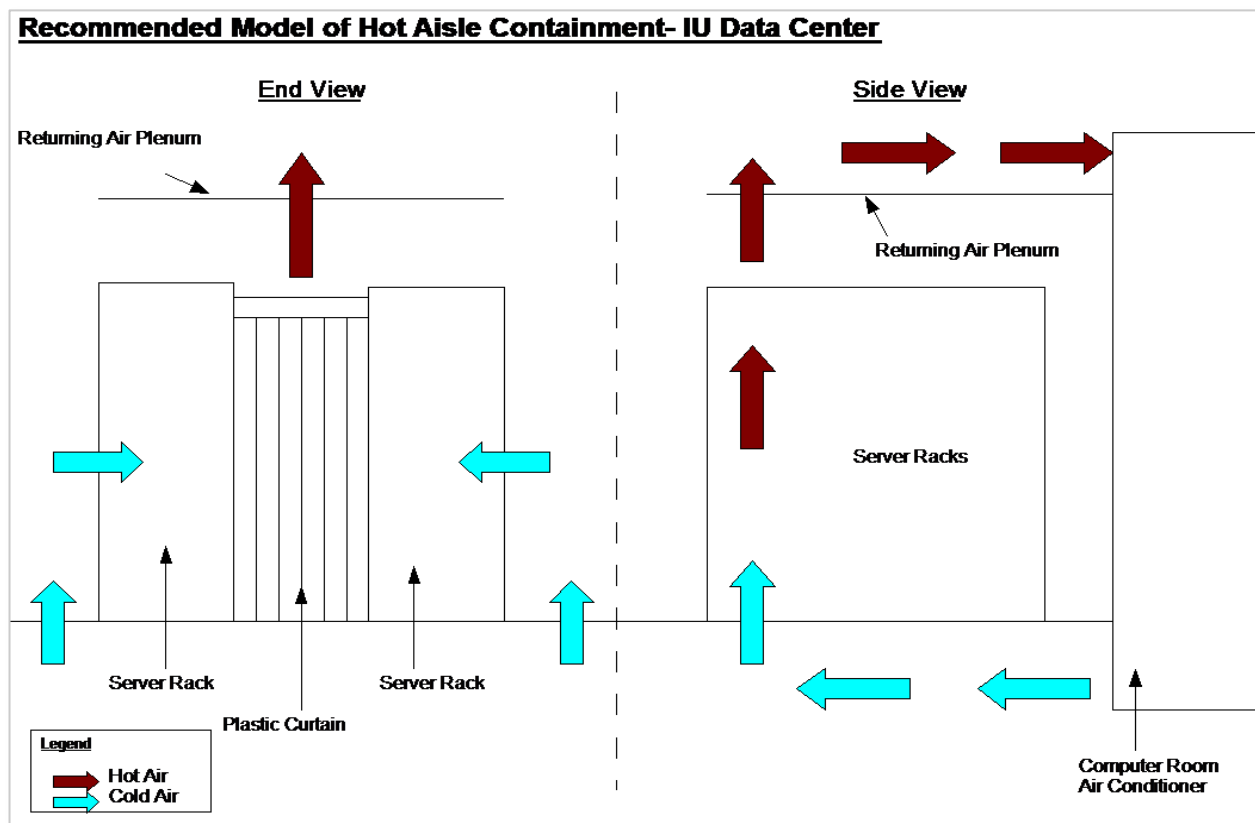
Figure 2. Recommended Model of Hot Aisle Containment.

The methods suggested here produce the electricity savings of HAC without the increased room temperature or the need for the construction of additional ventilation systems. This approach does not require any major modifications to the existing fire safety devices because the aisles are only sealed on two sides and the false ceiling can be placed above existing detectors and fire suppression devices.

Ideally this text would conclude with an exact estimate of the financial costs and benefits of installing this form of aisle containment. Unfortunately, aisle containment is very much a 'boutique' process with the exact costs being specific to the individual facility. The Department of Energy recommends that before any form of aisle containment is installed, managers need to perform a detailed survey of airflow within the server room to fully understand how best this flow can be improved through containment. It is only after this kind of survey has been conducted that the exact cost of containment can be identified; the extent of the work required will depend on the efficiency of the existing airflow (U.S. Department of Energy, 2010).

From a sustainability perspective, aisle containment is a worthwhile idea because it will reduce electricity consumption. From a financial perspective the merits of aisle containment are considerably less certain. The reduced cost of electricity is certainly beneficial, but it may be offset by the cost of retrofitting an existing data center with aisle containment technology. Although there are low costs methods by which aisle containment can be implemented, no firm conclusion regarding cost savings can be drawn until a thorough study of existing airflows has been conducted.

Goal 3: Estimate the Energy and Cost Effectiveness of Virtualizing Department Server Applications within the Data Center through UITS Intelligent Infrastructure

Decision makers must exercise their understanding of the cost and energy effectiveness of different virtualization scenarios in order to make sustainable choices. Ergo, it is crucial to conduct comprehensive calculations which spread beyond department walls. This portion of the analysis reviews what estimations have already been published concerning the costs and benefits of virtualization UITS Intelligent Infrastructure, specifically a graduate report from the Kelley School of Business.

The Kelley report is similar to ours in that it was conducted by graduate students with limited resources and short deadlines and thus symptomatically presents room for expansion. The discussion on their report includes many recommendations, which Indiana University may implement to obtain more informative calculations. Our own estimations identify IT department financial incentives against virtualization and specifically recommend that the IU Data Center consider more affordable storage systems which may offer IT departments a better value.

The Kelley School of Business UITS Intelligent Infrastructure Report

The Kelley School of Business conducted a cost-benefit study on ways that UITS Intelligent Infrastructure could reduce the university's overall costs while simultaneously reducing their carbon footprint through green technologies. This report argued that utilizing technologies, mainly server virtualization, would greatly benefit the university and all parties within. At first, this claim makes sense: reducing the number of physical servers through virtualization will therefore reduce overall electricity costs, so large scale virtualization should take place. However, the study made broad generalizations and did not consider many of the costs that would occur at various department levels at IU. Therefore, we have two main recommendations for a more detailed study of UITS Intelligent Infrastructure: 1) conduct and in-depth departmental analysis, and 2) clearly define the accounting domain since certain costs (e.g., electricity) are not paid by the individual departments.

In regard to the first recommendation, the Kelley School CBA examined a report conducted by VMware

on its virtualization service. The authors attempt to apply the cost and benefit valuations from that single source to Indiana University. However, this is not specific to the University because the private company requirements are not the same as those of a public institution. For example, private firms are likely focused on a narrow set of tasks whereas a large, research university (such as IU) has diverse and computationally intensive needs. It would be more effective for IU to conduct its own study on the culture of IT and look at the actual needs of the university. Therefore, we recommend that a detailed departmental study of IT management practices at IU is necessary.

The surveys and interviews with IU Bloomington IT managers revealed a number of unique cultures and needs between departments. For example, one department may be smaller with low-end server needs such as a file/print server that contains small amounts of student information. This department may determine that it is cheaper to have the IU Data Center manage their server for two reasons. First, it would be cost-effective for the data center to maintain and upkeep their server (the data center buys products in bulk, so they have a cheaper parts from server companies, such as Dell). The second reason departments with low-end needs benefit from virtualization is because of security. There is student data on their servers that the small department cannot protect as effectively as the Data Center, which has the latest virus, spyware, and malware security technologies. Much of this software could be expensive to purchase and maintain for a smaller department, thus making virtualization a more feasible option.

In contrast to this is a large department with high-end computing and server needs. Based on an interview with an IT manager at such a department, we found that it only virtualized one of its many physical servers with UITS II. It was an intranet server which needed nothing more than the base requirements that the Data Center offers. During the interview with the IT manager, it was determined that this department chose to virtualize in-house, and keep its physical servers, because it saves money where as complete virtualization with the data center is too expensive. For example, it costs the department $8000 dollars to virtualize four of their servers in-house. However, based on their CPU requirements, and storage requirement of 60 terabytes, it would cost them $76,800 per year to virtualize with the Data Center (1TB=1024GB; 1024GB*60=61,440GB; 61,440GB*$1.25=$76,800). The main cost comes from storage, which is $1.25 per gigabyte per year (see Appendix DC, Table DC-1).

Based on our interviews, it is evident that each department has unique computing and server needs. The Kelley School report has a table titled "System Assumptions" which offers server specifications that are not at all similar to either of the two departments interviewed. Clearly, using generalizations will yield inaccurate results. It would be more effective to calculate cost for the individual departments and base further conclusions on average costs rather than on a fictional average server.

Furthermore, the report assumes that people will jump on board with virtualization because it will cut down on electricity usage and therefore reduce electricity costs, which will benefit the environment. However, this is not necessarily the universal perspective of IT managers. In the interviews with department IT managers, we found that the cost of hardware and backup were the major considerations, rather than electricity costs. The departments were not primarily concerned with environmental impact. Additionally, some departments were concerned that virtualization would negatively affect their staff and the size of their budget.

After learning of these budget concerns, our second recommendation is that the accounting domain needs to be clearly identified. The cost savings from reduced electricity consumption fall outside the domain of the individual department. Based on the research our group engaged in, we found that

electricity costs are not being paid by the individual departments. As a result, departments do not have the incentive to adopt strategies to use less power because the departments will not see the benefit to reducing their usage. Similarly, reduced carbon emissions are outside the accounting domain of both the departments and IU. Based on this information about the accounting domain, carbon emissions should be ignored because they will be captured in reduced electricity costs.

The original report correctly identifies many of the most important costs and benefits which arise from virtualization. However, the majority of these costs and benefits are incorrectly monetized and applied to an unclear and inappropriate accounting domain. The Kelley student analysis is too vague in its definitions and research methodology to use in any specific situation. A much more rigorous analysis, along the lines laid out in this text, is required before any practical conclusions can be reached.

University Wide Energy Savings from Virtualization

The entire intelligent infrastructure is run out of the data center's enterprise pod. The data center uses 73 Dell R810 models with two sockets, eight core install base, and between 128 and 192 gb of memory. The Energy Star fact sheet for one of these servers estimates power consumption between 6,552 and 8,616 kWh/year.   These servers run about 1,700 virtual servers, or an average of 23.28 virtual servers per physical server. So, on average, a virtual server consumes between 281 and 369 kWh/year. For this estimate, we will accept the highest estimate: 369 kWh/year.

Estimating one single departmental server to represent all others is not realistic, due to the variety of departments and demands each department places on its servers. However, we can determine a lower bound estimate for energy savings by picking a very low end server with very low load. This way we can say energy savings from virtualizing are at least X, and very likely much greater. It is also useful to note that IT departments which can achieve a similar ratio of virtual to physical servers by virtualizing in-house will also achieve significant energy savings.

Dell's two lowest cost servers—the T110 tower server and PowerEdge R210 rack server—would consume between 1,028 – 1,783 kWh/year and 1,254 – 2,175 kWh/year respectively. Even at the lowest rate, virtualizing a single server would save at least 659 kWh/year for a tower server and at least 885 kWh/year for a rack server. The average university power cost over the last year was about six cents/kWh, so virtualizing a single server would save at least $53 per rack server and $40 per tower server.

This estimate certainly understates the savings from virtualization. For one, we can be certain all IU departments are not using bargain bin servers at minimal capacity. Even modestly increasing the server type dramatically increases available savings. Second, from a cost perspective, the data center pays a lower rate per kWh than the University as a whole, so even without energy savings, the virtualizing at the data center would reduce university costs. Third, the IU Data Center's large scale UPS, CRAC, and AC to DC conversion units would also increase energy savings.

The environmental benefits from reducing power consumption are difficult to calculate. Duke Energy, which supplies Indiana University with electricity, uses primarily coal powered plants. However, we are not sure exactly what type(s) of plant(s) support IU Bloomington, and thus cannot be certain of the reduction in carbon emissions achievable.

Cost Comparison: Virtualization with UITS II v. Amazon's EC2 and S3

It may be worthwhile to compare costs of different virtualization services. Amazon, for example, offers a cloud computing service. The pricing plans are different, which makes comparison tricky. Amazon charges based on a few hardware configurations, with little room for adding another processor or gigabyte of memory without jumping up to a new plan. UITS charges for a base level machine and users may add memory or CPUs incrementally. While both services offer incremental storage, UITS provides departments with a more flexible pricing plan.

One way to compare the two services is to compare the Amazon v. UITS costs for a given machine. Comparing the two pricing plans offers some quick comparisons. Amazon's storage and memory offerings are dramatically cheaper. Memory cost an average of about $56/gb per year compared to $125 per year through UITS. Hard disk space costs $.20/gb per year on Amazon, including additional bandwidth charges. UITS charges $1/gb per year. On the other hand, Amazon's processing units were more expensive, averaging about $186 per virtual core per year, whereas UITS charges $40/core per year. For details, see Table DC 10 in the appendix.

The result is that UITS is a better choice for low demand servers, or very CPU-intensive servers. Amazon is less expensive for servers which require large amounts of memory or large storage space. Since Amazon pricing is chunkier, the more of an Amazon server you use, the more cost effective it will be to virtualize. The incremental cost of going from one of Amazon's virtual server to another is substantial, so server applications that would underutilize the minimally sufficient Amazon server will find UITS virtualization service relatively more attractive.

Cost Comparison: Virtualization with UITS II v. Physical Server In-House

In conducting departmental interviews with IT managers we found that not all departments had similar needs for virtualization. Some departments chose to virtualize, others partially virtualized, and some did not want to virtualize at all. The most common reason to not virtualize was because IT managers found the cost of UITS II to be unfavorable. In one interview we were told that the cost of storage and memory was too much, so they chose to virtualize in-house in order to save money. Therefore, we decided to examine what costs would entice someone to want to keep their servers in-house.

We first examined the pricing information that UITS offered (see Appendix DC, Table DC-1). We found that considerable costs could be incurred by those departments that had high storage and memory needs because the price for each additional gigabyte of storage was $1.25, and each additional gigabyte of memory was $45. From our interviews we found that those departments that had low-end needs (e.g., file/print server) had an advantage to virtualization because they did not require as much storage and avoided the high marginal costs.

We then decided to take an in-depth look at specific server configurations. We primarily looked at Dell models since most departments operate Dell servers. From the list of servers we found that there were three common types: PowerEdge 2970, PowerEdge R510, PowerEdge R710. Regarding the Dell 2970 (see Appendices, Table DC 2), we can see the base server specifications for the server. Dell's price for this particular model was $2,859.00. Many departments elected to purchase technical support through Dell for replacement parts and minor maintenance, which is estimated to cost $1,500.00. The price for the 2970 model then increases to $4,359.00. However, most departments keep their servers for the full

life-cycle of five years, so we calculated that this particular server would cost $871.80 per year for five years. In this table we also calculated the expected cost for this type of server to be virtualized through UITS. The per year prices for fiscal year 2010-11 and 2011-12 were, respectively, $3,431.25 and $2,843.00. The cost for a department to virtualize this type of server for two years was $6,274.25. We then estimated the costs for three more years and determined that the price to virtualize at UITS was $11,273.75. This was much higher than the cost to run the server in-house.

We wanted to see if such a large difference in virtualization price was common for other models. Tables DC-3 and DC-4 (see Appendix DC) offer information about two Dell PowerEdge R510 server configurations. In Table DC-3, we can see that the price for running the server in-house will be less expensive than virtualizing with the data center over five years: $2,479.00 versus $2,981.25. However, it would be better to not virtualize the second server because the cost is $4,279.00 versus $7,984.25 for virtualization at the data center (see Appendix DC, Table DC-4). The major factor contributing to the price increase in this scenario comes from the need for 24GB of memory (RAM).

Tables DC-5, DC-6, and DC-7 (see Appendix DC) have specifications for the Dell PowerEdge R710 servers. In each case we can see that the cost to keep the server in-house for a five year life cycle is less than the cost to virtualize at the data center. It is clear, from the information in the tables that the biggest costs come from memory and storage, so if you have high-end needs, then it may be more cost-effective for departments to not virtualize.

Based on the cost information we found, we then hypothesized that if departments had to pay their own electricity costs, then it would be more beneficial to virtualize at the data center. However, we then determined that this was not necessarily true.

We calculated what the kWh was that a department would have to pay for each server scenario as well as the costs for tape backup. From this information we determined a new cost for a five year life cycle. The Dell PowerEdge 2970 went from costing $4,359.00 (see Appendix DC, Table DC -2) to $10,977.00 for backup and if the department had to pay electricity and backup costs (see Figure 3, "Dell PowerEdge 2970" below).

Figure 3. Dell PowerEdge 2970 Cost Estimate

Power Costs:	
kWh per year:	$159.60
kWh--5yr:	$798.00
Backup Costs:	
Tape 5yr:	$3,450
Backup Software License Fee:	$570
Tape Drive:	$1,800.00
TOTAL SERVER COST:	
Server:	$4,359.00
Power:	$798.00
Backup:	$5,820
Grand Total:	$10,977.00
UITS Virtualization Cost:	$11,273.75

Contrary to our hypothesis, we determined that this new lower cost was still less than the cost to virtualize at the data center ($11,273.75). Again, the major costs come from storage.

Our group then wanted to determine if this was the case for our other scenarios. The low-end R510 server would cost more to run in-house than at the data center, but the high-end model would still be less expensive to run in-house (see Figures 4 and 5 below). The memory needs and costs are much higher for the high-end model which would make virtualization less appealing.

Figure 4. Dell PowerEdge R510: Low-End Server Cost Estimate

Power Costs:	
kWh per year:	$392.10
kWh--5yr:	$1,960.50
Backup Costs:	
Tape 5yr:	$450
Backup Software License Fee:	$570
Tape Drive:	$1,800.00
TOTAL SERVER COST:	
Server:	$2,479.00
Power:	$1,960.50
Backup:	$2,820
Grand Total:	$7,259.50
UITS Virtualization Cost:	$2,981.25

Figure 5. Dell PowerEdge R510: High-End Server Cost Estimate

Power Costs:	
kWh per year:	$392.10
kWh--5yr:	$1,960.50
Backup Costs:	
Tape 5yr:	$300
Backup Software License Fee:	$570
Tape Drive:	$1,800.00
TOTAL SERVER COST:	
Server:	$4,279.00
Power:	$1,960.50
Backup:	$2,670
Grand Total:	$8,909.50
UITS Virtualization Cost:	$7,984.25

We saw similar results with the R710 models (see Appendix DC, Tables DC-8, 9, and 10). It would be more efficient to virtualize the low-end model, but not the mid-range or high-end ones because of the memory needs.

Based on our server scenarios we determined that, due to the costs for storage and memory, some departments may not find virtualization at the data center to be cost effective. Even when we factored in backup and electricity costs, the majority of our scenarios favored no virtualization. So, departments that have low-end needs may find greater benefits to virtualization because they would not have to pay upkeep or maintenance costs on their servers. However, it would be more cost-effective for departments with high-end needs, even when faced with paying electricity costs, to remain or even virtualize in-house.

Goal 4: Provide Insight on Overcoming Institutional Hurdles to Expanded Adoption of Data Center Virtualization

There exists a strong culture of autonomy among IT staff, faculty, and departmental administrators. A significant portion of each group still values being the "master of one's data." An important point to keep in mind is how each group's conception of professional autonomy can conflict with others and make continued improvements in energy efficiency difficult. This section will address ways to balance professional autonomy and increased virtualization through UITS.
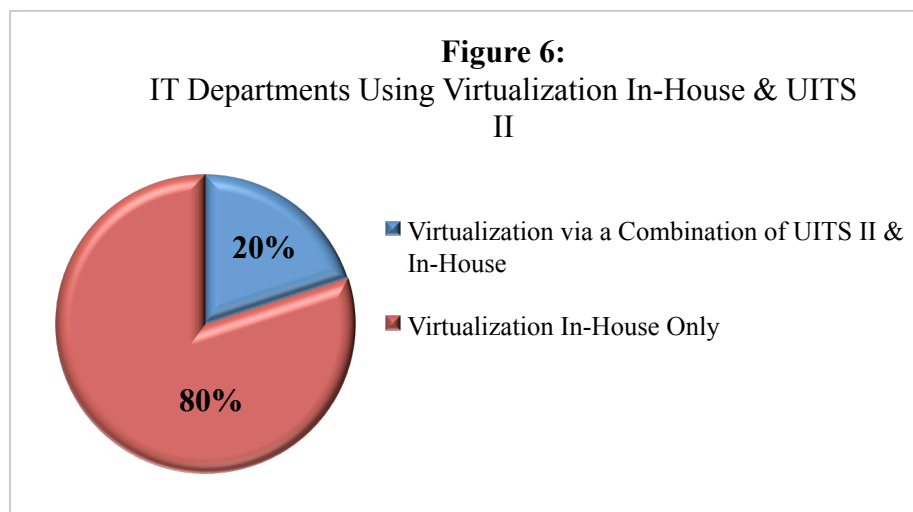
One way professional autonomy manifests itself is during grant applications where faculty is required to explain how the money will be spent. It is commonplace for faculty to request a server and other hardware. By the time the application is filed, faculty does not want to change plans. At this point, IT staff views its role as recommending certain hardware rather than trying to challenge faculty autonomy. Admittedly, bureaucratic hassles of changing grant spending descriptions may be prohibitive at this point. Assuming that there are no technical reasons for new hardware for a given research project, IT staff could advise faculty prior to completion of the grant application that requesting new hardware is unnecessary.

Granted, faculty would likely be skeptical of a perceived to challenge their autonomy, but this innovation has the advantages of trialability and observability. UITS could confer with departmental staff on how best to introduce this issue to faculty and selected departments could measure if this topic of discussion reduces faculty requests for new hardware. Should faculty be receptive to this message during initial trials, the policy could be pursued University-wide.

Among respondents to our initial survey, there is variation of concern regarding the possibility that virtualizing at the data center could negatively affect the size of a department's budget and staff. This perception partially undermines the argument that virtualizing at the data center will free up departmental IT staff for other tasks. Two respondents gave a grade of 4 or 5 (5=strongly agree) regarding virtualization through UITS negatively affecting the size of their staff and budget. A third respondent gave a 4 regarding virtualization through UITS affecting the size of the budget. While a majority did not cite potential reductions of budget or staff as a concern, this significant minority points to ongoing concerns among some departmental IT personnel. An administrative source said that departmental concerns regarding budget and staff were legitimate, although the responder did not give specific instances of negative effects on budget and personnel at IUB. Concern with budget and staff is another example of the resilience of the culture of departmental autonomy.

Whatever the relative advantages of virtualizing through UITS, departmental staff will be resistant toward fully utilizing Data Center services if they believe that it could decrease their budget or result in staff being transferred or laid off. This concern is likely stronger during times of fiscal restraint. An opening for UITS is to actively address departmental concerns about budget reductions and IT staff being transferred or eliminated because of virtualization through the Data Center. UITS, in concert with central administration, may be able to reach out to individual departments and allay fears in this matter.

Regarding the administrative culture of autonomy, the impulse to remain master of one's data is especially strong if you already have skilled personnel and a large budget. Fifty-eight percent of respondents who answered this question indicated that their department had specific technical or workload demands that made utilization of internal servers a necessity. Departments with large IT budgets and well-trained personnel (GIS, Business, and Medicine, for example) may have the capacity to be more responsive to the idiosyncratic data management needs of the department than is realistically feasible for UITS. This is especially the case for departments that rely heavily on customized servers. The additional expertise and size of these departments also makes them candidates for in-house server virtualization. This was indicated in our survey results as 100 percent of the departments against virtualization with UITS II were already practicing virtualization within their department and only 20 percent of departments using virtualization in-house placed a virtualized application in the Data Center.

Figure 6:
IT Departments Using Virtualization In-House & UITS II

- Virtualization via a Combination of UITS II & In-House — 20%
- Virtualization In-House Only — 80%

Those operating "small shops" may be less current regarding knowledge of what the data center charges for specific services. They may be operating on obsolete information because they have not done substantive investigation of services and rates. Unfortunately, these smaller shops do not have the personnel to engage in comprehensive cost/benefit studies of the potential relative advantages of virtualizing through UITS. As explained in the previous section, departments with only one or two servers and modest storage needs have the most to gain by virtualizing through UITS. However, these small shops are still able to comfortably fit existing servers into their budgets and may be skeptical about virtualizing through the Data Center. Smaller shops may be among those most ready to adopt virtualization and may benefit from additional outreach from the Data Center. A potentially useful tactic would be to focus on the small size of their staff and emphasize how virtualizing through the Data Center could free up person hours for more useful and rewarding tasks.

Only one respondent claimed that a letter regarding their energy use would influence their thinking regarding potential energy (and resultant cost) savings of virtualizing through UITS. Considering the perverse incentive structure of not paying one's electricity bill independently, there is no economically compelling reason for IT staff to take energy use into consideration when deciding whether or not to virtualize through the Data Center. Overcoming this hurdle requires the central administration to demand increased fiscal responsibility for departments regarding utility payments. Although this change appears unlikely in the foreseeable future, the continued decline of public funding may result in the university implementing structural changes that were easily dismissed in the past. If UITS and central administration both believe that this structural change offers significant savings for the university as a whole, a convincing, empirically-based argument is best presented sooner rather than later.

Based on the previous discussion of these goals, we present the following recommendations to the University:

Recommendations

Recommendation 1: *Consider Pursuing the Energy StarCcertification from the EPA.*

As the IU Data Center continues to expand and invest in energy efficient methods, it may further meet its goal of establishing Indiana University as a role model of sustainability by achieving Energy Star certification from the EPA. This certification accounts for more variables than PUE and would allow the IU Data Center to compete more fairly with other leading data centers which take advantage of manipulated variables such as geographic location and climate etc.

Recommendation 2: *Revisit Hot Aisle Containment as Feasible Configurations May Allow for Material Energy and Cost Savings Resulting From Improved Temperature and Air Current Control.*

The Data Center is already quite efficient, and would likely become more efficient as more floor space is used. We recommend the Data Center look into the false-ceiling hot aisle containment. Additionally, Facebook made its data center designs and specifications available online at http://opencompute.org. Facebook claims a PUE of 1.15, so the IU Data Center could almost certainly learn new strategies for reducing waste without sacrificing redundancy, up-time, or capacity. Although some of these strategies may not be feasible, such as using outside air for cooling, or using waste heat in the winter to heat offices, there is plenty on the site. For example, the Data Center might also consider increasing the ambient temperature in the pods, powering down unused servers, considering solid state drives in highly read-only situations, etc.

Recommendation 3: *Increase the Value of UITS II by Offering More Affordable Storage Packages and Exploring Intangible Savings such as Dependability and Staff Time Use.*

One finding from the survey and interviews was that disk space at the Data Center was relatively expensive when compared to physical servers and mirrored drives or tape backup. This may be partially the result of differing technologies; the Data Center is probably using low latency fiber channel 15,000 RPM SCSI drives, whereas IT departments may be considering 7,200 RPM SATA drives. It may be worthwhile for the Data Center to consider offering lower-cost, higher-latency storage. A SQL server under load may require a top-of-the-line storage option, but a simple file server likely needs more space than speed.

Our cost comparison showed that virtualizing with the intelligent infrastructure is not always lower cost, even when taking into account power consumption and backup. In general, the Intelligent Infrastructure is attractive to server applications with low resource requirements or CPU intensive tasks. The Intelligent Infrastructure is less cost-effective for tasks with high storage or memory requirements.

When introducing II, it may be more effective to market based on hard-to-quantify benefits rather than cost alone. These benefits are difficult to do a perfect one-to-one comparison and may be left out of departmental cost comparisons. Additionally, these benefits, such as IT administrator's opportunity costs, reduced maintenance headaches, secure stationary and off-site backups, and other Data Center features, may be the unique strengths the Data Center has to offer.

Recommendation 4: *Invest in Consensuses Building With IT Departments, Aligning Organizational Incentives and Goals Between the Data Center and Autonomous Departments.*

The professional autonomy of IT staff, faculty, and individual departments (and the inevitable conflicts of interest) will make implementation of green technology challenging. UITS will be well-served by redoubling its efforts to reach out to individual departments to address their idiosyncratic needs and concerns. In the process of addressing especially contentious issues (for example, uncertainty regarding budget and personnel allocation), UITS could partner with central administration to reassure staff and faculty that great care will be taken not to penalize departments for implementing sustainable technologies.

Conclusions

The new IU Data Center allows Indiana University to greatly expand its information technology operations into the future. By focusing on sustainability, the Center is also providing solutions for the environment as well. The recommendations outlined in this analysis highlight four specific areas where Indiana University may further reduce the impact of its IT activities on the environment through power conservation.

Obtaining data center Energy Star certification may allow management to identify areas for additional conservation and should increase the green reputation of the University. Using partial aisle containment within the data center could reduce the amount of electricity used cool the data center. Increasing the appeal of UITS II to department IT managers will allow the University to maximize the sustainable impacts of virtualization. Finally, increased dialog across the University will allow managers to make more informed decisions regarding the environmental impact of their IT practices and the alternatives available to them. Collectively, these recommendations promote sustainable IT through a spirit of collaboration, self-evaluation, and innovation.

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Duplex Printing and Reducing Printing by Students and Faculty

The Duplex Printing Group was tasked with determining steps the University had already taken and could continue to take to meet students' needs and control costs while focusing on sustainability. As we progressed in our research, we investigated IUB student preferences related to printing, IUB's current printer settings, the print quota system on campus, and emerging technologies, such as solid ink technology, Ecofont, and Adobe Acrobat Pro X. Throughout the process, we learned that the University can take many steps to mitigate paper consumption by shifting the culture of printing. We believe that this shift will reduce the University's carbon footprint as a result of the savings generated from a more aware community and potentially save the University money.

In the following pages, our recommendations range from the simple – posting clear instructions for changing the printing setting on PCs and Macs at IUB (both on computer desktops and at workstations) – to complex – phasing out the print quota system on campus in favor of a system that encourages less printing and thus less printing waste.

Beyond our recommendations for printing, we also think it necessary to emphasize the importance of a swift move towards a decentralized system for utility billing at IUB. While researching energy consumption by IU Chemistry and IU Athletics printers, we were continually plagued with the following question: why should this department, or any department for that matter that is not paying its own utilities, set energy conservation or reduction goals as a departmental priority? In order for the University to mitigate growing energy costs, this must be a priority of all departments.

Finally, as we were guided through the halls of the Chemistry Building, we were also pleasantly reminded how a relationship built on trust, mutual respect, and shared goals can result in positive outcomes. We would like to take this opportunity to commend the individuals we collaborated with from IU Chemistry and stress the importance of clear communication, unified planning, and information sharing between departments at IUB. These findings are at the very least equally important to what lies ahead in this section.

Purchasing at Indiana University

Introduction

Our group analyzed the total toner and paper purchased on campus in 2009 as well as the recycled paper purchased over the past five years. In 2009, Indiana University spent $1,148,593.51 on paper. Recycled paper purchased in this year represented 23.57 percent of the total paper purchased on campus (i.e., the total recycled paper bought was $270,709.93). Overall an increasing trend in purchasing recycled paper has been seen since 2005.

Methodology

Data for this section of our research was provided by Nathan Smith of Indiana University Purchasing; the data include ink, toner, and paper purchases made at all eight Indiana University campuses[3]. Additional information for recycled paper purchasing was provided to our group from 2005 through 2010. From this data, we were able to find purchasing and vendor trends.

Results and Discussion

In reviewing the purchasing information, we determined the total costs for purchasing paper and toner at all eight Indiana University campuses for the period of July 2009 through June 2010. From this data we determined $1,148,593.51 was spent on paper and $828,081.55 on toner (Appendix DP, A1). This amounts to $1,976,675.06 spent by the University on paper and toner in the last fiscal year. In analyzing the purchasing characteristics, we determined that paper is bought from three vendors, with the majority being purchased from BC-PTD (48 percent) (Appendix DP, A2). Purchasing for toner is done through 29 different vendors, with the majority being done through Hewlett Packard (HP) (36 percent) (Appendix DP, A3). Moreover, in analyzing the solid ink purchasing characteristics, our group found that solid ink makes up approximately 0.11 percent of the toner purchases (i.e., $934.57 was spent on solid ink).

Since 2005 the total amount spent at Indiana University on recycled paper has increased dramatically, from $5,637.05 in 2005 to $270,709.93 in 2010 (Appendix DP, A4). Over this time horizon, this translates to an average annual growth rate of 117 percent; however, the yearly annual growth varies drastically from year to year. The trend had been upward sloping until 2009-10, when the total spent on recycled paper decreased slightly. The cause for this loss in recycled paper purchased is unknown. Corresponding with this growth, the total number of vendor brands, purchased by Indiana University, has increased (Appendix DP, A5). However, the total number of vendor the University purchases from has decreased to only two vendors in recent years. Since 2005, the favored recycled paper purchased by the University is 100-percent-recycled-content. Also, 50-percent-recycled-content paper has been purchased more over the past five years (Appendix DP, A4).

Recommendations

Our group's recommendation for the University is to develop a purchasing plan in line with the mission of the Sustainable Computing working group or the Office of Sustainability. Specifically this group's goal is to develop a plan that reduces "the environmental impact of our technological practices and effectively employ technologies to lower the environmental impact of the campus and its constituents" (Indiana University Office of Sustainability, 2009). Overall an easy method for IU to reduce its carbon footprint would be to purchase more recycled paper (as a percentage of the total paper purchased).

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[3] IU Bloomington, IUPUI Indianapolis, IU East, IPFW Fort Wayne, IU Kokomo, IU Northwest, IU South Bend, and IU Southeast

Conclusions

In conclusion, our group determined the purchasing trends for recycled paper from 2005 to 2010. Over the past five years, the total spent on recycled paper has increased drastically. This indicates an increased demand for the product. We determined that the majority of recycled paper purchased is 100- percent-recycled-content. However, recycled paper amounted to only 23.57 percent of the total paper purchased on campus. We therefore recommend that the University develop a recycled paper purchasing plan with the input of the Office of Sustainability that includes, as one of its main goal or objectives to reduce the University's carbon footprint.

Printing Preferences at Indiana University-Bloomington

Introduction

Near the beginning of this project, the Duplex Printing Group determined that understanding student printing preferences at IUB would be central to any recommendations we produced. Furthermore, we learned from our research that such a survey had never been carried out on the IUB campus. Thus, we designed and distributed a student survey to measure IUB student printing preferences (Appendix DP, B).

Methodology

After designing and editing our survey, Barbara Bunch in the Office of the Registrar, generated a random sample of 10,000 (about a quarter of all IUB students – at the beginning of the spring 2011 semester, 40,456 students were enrolled at IUB (IU News Room, 2011) undergraduate, graduate, and PhD students on campus. The School of Public and Environmental Affairs' Masters Program Office graciously agreed to distribute our survey through the office's Survey Monkey account.[4] On March 9, 2011, the completed survey was distributed to 9,968 IUB e-mail accounts.[5]

Survey questions were designed to determine students' view of the printing quota system, user knowledge of printers on campus, user preference in printing, the reasons behind those printing preferences, and the need for posted printing instructions in IUB computer labs.

Results and Discussion

Of the 1,902 survey respondents (response rate of 19.1 percent), the majority were undergraduate students (68.5 percent) and female (56.4 percent) (Table 1). These numbers don't exactly match

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[4] We investigated our own Survey Monkey account, but free accounts through the Website have a maximum of one hundred survey responses per month, so we explored other options.
[5] Twenty-one e-mail accounts were no longer active and 11 of the 10,000 had previously opted out of Survey Monkey solicitations

the enrollment numbers at IUB (Indiana University Institutional Research and Reporting, 2010)[6] (75.1 percent undergraduate; 11.6 percent graduate; 12.2 percent doctoral). Based on the presumed makeup of our sample (closely related to the true enrollment at IUB), our results indicate that graduate students were more likely to respond to the survey than undergraduate and doctoral students. This may be explained by salience theory (Groves et al. 2004, 25-26.) – that those individuals most interested by our topic (i.e., sustainability, similar educational level as the research team, or duplex printing) are more likely to complete the survey. It may be reasonable to assume graduate students are most interested in this topic. Several doctoral students, who are enrolled at IUB but studying in remote locations, contacted us throughout the survey to inform us that, while they were interested in the survey, they did not feel able to provide an insight on the topic, since they were either not in Bloomington or not in the habit of using IUB printers.

The theory that survey respondent's interest is related to their participation gains even greater weight when we consider that 93.2 percent of survey respondents indicated that they used printers on campus (Figure 1). Comparatively, only 3.94 percent of respondents indicated that they did not use campus printers. Based on our results here and from the research we conducted on print allotments at IUB, the vast majority of IUB students *do* use printers on campus. It is fair to say that respondents were interested in our survey and our response rates benefitted from this interest because a great number of students take advantage of IUB printers.

Table 1. Gender and education level totals (and ratios) of IUB sustainable computing survey respondents (n = 1,902).

Gender	Undergraduate Students	Graduate Students	Doctoral Students
Female	**762** (40.1%)	**196** (10.3%)	**115** (6.0%)
Male	**537** (28.2%)	**188** (9.9%)	**99** (5.2%)
No gender provided	**2** (0.1%)	**3** (0.2%	**0** (0%)

Survey respondents who indicated that they did not use printers on campus were not included on the majority of the remaining questions, since the questions pertained to printing specifically. That said, we felt all respondents should be afforded the opportunity to provide input on their preferred default printing setting (Figure 2). Of the 1,902 respondents, only 20 percent would like to see the University leave its printing default setting at simplex. The remaining 80 percent either prefer a duplex default (60 percent), have no preference (16 percent), or failed to answer the question (4 percent). A slightly higher percentage of females (17 percent) had no preference when compared to males (15 percent), while the other three preferences (single-sided, double-sided, and no answer provided) were nearly identical (Appendix DP, C3). Similarly, preference among various education levels was only marginally different - with a direct relationship between duplex preference and educational level (59.0 percent of undergrads; 60.1 percent of grads; and 62.0 percent of doctoral students). Also, undergraduates (17.1 percent) and graduates

(15.5 percent) were more likely to indicate no printing preference when compared with doctoral students (12.6 percent) (Appendix DP, C4).

"A reduction [in paper consumption] of just 500,000 pages represents the cost of 10 computer workstations or 3 printers."
– Marc Wagner, IU STC Printing Services

As previously mentioned, survey respondents who indicated that they did print on campus were directed to questions related to on-campus printing. The first of these questions found that only 5.29 percent (Appendix DP, C5) of respondents would continue to print simplex, if their print quota was "charged less" when printing double-sided. We purposefully did not assign a value to the "charged less" because interviews with printing specialists on campus indicated that the true savings from printing duplex has yet to be determined at IUB, although Marc Wagner offered some monetary projections related to printer default settings:

- A 500,000 page reduction in printing (or 1.56 percent) "represents the cost of ten computer workstations or three printers"

- "It costs UITS eight cents [in ink/toner costs] for you to print two page-images on two sheets of paper. It costs UITS 7.5 cents to print those same two page-images on one sheet of paper. To save the four-cent cost of printing one simplex page, you would have to print eight sheets of paper in duplex (or 16 page-images)" (Wagner, 2011)

Figure 1. Ratio of survey respondents who use IUB campus printers (Survey Question 7 (1))

No
4%

No answer
provided
3%

Yes
93%
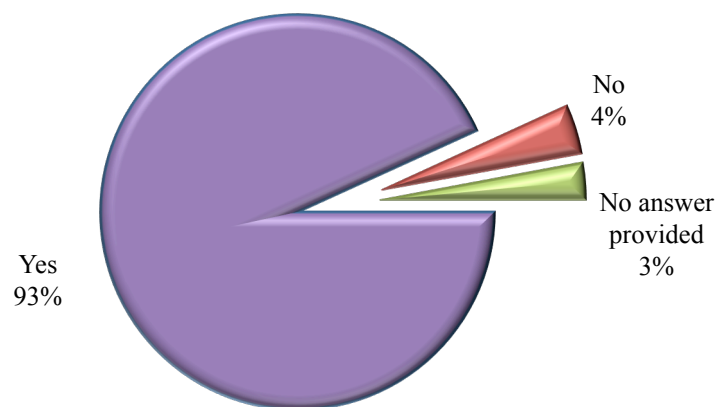
Since simplex is the default on campus, we were curious how many students knew how to change the setting (Appendix DP, C6). Of the 1,759 respondents,[7] 79.6 percent (or, 1,400) said that they did know how to change the print setting from simplex to duplex. The remaining 359 respondents (or, 20.4 percent) indicated that they did not know how to change the setting.

Figure 2. Student printing preference ratios at Indiana University-Bloomington (Survey Question 8 (1))
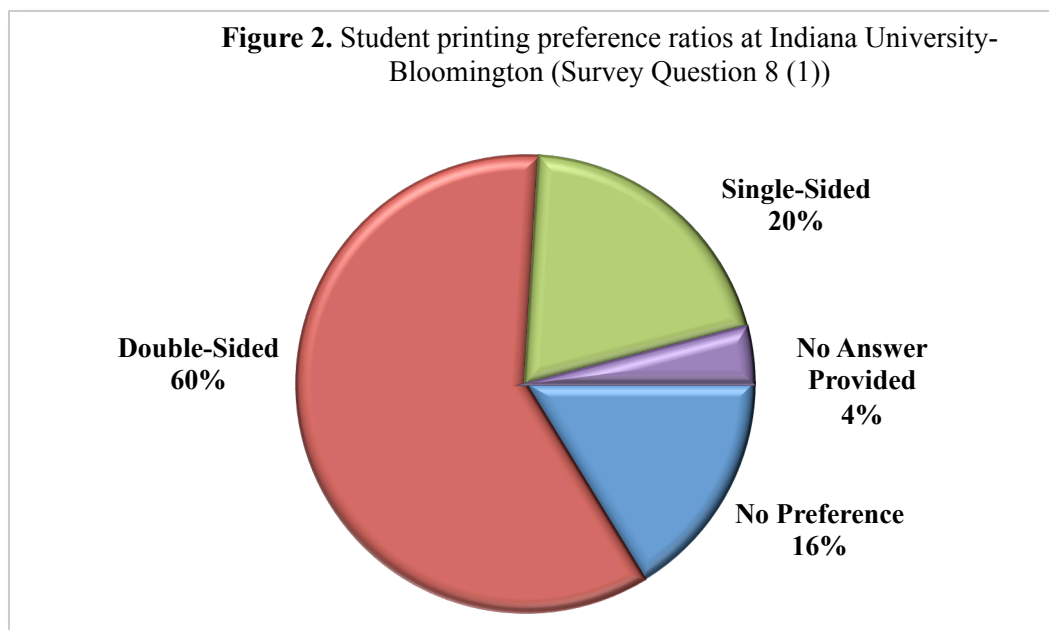
The vast majority (90.5 percent) of those who did not know how to change the setting indicated that they were interested in learning how to change the setting in order to print duplex. Thirty-four (or, 9.5 percent) of the 359 who did not know how to change the setting had no interest in learning.

Of the 1,759 respondents, the most common answer given for not printing duplex was "other." These reasons ranged from a belief that reading was easier on single-sided pages to an attitude that if the user is going to be charged for two pages, then the user is going to print two pages. The most common of the other responses involved highlighting, purpose of the printing (e.g., reading music), or the inability of the machine to perform a duplex print. 13.9 percent of respondents indicated that they were unsure how to print duplex, which was also a common "other" comment; users emphasized frustration in the differences of printing from a Mac versus a PC (Table 2).

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[7] Again, those who indicated that they did not use IUB printers on campus did not participate in this question

Table 2. Responses from IUB students as to why users do or do not print duplex (Survey Question 5 (3), Appendix DP, B) (n = 1,759).

	Undergraduate Students	Graduate Students	Doctoral Students	Total
I am not sure how to change the setting	**202** (11.5%)	**32** (1.8%)	**11** (0.6%)	**245** (13.9%)
I print double-sided	**606** (34.5%)	**204** (11.6%)	**119** (6.8%)	**929** (52.8%)
It takes too much time to change the setting	**82** (4.7%)	**14** (0.8%)	**5** (0.3%)	**101** (5.7%)
My professors require me to print single-sided	**146** (8.3%)	**28** (1.6%)	**10** (0.6%)	**184** (10.5%)
Other	**186** (10.6%)	**64** (3.6%)	**50** (2.8%)	**300** (17.1%)
Total	1222	342	194	1759

Further, we gathered information on why users did not print duplex, we thought it only fitting to understand why users chose to print duplex. We designed a follow-up question for the 929 respondents who indicated they printed double-sided. Of the 929, 742 (or, 79.9 percent) indicated that they printed double-sided because users believed that by doing so they would "improve our environment." 510 (or, 54.9 percent) of respondents indicated that they printed double-sided because it weighed less, 19 (or, 2.0 percent) said their professor required duplex printing. 163 (or, 17.5 percent) cited other reasons for printing duplex. The most common, cited by nearly half of these "other" respondents was that the paper took up less space. Other common answers were: duplex printing saved the University paper and money; and that it saved users on their print quota (Survey Question 6 (1), Appendix DP, B).

While designing our survey, we predicted that some students may not have the knowledge to change printer settings, so we designed a question to measure students' desire for posted instructions either in the computer labs or on computer desktops (Survey Question 7 (1), Appendix DP, B). Only respondents who had previously indicated that they printed simplex were directed to this question (directed from Survey Question 5 (3), Appendix DP, B). 830 students were surveyed, and (79.9 percent) indicated that they would print duplex if instructions were posted in computer labs and/or on computer desktops (Figure 3).

We found that three times the students (of our survey) prefer a duplex default to that of a simplex, and students who are currently printing simplex would be willing to change their behavior if they were offered an incentive in the form of a decreased charge to their quota or in posting instructions on how to print duplex.

Figure 3. IUB survey respondents who indicated they currently print simplex who would shift to duplex with posted instructions (Survey Question 7 (1))
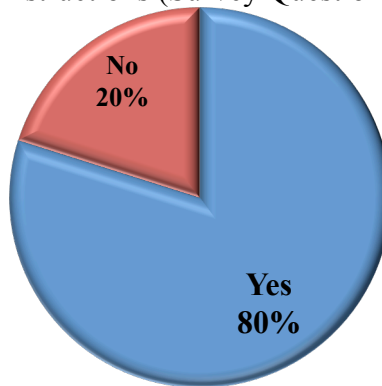
Recommendations

Based on our survey results, we believe there are several steps the University can take to reduce paper consumed via printing (specifically at Student Technology Centers (STCs)). The recommendation that requires the least from staff would be to create a duplex printing instruction set that would be housed on the desktop of each computer *and* at computer workstations; this would vary for a Mac and a PC, since the steps taken to print duplex are slightly different. The guide would consist of a series of screen shots taken at each step of the printing process (Appendix DP, D). Based on our findings, 80 percent of users who currently print simplex would be willing to shift to duplex with posted instructions.

A second suggestion is that UITS alter the default setting within Microsoft, so that all margins move from one inch to ¾ of an inch. Based on multiple studies – the 2001 Mueller Report, the 2008 Hanks IUB report, and others – adjusting the margins in Microsoft could save the University considerable paper. During compilation of this document, we saved 6 pages simply by adjusting the margins a quarter of an inch. Secondly, some fonts use more ink/toner than others (see Ecofont, p. 103). Research performed at the University of Wisconsin-Green Bay in 2009 states that the "greenest" font is Century Gothic, followed by Ecofont's Vera Sans font, and then Times New Roman. We chose Times New Roman for this project, because it is "greener" than Arial and Calibri (Microsoft's default) and based on our discussions with campus technicians (Chastain, 2011) is more widely accepted by readers than Century Gothic.

We understand there may be some resistance to completely shifting the default printing setting from simplex to duplex at IUB, but many of the new printers located in STCs are new models of printers – the HP 4515, specifically (like those located in the Business/SPEA Information Commons) - that based on testing at other universities are performing comparably when defaulted to duplex (University of Michigan Information & Technology Services, 2011). While a campus-wide duplex default setting is preferred by the IUB student body, based on our survey,

we believe the best option might be expanding the Business / SPEA Information Commons study across campus to easily allow users to define their preference when logging in. We believe that by allowing users the freedom to alter the setting themselves, fewer student errors will occur (e.g., printing double-sided when a user must produce a single-sided document such as when printing music) in the printing process.

Conclusions

Based on our survey, it appears IUB students are ready and willing to print duplex. Adjusting printers in Student Technology Centers to a duplex default seems to be a viable option for many of the computer labs on campus particularly those with newer technology. When the University decides to alter the setting, technicians and supervisors will likely be met with little resistance from the student body. By allowing students to choose the printing setting when signing in, the University may be able to reduce error prints and eliminate user frustration in adjusting settings to meet needs.

In the meantime, providing clear instructions on changing the setting will improve user experience and satisfaction. IUB should begin planning for paper reduction on campus using a mix of margin adjustment, print allotment reduction, font adjustment, software training (e.g., Adobe Acrobat Pro X) and incentivized duplex printing (even if it is a modest incentive). As IUB's own Marc Wagner noted, a 1.56 percent reduction in paper used on campus represents a savings equivalent to the cost of ten computer workstations.

Default Printing Settings

Introduction

Previous studies, like the internal research conducted in 2008 on the University of Michigan's Hewlett Packard 4300/4350 machines, found that printers set to duplex result in a greater number of jams than when set to simplex. This fact is not disputed by our research, but we find it important to emphasize that such studies are obsolete when published, due to the continual upgrade of technology on campuses around the country. Yes, for *some* machines (i.e., dated printers) duplex *may* not be the most efficient default setting. The determination of whether a machine performs duplex or simplex more efficiently, when considering energy consumption, paper usage, and jam frequency, should be made on a machine-by-machine basis. Thus, sweeping generalizations about the efficiency of all technologies with respect to duplex printing cannot be made without careful study of the machines housed and used at Indiana University-Bloomington. For instance, more recent studies at the University of Michigan "found that duplex print [with HP's new model, the HP 4515] has been more reliable than with the HP 4350/4300." Therefore, the University of Michigan's Information and Technology Services plans to further study the new machines being used on campus, and seek out user preference to determine the best default settings (like we have done with our survey at IUB) (University of Michigan Information and Technology Services, 2011).

The purpose of this section of our research is to provide information on the spring semester 2011 studies conducted in the IU Athletics Computing Services department, the Business/SPEA Information Commons, and the IU Chemistry Department,[8] and offer our recommendations on a formal printer test structure. This is so departments at IUB can determine the best printer default setting for their machines.

Methodology

Early in our process, we made contact with Troy Chastain (IU Athletics), Brian Crouch (IU Chemistry), Bill Creech (Xerox), and Susan Coleman Morse (University Information Technology Services (UITS)) about studying machines housed in Assembly Hall, the Chemistry Building, and the Business / SPEA Information Commons (BSIC). Within Assembly Hall, we were interested in comparing the energy consumed, jam frequency, and paper used over a four-week period by printers set to a simplex default versus a duplex default[9]. The BSIC was already conducting a study where students were prompted to choose a printing option (single-sided, double-sided, didn't care, or didn't intend on printing) when logging on to the machine, so we requested data and interviews of the technicians administering the test. Finally, within the IU Chemistry department we aimed to study the electricity consumed by various printers in the department. It was particularly important for us to target IU Chemistry, because the building houses nine Xerox Solid Ink machines that, up to February 2011, had not been monitored for electricity consumption.[10]

IU Athletics – Assembly Hall

With the assistance of Troy Chastain, we first identified three printers to study over an eight-week period. We decided to monitor only three machines due to complications involved in getting entire departments to participate in an eight-week study during busy athletic seasons. Also, and more importantly, only a portion of the printers within IU Athletics have the capability to print duplex. Collectively we identified three printers to monitor – one in the compliance office, concessions, and marketing. The supervisors in the areas where these printers were located were contacted early in the process to explain the importance and logistics of the study, and to gauge their willingness to participate. All kindly agreed to participate in the study, and thus have their printing totals, energy consumption, and jam frequency monitored for eight weeks. They also agreed to have the participating printer default settings switched from simplex to duplex for four weeks in March.

After further inspection, the printers in compliance and marketing did not have the duplexer installed, so we were unable to include them in the study. Instead, we monitored the concessions' printer and two printers located in Computing Services. All users were notified in advance of the

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[8] Although the IU Chemistry study focused on electricity consumption of the department's machines, we learned many valuable lessons about conducting a strong study

[9] Combined eight-week study, four defaulted to simplex, four defaulted to duplex

[10] Which is of particular importance because the solid ink machines must heat up to melt the resin ink used

pending study and encouraged to contact Troy Chastain or us if they had further questions or concerns.

On February 4, 2011, Kill-a-Watt energy meters were installed on the three machines including an HP Color LaserJet CP 6015 in Computer Services used as a central printing point for several departments, an HP LaserJet 4350 in Computer Services used for Computer Services printing only and an HP LaserJet 2300 in Concessions. Usage pages, providing information on printing totals of each machine at installation of the Kill-a-Watt Meters, were collected, and Kill-a-Watt meters were installed. In addition, staff in each office were given a brief tutorial on how the energy meter was used.

After the first four-week period, we returned to the participating machines on March 4, 2011, interviewed the users, and collected a usage page and energy reading on each machine. Then, with the aid of Troy Chastain, the printers' default settings were altered from simplex to duplex. Users were reminded in person that the printers would default to duplex for the following four weeks. To be thorough, the department, as a whole, was sent a reminder via e-mail. The energy meter was reset to zero for the second half of the study. The usage page was filed along with each machine's energy reading.

At this time, we learned that the HP LaserJet 4350 machine had been replaced abruptly due to machine error and energy, jam, and paper consumption readings had not been recorded prior to replacement. Thus, we removed the energy meter from the replacement and instead included it in the IU Chemistry study.[11]

Three weeks later, on March 25th, the final two Kill-a-Watt meters were removed from the HP 6015 and HP 2300 printers, so that we could include the energy meters on IU Chemistry printers.[12] At the time of the removal, we again interviewed users, recorded readings from the energy meters, and printed usage pages from each machine. Troy Chastain then provided us with error logs (jam frequency) for the HP 6015 for our study period. The HP 2300 does not have the capability of printing an error log, so we used the interviews of end users as our proxy for error logs (jam frequency) on this machine.

Since the second half of the study only ran for three weeks, the results have been adjusted to reflect a per day (in the case of jam frequency) or kilowatt-hours (KwH) consumed (in the case of energy consumed) total, so that we can more easily compare the first (simplex default) 28-day totals with the second (duplex default) 21-day totals.

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[11] Primarily because there was a shortage of energy meters on campus at this time and also because we did not have the time to restart the study on a different printer

[12] Again, we decided to remove the Kill-a-Watt Meters in Athletics due to the shortage of energy meters on campus, and because the IU Chemistry study had become our priority

Business / SPEA Information Commons

The BSIC study was a two-month experiment conducted by the Student Technology Center in which users were prompted to choose their preferred printing method when logging in (Appendix DP, 4). Once the user made a selection (whether simplex, duplex, no preference, or not printing) the computers modified the print settings to match the selection. This system also recorded the amount of paper printed in each print setting and the jam frequency of the three printers in the BSIC.

IU Chemistry Department

After meeting with Susan Coleman Morse, we learned that the Chemistry Department owned solid ink printers. Our group was then able to hold an informal interview with the Chemistry IT department to discuss these machines. Brian Crouch, Manager of the Information Technology Group (ITG), agreed to partner with us for the purposes of our energy consumption study. Over the six -week study, thirteen printers in student areas, faculty rooms, and business offices were monitored for energy consumption using Kill-a-Watt meters and paper usage using printer usage pages. Staff members, Scott Harrison and Gabe Hale, accompanied us each week to the machines (for security and navigational purposes[13]) so we could retrieve a printer usage page and record energy consumption. In each location we monitored, we explained the purpose of our study to end users. Fortunately, all participants within the Chemistry Building were extremely accommodating.

Results and Discussion

IU Athletics – Assembly Hall

The results of the seven-week study in IU Athletics indicate that user behavior is an important variable to consider in studies measuring printing. The printers were measured at a simplex default, the standard default within IU Athletics and at IUB, throughout the month of February. During this time of year, the department prints a great deal of materials for the close of basketball season, and users indicated that we could expect to see greater all-around printing totals in February than we could in March. Our results revealed that the users in each department were correct (Tables 3 and 4).

Furthermore, as more pages are printed, the electricity consumed per page decreases. Based on the results of the HP 2300 machine, the printer consumed nearly as much electricity per day when it was printing 48.7 pages per day as it did when printing nearly half that total (28.8 pages per day). This indicates that printing is not the major determinant of electricity consumption in this department. Based on interviews, the HP 2300 is not powered down at the end of business days. Additionally, the HP2300 had no jams over the seven-week study and printed zero duplexed pages. Users explained that they could not remember the last time they had printed a

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[13] For inexperienced visitors, the Chemistry Building is difficult to navigate

document that exceeded one-page in length. Nearly all of Concessions' printing is one-page invoices. Over the life of the printer's 101,369.7 pages printed, only four have been duplex.

Similarly, within Computing Services, we found that during the first half of the study the HP 6015 printed nearly five times the amount of pages when compared with the second half of the study (Table 4). Unlike the HP 2300, the HP 6015 is powered down at the end of each business day, yet the machine does see a drop in kilowatt-hours consumed per page when set to simplex largely because the vast majority of electricity dedicated to the machine keeps it powered on throughout the working day. An increase of an average of 456.9 pages printed per day over the two study times is only responsible for a 0.41 Kw/h consumed per day increase. This again suggests that the majority of the energy dedicated to this machine is in keeping it powered throughout the business day.

Table 3. Comparison of paper consumed, electricity used, and jams frequency of an *HP 2300* (housed in the Concessions department of IU Athletics) when printer defaulted to simplex versus when defaulted to duplex.

Default Setting	Pages Printed per Day	Duplex Pages Printed per Day (% of total)	Kilowatt / Hours Consumed per Day	Kilowatt / Hours Consumed per Page	Jams per Day	Jams per Page
Simplex	48.7	0 (0%)	0.25 Kw/h	0.00519	0	0
Duplex	28.8	0 (0%)	0.24 Kw/h	0.00839	0	0

We observed an increase in jam frequency when the printer was set to duplex default, but interestingly, the number of duplex pages printed per day during the simplex portion of the study was over 150 times the average number printed per day when the machine was set to duplex, suggesting that duplex printing may not be the cause of jams in the second half of the study.

The research team also observed an increase in jams with additional printing, but the frequency of those jams was still less than one jam for every 1,700 pages printed for the first half of the study, and one jam for every 650 pages printed for the second half of the study. Overall only thirteen errors (jams) were recorded over the seven-week study.

Based on discussions with technicians across campus,[14] the general consensus is printer performance wanes as the number of pages printed and age increases. That is, generally speaking, the older the machine, the more maintenance must be performed on it. Age is merely one of the many variables that must be considered when attempting to gauge whether duplex printing is more efficient, and thus preferable to simplex printing. Further, it was impossible for

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[14] Troy Chastain, IU Athletics; Mathew Decker, UITS; Scott Harrington, IU Chemistry

us to determine causation in this study. Error logs do not explicitly inform the research team whether the failure was caused by a duplex feed.

Table 4. Comparison of paper consumed, electricity used, and jam frequency of an *HP 6015* (housed in the Computing Services department and used a central printing station for multiple departments) when printer defaulted to simplex versus when defaulted to duplex.

Default Setting	Pages Printed per Day	Duplex Pages Printed per Day (% of total)	Kilowatt / Hours Consumed per Day	Kilowatt / Hours Consumed per Page	Jams per Day	Jams per Page
Simplex	582.2	182.3 (31.3%)	1.92 Kw/h	0.00330	0.32	0.00052
Duplex	125.3	1.2 (0.9%)	1.51 Kw/h	0.01209	0.19	0.00152

Other, more thorough studies performed by other institutions (see Best Practices, p. 130) suggest that newer technology performs duplex printing with increased efficiency and speed (one complaint of older machines). If departments are willing to test-pilot new default printing settings, and if errors or jams occur with similar frequency, there is reason to believe that duplex settings may result in reduced paper consumption, a mitigated carbon footprint, and a real cost savings for IUB and its many departments.

Business / SPEA Information Commons

There were 5,885 unique usernames who participated over the course of the two-month study in BSIC. During that time 27,516 printing selections totaling 268,677 pages printed were recorded. Of the 27,516 printing selections made over the two-month study, over 54 percent of all selections were made for duplex printing (Table 5). While a little over 54 percent of all selections indicated a commitment to print duplex, 61.2 percent of all printing jobs processed were duplex. However, the amount of paper printed was slightly different than the recorded printer setting. Simplex printing resulted in 58,674 pages printed, whereas 210,003 papers were printed duplex. This suggests that, over the course of this study in BSIC, people utilize duplex printing more, on average, than simplex printing. However, it is difficult to draw a conclusion on a two-week experiment; more research is needed to determine users printing habits. Had all pages printed over the two-month life of the study been printed simplex, the BSIC would have used an additional 58,701 pieces of paper, which represents additional costs for the University. The total number of jams over the two-month period was: four jams in printer A, six jams in printer B, and 22 in printer C (Table 6). Like we have mentioned throughout this section, it is challenging to assign causation (simplex versus duplex) to errors (jams), but even so, the BSIC saw a total of only 32 jams over the course of the study. Twenty of those jams occurred on one machine over a ten-day period. Still, over the two months on the three machines, one jam was recorded for every 8,396 pages printed. We have failed to obtain data on whether the jams were

caused by a duplex or simplex setting. Therefore, it is difficult for us to conclude the relationship between print setting and jams. Such an analysis would require greater user input, but may be worth pursuing in the future. Additionally, according to Mathew Decker of STC, the higher the page count on a printer, the greater number of "issues" the user will experience with the machine. The printers studied in BSIC are considered relatively new, and Mr. Decker suggests conducting the same test on machines with greater page counts to measure comparative reliability.

IU Chemistry

From the study within the Chemistry Department, we determined the kilowatts used per hour for thirteen printers within the Chemistry Building. These printers included three solid ink printers and ten traditional LaserJet printers, providing us with a wide spectrum for comparison of energy usage between different makes and models of printers. In the end, we were unable to include the HP DesignJet Z6100 PS poster maker in our analysis due to the measurements being in total feet, not in pages used. Also the HP LaserJet 2420 dn printer provided us with inaccurate page measurements. Therefore, we were unable to include results from this printer as well.

Each week we observed the total kilowatt hours used as well as the total number of pages printed. From these two numbers, we derived the kilowatt hours per page printed (Appendix DP, F1). During the study we monitored the trends of different printers throughout the department. From this research, we determined that solid ink printers use comparable amounts of energy, on average, as other machines.

In assessing the average kilowatt hour used per page for solid ink machines (Xerox 8560, Xerox Phaser- 6360 DN, Xerox 8860 MFP), we determined that these machines do use slightly more energy than laser jet printers (Appendix DP, F2). However, the amount is comparable. Specifically solid ink printers used an average of 0.0158 KwH per page in week one and 0.0145KwH per page in week two. This translates to a total average of 0.0152 KwH per page. For laser jet printers we assessed the Xerox Laser 550 DT, HP LaserJet 4250, HP Color LaserJet CM, 3530 MFP Series, Savin AC 205, HP color LaserJet 4600 dn.

During week one these printers used an average of 0.0083 KwH per page, and for week two they used 0.0112 KwH per page. This is a total average of 0.0098 KwH per page.

Several factors may have impacted these results. This study began over spring break when printing patterns may not have reflected normal usage. Our study monitored personal printers and heavily used printers, and it is unclear at this time what settings are in place for all of the printers in our study (i.e., sleep mode settings). For some printers a proper sleep setting may be more important in total energy savings than the efficiency of the printer. Several printers within our study are powered down as a normal practice each night, but this does not occur for all printers (Harrington, 2011). Lastly, we are unsure if any of our data was corrupted due to the kilowatt monitor being removed. Such a "re- setting" of the Kill-a-Watt energy meter could have

Table 5. Results of the STC Duplex Printing conducted in BSIC from January to March 2011.

SPEA Printing (Simplex)		
Printer Name	*Pages Printed*	*Sheets of Paper*
spea_ic_a	3225	3225
spea_ic_b	15991	15991
spea_ic_c	39458	39458

SPEA Printing (Duplex)		
Printer Name	*Pages Printed*	*Sheets of Paper*
spea_ic_a	8214	4267
spea_ic_b	77984	41042
spea_ic_c	123805	65104

Job Totals		
Job Attribute	*Number of Jobs*	*Percentage of Jobs*
Duplex	27295	61.19%
Simplex	17314	38.81%
Total	44609	100.00%

Log-in Selection Totals		
Selection	*Printing Preference*	*Percentage Selected*
Single	8125	29.53%
Duplex	14862	54.01%
No Printing	3412	12.40%
Doesn't Matter	1117	4.06%
All Choices	27516	100.00%

Table 6. Errors recorded in the error logs of the BSIC printers (HP 4515s) over the course of the Duplex Printing Study.

Month	Printer A	Printer B	Printer C
January	1	2	0
February	3	3	2
March	0	1	20
Total	4	6	22

been caused by removal of students or other users or a power outage. Furthermore, we did not conduct tests on the accuracy of each device, so there may be discrepancies in the data because of the performance of the Kill-a-Watt meters used.

Recommendations

IU Athletics

We recommend that the department conduct a cost analysis (Table 4) of the IU Athletics printers with respect to ink/toner consumption to determine the cost per page currently being incurred for each printer.[15]

Business / SPEA Information Commons

The study could potentially be improved with a more detailed data-recording mechanism. For example, a better recording design on jam frequency of each printer and printer setting at the time of printing could clarify the correlation between print type and machine jam. Another consideration of future studies like this one is energy consumption of each printer – easily done by installing energy meters on each machine and taking regular readings (Figure 6). Additionally, a formal test structure for measuring printers based on our recommendations may be worth considering (Figures 5 and 6).

IU Chemistry

From our research, and the study conducted within the Chemistry Department, our group developed recommendations for further research. First, our group recommends researching the settings currently being used on printers. Then, additional research should be conducted regarding the cost savings from installing and training staff members to use sleep settings onto applicable printers. The majority of energy used was found to be attributed to leaving the machine on either during the day and also, for some machines, at night. This finding is consistent with the finding of the IU Athletics study. Applying sleep mode settings and turning printers off

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[15] This study will actually begin May 2011

for the night or the weekend can realize a reduction in energy. We also recommend that IU conduct a cost analysis for smart strips. Smart strips power off energy to accessories, such as a printer, when power to the computer is turned off. In many cases, energy is consumed even if a printer is off (known as idle current). Some power strips can prevent idle current and unnecessary powering of appliances, and departments across campus should investigate their cost savings, although we anticipate cost savings related to energy consumption will be a peripheral concern of IU departments until payment of utilities is decentralized across campus. That is, we assume only departments truly dedicated to the environment (i.e., The Office of Sustainability) will pay for energy efficiency upgrades, since departments implementing the efficiency upgrade only bear the cost of the installation/product and receive no financial reduction in utility billing.

Indiana University increases its energy consumption by approximately 16 percent per annum (Appendix DP, F3). The University pays approximately 7.24 cents per kilowatt-hour. Reduction in energy consumed, specifically with printers, would result in cost savings for the University (City of Bloomington, 2006; IU Energy Challenge, 2011). With increasing energy consumption across campus, additional research should be conducted regarding the payment structure for electricity. Specifically, since the University pays the bill and not each department, there is little incentive for departments to conserve. It should be analyzed whether some mechanism should be created to improve each department's accountability and awareness of energy consumption.

Collectively

One of the more important issues we learned from conducting this research is the central role a formal test structure could play in future studies. We believe the formalized structure would benefit from exemplary research team / end user relationships and vice versa (like the one fostered between this research team and IU Chemistry). Both the research team and end users have information that benefits the other, and thus an open, trusting partnership is the cornerstone for successful projects.

We also understand that such a collaborative environment may appear threatening to some individuals or entire departments. An agreed understanding that change is challenging for all involved parties will aid the investigative partnership. But, at no time, should individuals' preconceived notions dissuade their desire for objective results. Cultivating a relationship of this nature takes time, which is not always at a premium at IUB, so we again realize there are limitations to our recommendations. With this in mind, we present an eight-step general formal printing test structure (with examples from our own research) for collaboration on campus followed by a more specific test model for future use.

These steps may seem time intensive to those who have never performed such tests, but in actuality the design of the tables likely took about the same amount of time as performing many of the steps. Conducting a thorough and strong print study should not be timely or overly complicated; instead it should be considered a collaborative effort to gain information that will aid departmental decision-making.

Conclusions

IU Chemistry

We found that, on average, solid ink printers do use more energy than traditional laser jet printers. However, the differences were not as extreme as literature stated. On average solid ink printers use approximately 0.0152 Kwh of energy per page, whereas LaserJet printers use 0.0098 Kwh per page. Future research on cost analyses, specifically cost per page analyses of solid ink compared to traditional ink, should be conducted. Additional research of printer settings, smart strips, and departmental energy conservation programs could one day lead to great savings for departments across IUB.

Table 5. The "General Formal Printing Test Structure" outline as determined by the Duplex Printing Group's research.

General Formal Printing Test Structure
1. **Conduct thorough background research:** In this project we read previous studies conducted at IUB, met with sustainable computing leaders on campus, and read reports from other institutions
2. **Identify end users or departments on campus who may be receptive to and/or benefit from the study being conducted:** We sought collaboration with IU Chemistry and IU Athletics, because we felt our findings may improve decision-making on expenditures, thus alleviating departmental costs. In contrast, this is not something we did particularly well with the Business / SPEA Information Commons study. In retrospect, we should have solicited an introductory meeting with technicians to explain the purpose of our research and form a relationship and mutual understanding moving forward
3. **Meet with identified end users and departments:** Clearly explain the study and its goal: In our initial meeting with IU Chemistry we explained that our study was being conducted on behalf of the sustainable computing leaders from step one to determine which printer models in the Chemistry Department were the most energy efficient. This was of interest to Chemistry's IT Group because understanding energy usage was another piece to their overall cost assessment
4. **Set-up clear schedules for the project with consistent, intermediary check-ins:** We could have been clearer with the IU Chemistry Department on exactly how many machines we were going to monitor, but this was contingent on how many energy meters we could obtain, which seemed to always change. Luckily, the department was flexible, and our consistent Thursday afternoon meetings and regular e-mails aided their preparation, even if it wasn't 100 percent flawless
5. **Know what you are doing and ensure that those with whom you are collaborating know what you are doing:** This begins with step one and is reinforced throughout, but researchers should have a clear understanding what they are measuring and how to get the data they require. This should also be communicated to end users and partner departments. Each individual's role in the project should be explained and each individual should be reminded that they are a crucial element in the project
6. **Be consistent and check all readings twice:** Similar to step four, but this is specific to the study itself. In Chemistry, install or read the Kill-a-Watt energy meter and gather a usage page from each printer - giving us detailed data on pages printed-to-date. In IU Athletics this step was followed by the printing of detailed error logs over the time period being studied
7. **Engage end users and department members:** Discussions or interviews with staff members throughout the process provide key details to the research being conducted. By listening, we learned about the many variables that must be considered during our study
8. **Share results and request feedback from end users and partner departments:** Our results from the IU Athletics study have already been shared with Computing Services, and are being used to design an ink/toner cost analysis study beginning in May 2011

Collectively

One way departments like IU Athletics, BSIC, and IU Chemistry can benefit is by communicating and sharing information. Throughout the process we were continually reminded of the need for departments to reach out to one another. We believe that formalized test structures and general sustainability-related prompts or savings tips housed and distributed by UITS could go a long way to reducing costs through smart, "green" practices.

Table 6. The "How to Test a Printer" outline as determined by the Duplex Printing Group's research.

How to Test a Printer
1. Assemble an objective team willing to monitor the device and give the team the authority to effectively monitor the machine for a pre-approved length of time
2. Schedule time to learn the various functions of the printer - Ideally when users are not present. This may be at the end of the business day or over holidays in a Student Technology Center (STC).
3. At the beginning of the test: a) Print usage pages; b) Install Kill-a-Watt energy meters; c) Print error logs; d) Design jam reporting sheets, so users can report jams – the more detailed the better; e) Train users and/or technicians to report jams, read energy meters, and print usage pages
4. Notify users of the test and set clear schedules for consistently monitoring machines – Again, an ideal time to take readings is when users are not present
5. Communicate objective goals of test in an unthreatening manner. Make concessions were necessary. (e.g., "We know this may mean an increased work-load in the short term, but our goal is to improve user experience and gain an understanding of our true costs.")
6. Take peripheral readings – Not all studies measure toner/ink, but some should, so step three should be repeated when new cartridges/drums are installed. When the toner/drums are replaced step three should again be repeated. Then, the results should be analyzed for true costs and paper coverage (by ink/toner). This will provide true cost per page totals.
7. Analyze the results
8. Share results and request feedback from end users and partner departments

Print Quotas and Allotments

Introduction

At Indiana University - Bloomington

The Student Technology Center (STC) Printing Services administers the Student Technology Centers (STCs) and Residential Technology Centers (RTCs) where most of the student printing takes place. There are currently a total of 136 STCs and RTCs disbursed among 56 buildings on campus (Indiana University Information and Technology Services, 2011[2]). STC provides students, faculty, and student organizations with specific printing allotments each semester. All registered students and faculty are automatically authorized a printing account. Each semester, undergraduate students are allotted 650 pages, graduate students 1000 pages, faculty 200 pages, and student organizations 400 pages (Indiana University Information Technology Services, 2011[1]). Graduate students are also entitled to bonus printing allotments. Graduate students working on their dissertations are allocated with a one-time 500-page printing allotment and 500 pages printing allotment for conducting research that is not funded by their departments or faculty advisors. In addition, each semester, graduate students employed as associate instructors are allotted 500 additional pages. There is also a bonus available that allows graduate students who live on campus to print an extra 100 pages per semester. STC provides non-students, students, and departments with supplemental printing allotments as well. This is a pay-as-you-go option targeted towards departments that want to compensate its employees and students for their work related printing activities (Appendix DP, F).

STC is responsible for storing all student and faculty printing data. A bill is sent to students who print over their printing allotment at the end of each semester. Each additional page printed over the allotment costs students four cents. Faculty and student organizations must have an available balance to print. STC also offers students a rollover option for unused pages. Students can request a rollover of up to 300 pages of unused printing allotment of their spring and summer semesters. However, the rollover option does not exist for fall semesters. In addition, the rollover option is not an automatic process. The deadline to apply for the rollover option for spring semester starts on the Sunday after fall semester finals and ends in mid-February. The rollover request period in the summer begins at the end of spring semester and goes through June. Students who fail to meet the deadlines are unable to transfer their unused pages to the next semester (Indiana University Information Technology Services, 2011[1]).

STC offers duplex printing in all its STCs and RTCs to reduce paper waste; however, the duplex printing does not provide students with a lesser charge to the printing allotment. In other words, a document printed on the front and back of one paged counts equally to the print quota as the same document printed on two separate sheets of paper would. In addition, some applications, such as browsers, automatically add an additional blank page to documents when printing duplex, which only counts against students' printing allotment.

This study looks at the student printing behavior from fall 2006 through spring 2010 to calculate paper usage among undergraduate and graduate students as well as determine their printing

patterns over these years. The study also provides IUB with recommendation on how to reduce paper usage and encourage students to conserve.

Indiana University Compared to Other Big Ten Universities

This segment of the project focused on printing default settings and quota at IU compared with other institutions in the Big Ten. While we attempted to collect data from all institutions within this conference the data includes information from six schools (Table 7).

Table 7. Big Ten Universities and enrollment size of each institution included in interviews (Big Ten Conference, 2011).

Institution	Student Enrollment
Indiana University-Bloomington	40,456
Pennsylvania State University	44,817
Purdue University	39,736
University of Iowa	28,705
University of Michigan	37,197
University of Wisconsin-Madison	42,099

Methodology

At Indiana University - Bloomington

In performing the study, we examined several studies previously conducted. One of the studies reviewed was Kristin Hanks' *Sustainable Computing Internship Report* of 2008, which investigated IUB printing and offered recommendations on how the University can mitigate its paper consumption. Since the completion of her study in 2008, no changes have been made to quota allotments.

After securing data from Marc Wagner of UITS, STC, we calculated the average numbers of paper printed each semester. From there, we determined the percentage of students that exceed their printing allotments each semester. In addition, we performed a trend analysis to examine the printing trends of undergraduate and graduate students from 2006 to 2010.

Indiana University Compared to Other Big Ten Universities

We began by gathering information for IU's student printing behaviors. Upon looking at the data collected, we agreed on the importance of including practices from other universities, specifically similar institutions.

Given that IU is part of the Big Ten Conference, we deemed it only fitting to collect data from institutions within the conference.[16] On February 23, all Big Ten institutions were contacted by

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[16] The Big Ten institutions include: Indiana University, Michigan State University, Northwestern University, Ohio State University Pennsylvania State University, Purdue University, University of

e-mail with the following questions:

- What is the default setting on the computer labs on campus?
- Do students have the option of changing this setting?
- On average, how much printing quota is used by undergraduates, graduates, and PHD students per semester?
- How much paper per year do students use for printing purposes?
- What is the total number of students that exceed their printing allotment per semester and/or per year?

After receiving only one response over the course of the next few weeks, a follow-up e-mail was sent exactly a month after the first e-mail. Upon realizing that e-mail may not be the best mode of communication, we began calling each institution on March 24. After several attempts, interviews were conducted with information technology representatives from the following institutions: Indiana University, Pennsylvania State University, Purdue University, University of Iowa, University of Michigan, and University of Wisconsin-Madison.
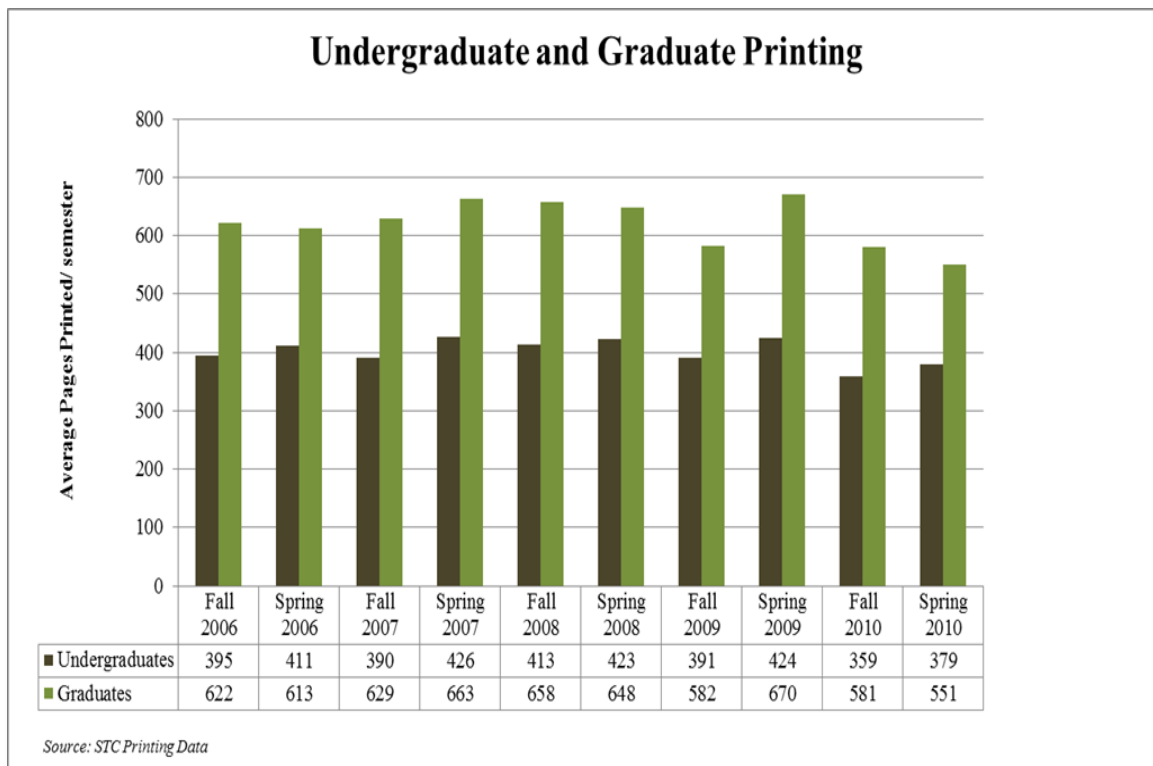
Results and Discussion

At Indiana University - Bloomington

In analyzing the data provided to us by the Student Technology Center of IUB, the following questions were considered:

1. On average, how much printing quota is used by undergraduate and graduate students per semester?

2. How much paper per year do undergraduates and graduate students use for printing purposes?

3. What are the total numbers of undergraduate and graduate students that exceed and fail to exceed their printing allotments per semester (and by what percent do they surpass or fall short)?

4. How do the printing trends of undergraduate and graduate students change over time?

5. What are the costs incurred by the undergraduate and graduate students that exceed their printing allotment per semester?

Through our analysis, we have calculated that IUB students print on average 30,736,863 pages per year (22,539,379 for undergraduates and 8,197,484 for graduates) from 2006 to 2010. We observed that on average graduates print more pages each semester than undergraduate students (Figure 4).

Illinois- Urbana Champagne, University of Iowa, University of Michigan, University of Minnesota, and University of Wisconsin-Madison

Figure 4. Average pages printed per semester by IUB undergraduate and graduate students (2006-2010).

When comparing the printing patterns of undergraduate and graduate students who exceed their printing quotas for academic years 2006 through 2010, the percentage of graduates who exceed their printing allotment is about one percent higher than the undergraduate students (Appendix DP, G1 and G2). On average, undergraduates who exceed their quota print 920 pages per semester while graduates who exceed their quota print 1,540 per semester (Appendix DP, G3). In other words, the percentage of graduates who exceed their printing allotment, print on average twice as many pages as the undergraduate students.

From 2006 to 2010 an average of 20.36 percent of graduates exceeded their printing allotment compared to 19.39 percent of undergraduate students. The 20.36 percent of graduates who exceed quota print 50.12 percent of total graduate pages printed, while 44.30 percent of total pages printed by the undergraduate students are printed by the 19.39 percent of undergraduates who exceed the quota (Appendix DP, G4). Both undergraduate and graduate students that exceed their printing allotments account for a high portion of paper printed.

According to the data provided to us by the STC, most students do not exceed their printing quota (Appendix DP, G5 and G6). On average, 80.61 percent of undergraduates and 79.64 percent of graduates remain under their printing allotments (Appendix DP, G7). Graduate students who remain under their printing quota print an average of 49.88 percent of the total pages compared to undergraduates who print an average of 55.70 percent of the total pages.

Given that on average 19.39 percent of undergraduates and 20.36 percent of graduates exceed their printing quotas each semester, we calculated the average additional cost incurred by undergraduates and graduates who exceed their printing allotments (Appendix DP, H). According to the results, both graduate and undergraduate students do not incur a great cost for printing over their printing allotment. On average, the undergraduates who surpassed the 650 page-allotment paid $10.80 per semester from fall 2006 to spring 2010. Meanwhile, graduate students paid an average of $21.62 per semester from fall 2006 to spring 2010.

Indiana University Compared to Other Big Ten Universities

The results of our interviews found that with the exception of Indiana University-Bloomington, the University of Wisconsin-Madison, and the University of Michigan, university computing labs set duplex as the default printer setting. As previously mentioned, Indiana University uses a simplex default across campus (Indiana University Information Technology Services, 2011[1]). The University of Wisconsin-Madison and the University of Michigan, on the other hand, elect to set printer defaults in each department – utilizing a decentralized system (Staley, 2011; Jones, 2011). Though the default setting was different at all locations, each interviewee indicated that students have the option to change the setting.

Next, we addressed student print quotas. Based on the information gathered, we found that most institutions allow students a quota in the form of a dollar amount. For example, Purdue University allots its graduate students $40 of printed pages (McCarty, 2011). Comparatively, the University of Iowa allots all students a $10 dollar balance, and once students reach the pre-determined dollar amount, they then were charged a $0.04 to $0.05 charge per extra page printed (black and white) (Fitzgerald, 2011). Other institutions allotted a page limit then charged an extra fee: Indiana University (650 pages/semester), Pennsylvania State University (110 pages/semester), and University of Michigan (400 pages/semester). The institution that stood apart from the rest was the University of Wisconsin-Madison, which does not use a quota system and charges $0.07 per page printed for all printed pages; however some departments at the institution do provide small quotas (Staley, 2011).

The final part of our analysis concentrated on the pages printed per year and the amount that exceeded quota. While we sought to determine the amount used by undergraduates, graduate and Ph.D. students, many institutions did not have or were unwilling to provide us with such data.

Still, we found that institutions that set duplex as a default setting had a lower amount of printed pages per year than those who used a simplex default. Additionally, we found that the pay-as-you-go system at the University of Wisconsin-Madison deters a great deal of printing, given the University's small printing numbers when compared to universities with print quotas in place. According to our data, we determined that Indiana University had the largest amount of printed pages and exceeded quota per year. While students are billed for this amount, we believe that having an inflated number of pages limits awareness and results in a greater amount of printing.

Recommendations

At Indiana University - Bloomington

Given our results, we recommend that the print quota be reduced to 400 pages per semester for undergraduates and 600 pages per semester for graduate students , in order to encourage students to print conservatively. Printing totals should be consistently monitored going forward to determine if the University is effective in reducing printing. We believe that an adjustment to the quota should be accompanied by a modest incentive to print duplex. Marc Wagner suggested that duplex printing cost the equivalent of 7.5 cents per two-sided page, while one-sided printing costs eight cents to print two pages (or, four cents per page). We believe this cost may either be out-of-date or ignoring the cost of paper – either way, we believe this figure should be recalculated, and students who print double-sided should be rewarded for doing so. Furthermore, we believe that students should be notified of their remaining print allotment each month via e-mail, and allotment savings due to duplex printing should be highlighted in this report. We believe awareness will only serve to further curb paper consumption on campus. Also, incentivizing conservation will go a long way to shifting the culture of printing on campus. We also recommend that students who exceed the print quota should be charged an additional cent per page over that allotment to further deter wasteful printing (moving from a four cents per page charge to a five cents per page charge). The current system used to charge users who exceed their quota should not be altered. That is, users who exceed quota should be charge through the Bursar and have a hold placed on their record until the outstanding balance is paid in full. The money generated from the increased charge of users over quota should be reinvested in the purchase of 100-percent-recycled-content paper for use in STCs on campus.

"Back in the day when we used the unlimited printing allotment we used to use ridiculously large quantities of paper. Yet once we changed to pay-per-page, it seemed as though students thought twice about their printing habits."
– John Staley, University of Wisconsin-Madison

Indiana University Compared to Other Big Ten Universities

We believe that phasing out the print quota may be in the best interest of the University. If IUB would like to reduce the number of pages printed on campus, altering the default printing setting and, at the very least, reducing the print quota may go a long way to reaching goal. This reduction in print quota may be the path of least contention, but we recommend a goal of total elimination of the print quota system over time. As one IT specialist at the University of Wisconsin-Madison said, "Back in the day when we used the unlimited printing allotment we used to use ridiculously large quantities of paper. Yet once we changed to pay-per-page, it seemed as though students thought twice about their printing habits" (Staley, 2011).

Conclusions

In conclusion, we estimate that IUB graduates print more than the undergraduate students. On average, while approximately 39 percent of students exceed their printing quota, those students

together account for 94 percent of total pages printed. Although more than half of the pages printed by the IUB students are over their printing quotas, they incur a very small cost for going over their printing allotment (four cents per page). We recommend that the university begin to look at print quota as a way to shift printing culture on campus – with the intention of reducing paper consumption and saving the University money.

Furthermore, we found that institutions within the Big Ten that set printers to the duplex default setting and have a strict pay-as-you-go (or, pay-per-page) system have decreased on-campus printing. We recommend that IUB let users choose their printing setting with a simple menu at log-in (Appendix DP, E) and incrementally phase out the print quota system beginning with an allotment of 500 pages per student. This number should be reassessed and reduced over time with the goal of a pure pay-as-you-go (or, pay-per-page) system in the future. We believe a reduction in the short term may be more feasible given the logistical hurdles associated with a completely new system.

Alternative Inks

Introduction

Our research into alternative inks focused primarily on solid ink technology, due to the technology's current use on campus. According to interviews with Mark Harris, owner of A+ Service Solutions, the individual in charge of solid ink sales to IUB, reports that there are over 60 solid ink machines at IUB (2011). We gained more knowledge of solid ink through interviews with Bill Creech of Xerox's Solid Ink Division. We also held interviews with solid ink users within the Chemistry Department (Creech, 2011). From this interview we confirmed that the Chemistry Department owns nine solid ink printers. We were also able to establish a printer energy consumption study in the Chemistry Department. The energy study within IU Chemistry sought to monitor the energy consumption of solid ink printers as compared with traditional laser or ink jet printers. Lastly, we conducted a literature review of the history of solid ink.

Literature Review

Solid Ink Background

Solid ink was created by Tektronix in 1986, and the first solid ink commercial printer was introduced in 1991. On January 1, 2000 Xerox purchased the Color Printing and Imaging Division of Tektronix. Currently, Xerox holds 23 percent of the market share for color printing; however, solid ink makes up a small portion of that share (Bulkeley, 2009). The main difference between the two machines is the post-consumer waste created by the laser printer. One study found that the solid ink printer created about 30 percent less cumulative energy demand and global warming potential than a traditional laser printer. Overall, a solid ink print generates 90 percent less waste than laser printers (Xerox Corp., 2010). The components, advantages, and disadvantages of solid ink will be explored in this portion of the paper.

Solid Ink Printer Components

A solid ink printer varies from a laser printer in its design. As compared to some other models, a laser printer can have as many as three times as many parts. In a color laser printer, examples of parts include photoconductors, transfer rollers, fuser rollers, fuser oilers, and supplies such as toner cartridges and waste toner bottles (Bozeman et al., 2010). Alternatively, there are only three main components in a solid ink printer (Appendix DP, J6).

1. **The print head**: puts ink to the print drum
2. **The print drum**: applies the image to paper
3. **The controller**: the operator of the printer which transforms the data from the computer to the printer

Additionally, exterior panels and a paper tray are put in to complete the printer's mechanics. Throughout the life of the printer, the only required maintenance is performed on the drum. Both the controller and the print head are constructed to last the lifespan of the printer. The fewer total number of replacement parts, required parts, and supplies translates to not only a more environmentally conscious product, but also to cost efficiencies resulting from less operating costs for maintenance (Xerox Corp., 2010).

"We love our solid ink printers." – Brian Crouch, IU Chemistry

The process of printing an image onto a sheet of paper is straightforward and will be described henceforth. The solid ink sticks are first placed into the printer. The ink sticks are then heated and liquefied into the print head which applies the ink onto the print drum (Appendix DP, J7a). Paper goes through the roller and the print drum, and the pressure from these components transfer the image from the print drum to the piece of paper quickly (Appendix DP, J7b). Furthermore, the image is created by heating the solid ink and applying melted ink to paper where it instantly solidifies. Since the ink sticks are solid, a cartridge is unnecessary and therefore there is nothing to throw away once the ink stick has been used up, reducing the post-consumer waste created (Bozeman et al., 2010).

Advantages

Xerox makes several claims as to the advantages of this technology, including its ease of use, vivid colors, and decreased environmental impact. Each color is shaped differently to allow for ease of ink installation (Appendix DP, J1; J2).

Solid ink uses solid ink cubes instead of toner, which is less toxic and safe to handle. Since they are a solid, they will not leak or spill. This technology also does not produce ozone, creating a safe workplace environment. Another advantage is that this printer produces vibrant imaging, even on recycled paper.

It has been stated that solid ink takes more time to heat up, but it has been found that it takes approximately one minute, which is equivalent to the time it takes laser printers to warm up. The

time it takes to print large documents is faster when compared to similar laser printers. Upon heating up, solid ink printer prints at up to 40 pages per minute (ppm). The ColorQube (the newest model of solid ink printer) has been stated to be able to print 85 ppm. This process can be further enhanced by using the Intelligent Ready feature; this element monitors previous printing activity and prepares the printer for anticipated printing (Xerox Corp., 2010).

Based on interviews with Mark Harris (2011), solid ink printers may be more desirable and relevant for some departments. For instance, departments printing a great deal of color pages with substantial ink coverage may benefit from Xerox's technology and page pack program. Cost analyses on campus (and more are planned – specifically in IU Athletics) have been conducted to determine the true cost incurred per page printed. According to Harris, the Food Services department on campus learned that labels produced by their laser machines were costing 35-40 cents per page printed. The department, after learning about the solid ink printers, shifted to the new machine, with per page costs at 4.5 cents per page printed (ibid).

One additional benefit of Solid Ink is that the ink sticks do not degrade or dry over time like traditional inks. For instance, we found cartridges in IU Athletics that were several years old that had yet to be opened for use in departmental printers. A traditional cartridge that sits for several years without being used is well beyond its intended shelf life and the ink within the cartridge is likely corrupted at some level and possibly dry (Leibacher, 2011).

Disadvantages

Several disadvantages exist with using solid ink. For instance, the ink can be scraped from the page since it is a waxy substance. Corresponding with this, since the ink is a solid substance, it must be heated to the page. Heating the ink requires more energy than laser jet printers, although based on our previous research this added electricity use is not exorbitant. When the printer is in "sleep mode" the printer will keep some ink melted, which uses 50 watts of energy. If the heated ink in these areas turns to a solid once again, this ink can no longer be used and will be purged to a waste ink tray. All of the color inks will be placed into the same tray and can, therefore, no longer be used. Since the ink must be heated, the printer cannot be moved until the ink has solidified for approximately ten minutes. In the newest versions of the product, fans have been added to reduce the cooling time from 30 minutes to only a few minutes (Arkin, 2008; Creech, 2011).

Additional problems are present with the components of solid ink. The ink is transferred onto a page by a fast-rotating drum. This part may have problems in the future, such as a stretched belt. The print head may become clogged due to the dust from the use of low quality paper. Print heads have been tested to be able to produce approximately one million prints. The alternative structural feature of having a fixed printer head may also cause the piece to become clogged, causing streaking on the paper. However, cleaning cycles can be used. Currently several models of solid ink printer exist. The ink from the different models cannot be used in the different models due to changes in the molded shape and in ink formulation (Arkin, 2008; Creech, 2011).

Life Cycle Assessment

Xerox conducted a life cycle assessment of a solid ink printer and a laser printer that printed 40 ppm and 42 ppm, respectively. After this research was completed, the printer went through a peer review to ensure the accuracy of the results and that generally-accepted life cycle assessment methodologies were used. Several differences and environmental benefits exist with solid ink technology. In this study the following components were analyzed:

1. Total lifetime energy invested in the manufacture
2. Transportation
3. Use
4. End-of-life of the two printers
5. Global warming impacts

During this project, the cumulative energy demand and the global warming potential were used in order to better estimate the total life cycle assessment. The cumulative energy demand is the total energy consumption used in manufacturing, transporting, using, and discarding the product. The global warming potential quantifies the amount of greenhouse gases contributing to global warming. This is measured in pounds of carbon dioxide. Although this study did calculate the post-consumer waste, total sheets of paper were excluded, since this would be equivalent in both studies. The study was conducted by completing 7,500 prints per month for four years, totaling 360,000 prints for the lifespan of the printer (Bozeman et al., 2010).

The result was that the solid ink machines produced lower levels of waste than their laser printer counterparts (Appendix DP, J3). Over four years, with 4,000 pages printed per month, solid ink produced only 19 pounds of waste, whereas a laser printer produced 246 pounds. This translates to a 90 percent reduction in the amount of post-consumer waste produced. As an example, the ColorQube has a 30 percent lower carbon footprint and a 30 percent lower energy consumption as compared with a laser printer (Appendix DP, J4). Solid ink technology has recently been developed to produce duplex documents, which decreases the overall paper consumption (Xerox Corp., 2010).

Overall the major contributor of greenhouse gases was in the energy required to run the solid ink printer (i.e., melting the ink sticks) during its lifespan (Appendix DP, J5). However, its overall low impact in the other areas negated the high energy consumption required. In analyzing the laser printer, the largest contributors for cumulative energy demand and global warming potential were energy use during the life of the product and required replacement parts, respectively (Bozeman et al., 2010). Although the solid ink printers cost more initially, the cost savings and environmentally beneficial opportunities must be taken into consideration.

Conclusion

Based on our aforementioned research in IU Chemistry and the review of solid ink technology above, we believe it to be worthwhile for departments to conduct cost analyses on departmental printers currently in use and compare those numbers to the price charged by Xerox's page pack

program. We believe that for some departments solid ink is not only a good environmental or sustainable choice, but also a good economic choice.

Other Study Areas: Adobe Acrobat Pro X, Ecofont

Adobe Acrobat Pro X

As part of our research, we were curious about various software available to Indiana University students that may reduce the need for printing. Early in the process the research team agreed to download Adobe Acrobat Pro X from IU's IUware Website and use it for the duration of the semester. The software allows users to make edits, highlights, and notate on PDFs. For some this was a natural transition; for others it was slightly more difficult. We expect similar reactions from other IUB students. That said, once we committed to using the software, we found we were working digitally with documents we had traditionally printed. Not all of us altered our behavior, but many did.

We believe that, as part of re-shaping printing culture on campus, emphasis should be placed on technology (like Acrobat Pro X) that reduces the need for printing. This should be done through the Office of First Year Experience, the Office of Sustainability, and by IUB faculty.

Ecofont

Ecofont is software that works in tandem with your current software to minimize ink usage. Like other fonts, Ecofont is downloaded and installed. The difference between Ecofont and traditional fonts is that Ecofont has small holes placed in the black area to mitigate the amount of ink consumed. Ecofont claims to save more than 25 percent on toner costs when using the Ecofont versus the traditional (hole-free font) (Ecofont, 2010).

Ecofont offers a free demo universities can download and use before purchasing. Ecofont is compatible with all printers provided by the vast majority of vendors (Appendix DP, K1). Another advantage of Ecofont is that it encourages environmentally friendly actions by the students by giving them an alternative way to print.

Despite its advantages, Ecofont has some shortcomings. One of the main disadvantages of the Ecofont is that it cannot be used to alter the font of existing PDFs or Websites, so it has limited utility. Another hurdle to the implementation of Ecofont as an IUB default is that it requires an investment by the University. Ecofont will provide a license for to the first university that signs a three-year contract for $4,500. This $4,500 price is a significant savings off the normal price that would be charged to IUB ($101,500).

Literature Review

A study conducted by the University of Wisconsin shows that traditional Century Gothic uses 30 percent less ink than the most commonly used default font: Arial. The study also indicates that Century Gothic saves more toner than Ecofont's free downloaded font: Ecofont Vera Sans

(Appendix DP, K2). Ecofont claims that its Ecofont Century Gothic font uses at least 25 percent less ink than the traditional Century Gothic tested by the University of Wisconsin (Ecofont, 2010).

Results and Discussion

We have found that Ecofont will give students an alternative method to print their documents, especially their rough drafts or temporary files. However, there are many concerns that STC brought to the table. According to the STC, many of the documents printed by the students are in PDF format, which cannot be changed to Ecofont. This limits the utility of Ecofont enormously. Some of their other concerns pertain to lack of previous research about Ecofont. STC also indicates that IUB is already implementing green methods to save toner, such as setting all printers at STCs to a much lower print density than their rated ability (Wagner, 2011). STC has also posted guidelines on how to conserve more paper on its Websites. Some of its suggestions are listed below:

- Edit before printing

- Avoid printing drafts

- Print double-sided

- Recycle unwanted pages

Recommendations

Keeping the concerns of the STC in consideration, we recommend that IUB students are provided with educational colloquiums where they learn about saving toner and reducing paper waste. The students, thus, can become more aware of their printing behaviors and take actions to reduce toner, such as deleting unusable images before printing. They can also delete spaces between documents to save more paper. We also recommend that IU changes its margin default on Microsoft Word from one inch to ¾ of an inch, thus reducing paper consumption. Regarding Ecofont, we recommend that a pilot study be implemented to test the results of Ecofont. The study should focus on measuring ink savings of Ecofont's "greenest font" – Ecofont Century Gothic.

Conclusions

While Ecofont may save on ink and toner, there has been very little research that proves its effectiveness. We recommend that Ecofont should be researched in a pilot study to measure its effectiveness. If effective, Ecofont may one day save IUB a great deal of money on ink and toner.

Conclusions

The number of opportunities Indiana University-Bloomington has to reduce paper consumption, shift printing culture on campus, and save money are numerous. Based on our research, students prefer printing duplex and when given an easy option to make their printing preference reality, do so. This simple, user-selected printing system (piloted in Business /SPEA Information Commons in the spring of 2011) should be permanently expanded to all IUB STCs and computer labs. Additionally, the University's quota system does not appear to be in line with actual student printing on campus (students print, on average, well below their allotment), and does not guide students toward conservation. It is our belief that IUB should follow the lead of other Big Ten Universities and lower the print quota in the short-term, with an eventual plan to phase it out completely.

Furthermore, the University should consider new and emerging technologies that move our campus into the digital age. Sure, not all documents should be digitized, but we believe that through education and persistence students will embrace paper-reducing software like Adobe Acrobat Pro X for digital note taking as opposed to traditional, paper notes. The University should do more to facilitate this shift on campus. Other technologies should be researched to determine if they are right for some or all IUB departments – Ecofont and solid ink technology are two examples. There exist many methods related to printing and paper reduction that the University can embrace to continue its sustainability-related momentum. It is our hope that the findings and recommendations we have provided will streamline future sustainable computing initiatives.

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IT in Sustainability

The IT in Sustainability Group researched ways in which information technology can be used to increase the sustainability of University practices. We looked for new opportunities, but soon discovered that many of them were already underway at IU or had been explored and not deemed achievable at this time. We also spent time examining technology improvements, such as sensors that reduce electricity used by vending machines, self-powered exercise equipment, and an iuMobile smartphone application that publishes bike rack availability. It was determined, however, that these projects were not truly applicable to the category of sustainable computing. Hence, we decided to present a catalog of efforts that are already underway at IU, as well as present recommendations as to how IU can continue to improve sustainability in the near future.

Catalog of Present Initiatives at IU

Green Teams Office Certification Program

The Green Team soffice certification program is one of the Office of Sustainability's initiatives to improve sustainability in the diverse departments that comprise Indiana University. The program consists of a linear series of four certificates – Seed, Sprout, Sapling, and Tree. Those who are interested in this program must organize and define certain standards to meet certification. One of the seven categories for attaining the certificate is sustainable computing. There are four checklists for each certificate level—all of which include sustainable computing—which become more difficult as the level of certificate gets higher. For example, at the Seed level, one criteria for sustainable computing is if the printers are set up to automatically duplex print (in the office toolkit for Seed level, the Office of Sustainability provides the instruction for setting their computer print default and information about duplex printing). At the Tree level, the checklist is marked complete if all the computer equipment purchased for one's unit is Energy Star-rated. This system gives departments and schools a blueprint for being more sustainable in computing, and has the potential to serve as a motivation for greener habits (Indiana University Office of Sustainability, 2009[2]).

Online Services

At Indiana University, many employee services harness IT's sustainability potential by eliminating paperwork and making tools available online. First of all, the Human Resources Management System (Indiana University Human Resource Services, 2011[2]) allows staff to conduct several activities electronically, such as payroll and employee information reporting, data extraction, and information analysis. On OneStart, employees can update and access records from their own payroll, taxes, and benefits files. Moreover, new employee orientation is completely an online process. New employees no longer receive paper packets from the Human Resources Department. Instead, they receive the information via e-mail. In addition, e-Paid Time Off (ePTO) recently became available to electronically record time-off taken on a monthly basis, as well as submit records to supervisors for approval (Indiana University Human Resource Services, 2011[1]).

Oncourse and OneStart have become very powerful tools for sustainability on this campus. Using OneStart, students can add or drop classes online even after the first week of the semester. This was not the case just a few years ago. Also, students can find classroom tools such as the syllabus, assignments, announcements, and other resources on Oncourse. As a result, students need only print the materials necessary and professors do not have to bring hard copies of class materials to every class. This has potentially saved the university a great amount of paper, though this has never been measured. In addition, professors can make students' ongoing and final grades available on Oncourse and OneStart, so the university does not have to mail grade reports or transcripts to every student. This saves the University significant resources because the staff does not have to spend as much money on postages, letters, and envelopes (Oncourse, 2011).

Transportation

Zipcar has become available at Indiana University Bloomington in the past year. Zipcar is a rental car service that allows people to use cars just for a few hours or an entire day. Zipcar at IUB also uses computing to make its service more accessible and convenient. Everyone, not just students, can reserve a Zipcar from any computer or mobile phone by visiting www.zipcar.com. Renters can use the Web to find a car near them, or search by the type of car they need. They can select cars by make or model, by category like hatchback and hybrid, or by amenities like iPod adapter. Moreover, any iPhone user with Zipcar app can tap his or her iPhone to lock and unlock the doors and even honk a Zipcar equipped with this service (Zipcar[1], 2011).

Zimride is a ride-sharing program sponsored by Indiana University Student Association. It uses Facebook and Google Map technology that enables those on campus to share seats or catch ride with IU students, faculty, and staff. Users can upload their daily commute or one-time travel to find the right matches. Also, users may connect the account to Facebook. Unlike Zipcar, there is no charge for this service but one has to be an IU student, faculty, or staff to use it (Indiana University Parking Operations, 2009).

We can find sustainable computing with the IU's campus bus service as well. We can view real-time bus locations from mobile phones or computers by visiting http://iub.doublemap.com/. This service is very convenient for students who want to know when the next bus will arrive so they can decide whether to wait for the next bus or just walk. Hopefully, all of these conveniences will encourage students and faculty to drive less by car sharing, carpooling, or taking a bus.
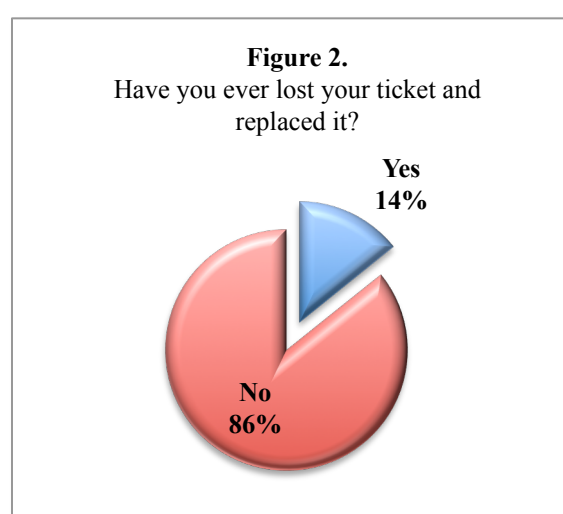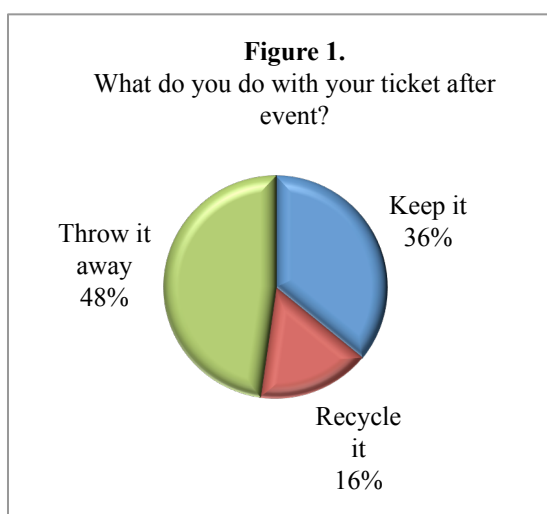
Initiatives in the Making

Electronic Ticketing

As a large research university, Indiana University is home to many athletic, theatrical, and other public events. For example, IU Football games attract over 40,000 attendants per home game and there are typically six home games in one season. IU Men's basketball team boasted over 15,000 attendants per home game in the 2009–2010 season (Salatin, 2011). Also, the Jacobs School of Music annually hosts about ten opera and ballet events. Paper tickets must be printed for all of

these events. Unfortunately, the university has not yet adopted the e-ticket system to reduce the number of paper tickets. Generally, patrons must have paper tickets in order to enter the events. While some people want to keep the paper tickets as souvenir, most people do not keep those after the events as can be seen in the following survey.
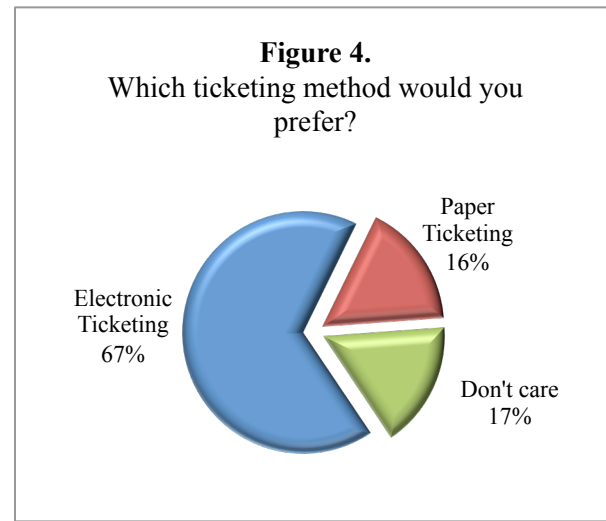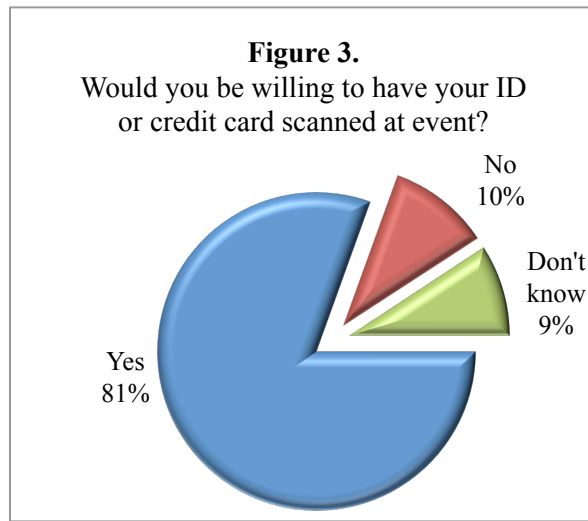
Student Survey

In a survey conducted on 1,900 IU students referenced earlier in this report, we found that nearly two-thirds of them do not keep their tickets after school events. Among those people who do not keep their tickets, 75 percent of them do not even recycle their tickets. If you add up those numbers for every university event that uses paper tickets, it represents a significant amount of paper wasted—over 30,000 tickets for men's basketball alone. In addition, 14 percent of respondents said that they have lost their tickets and replaced them. Under the current paper ticketing system, ticket-holders have to pay small fees in order to replace lost tickets. However, under e-ticketing system, people do not have to worry about lost tickets and replacement fees because they do not carry paper tickets. The following figures (1-4) display the results from student survey.

Figure 1.
What do you do with your ticket after event?

Keep it 36%
Recycle it 16%
Throw it away 48%

Figure 2.
Have you ever lost your ticket and replaced it?

Yes 14%
No 86%

The survey also asked students if they would be willing to have their IDs or credit cards scanned at the event in lieu of presenting paper tickets. A large majority, 81 percent, of respondents responded "yes." There were some respondents concerned about increased risk of identity theft or credit card theft. Overall, however, most people were comfortable with the idea of presenting their IDs or credit cards. Finally, we asked students which ticketing method they would prefer. Two-thirds of respondents preferred electronic ticketing over paper ticketing. And 17 percent of the respondents did not care one way or the other. Only 16 percent of respondents said that they would prefer paper ticketing. Some of the primary reasons for supporting electronic ticketing were that it is more convenient, hassle-free, and environmentally-friendly. Also, some people were concerned of losing paper tickets and replacing them. Some reasons against the e-ticketing

system were that people would like to be more flexible in terms of giving tickets to other people. And some students were not comfortable with the idea of presenting credit card.

Figure 3.
Would you be willing to have your ID or credit card scanned at event?

No 10%

Don't know 9%

Yes 81%

Figure 4.
Which ticketing method would you prefer?

Paper Ticketing 16%

Electronic Ticketing 67%

Don't care 17%

Various Methods for E-ticketing

Ideally, students would be able to present their student IDs or credit cards and enter events, since the IU student ID card is already used for several services on campus such as admission into workout facilities and meal points. For the general public, there is the new possibility of utilizing mobile phones. A mobile phone user can simply download the e-ticket and present the bar code to the usher upon entering an event. The user does not have to own a smartphone to use this method. Any mobile phone with Internet access is sufficient for this technology (Fisher, 2010).

Many professional athletic organizations have already adopted the paperless ticket system. In the NBA, the Denver Nuggets implemented the paperless ticket system as one option. People can just bring the credit card used during purchase or any other electronic ID (credit card or driver's license). The patron's card will be swiped at the door by a Guest Services representative using a hand-held device and the patron will receive a seat locator identifying seats. Under this delivery method option the ticket is free, whereas people have to pay small fees to use will call or standard delivery methods. There are, therefore, financial incentives to using the paperless delivery method. Further, Tickets.com, with ProVenueMobile technology, has made mobile ticketing available for 13 Major League Baseball teams including the Oakland Athletics. (Fisher, 2010) For those teams' home games, people can search and purchase tickets with their mobile phones.

Status Quo at Indiana University Bloomington

After checking with the IU departments which host large events, we found that only IU Athletics have a partially paperless ticketing system. The other two departments have no paperless ticketing option at all.

According to Tridib K. Pal, House/Ticketing Manager of Musical Arts Center at IU, at this point there are no plans to replace paper tickets at the Jacobs School of Music simply because it is not cost effective in terms of the hardware and infrastructure necessary for such a system to work properly as the majority of their ticketed events utilize reserved seats. Seat information is not available on a credit card or student ID. Mr. Pal said the school will continue to look for other alternatives to paper tickets that work for patrons (Pal, 2011).

Department of Theatre and Drama also does not have specific plan to replace paper tickets. Nonetheless, Assistant Box Office Manager Brandon Cavaness at Auditorium said that electronic ticketing system is the industry's trend and that he envisions the change coming to IU in 2-3 years. (Cavaness, 2011)

IU Athletics has already begun implementing electronic/paperless tickets in certain aspects of their operation. Currently the student football season tickets are administered electronically; the tickets are loaded onto each individual's student IDs and those are scanned at the gate to gain admission. Because of the complexities involved in the allotment of student basketball season tickets, the department simply cannot issue these electronically. Unless the seating process changes IU Athletics may never be able to introduce electronic tickets to student basketball tickets (Salitan, 2011).

Public seats will be IU Athletics' next area of focus in electronic ticketing. IU Athletics needs to determine what will work best for operation (i.e., credit card, driver's license, or something else) and then make sure that they are operating within Payment Card Industry (PCI) Compliance regulations.

Unfortunately, there are some setbacks with electronic ticketing system that need to be addressed. First, an electronic system is not completely paperless because patrons need to find their seats once they enter venues, so patrons still receive a seat locator card which is made of paper. Second, there are complexities involved when people purchase tickets for other people as a gift. In this case, the credit card which is used to buy the ticket cannot be scanned. Therefore, the patrons must bring something other than credit card (i.e., ID or some type of voucher). Michigan State University, which already has electronic ticketing system in place, allows people to use purchaser's ID to enter events.

Recommendation

Indiana University outsources its ticketing business to Ticketmaster. However, Ticketmaster only sells tickets on behalf of promoters, teams, bands and venues. This means that Ticketmaster does not set the delivery options for the event. If IU chooses to do so, it can implement the electronic, paperless ticketing system, regardless of Ticketmaster's opinion (Ticketmaster Fan Support, 2011).

As mentioned above, the biggest barrier to the system change currently is the cost. However, as can be seen in the student survey, students are supportive of the electronic ticketing system and a big majority of them preferred it over the paper ticketing system. As a prestigious public

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university leading the sustainability effort, Indiana University should look into paperless ticketing as technology becomes more available and costs decrease.

Green Teams Communication

Background

Green Teams are an important component of sustainability initiatives at Indiana University. They are formed independently within individual departments throughout campus and initiate activities that promote sustainability in their respective departments. A Green Team, as defined by the Office of Sustainability, is "an informal group of faculty, staff, and students in a particular campus unit who work collectively to promote environmentally-friendly practices within that unit" (IU Office of Sustainability, 2009[1]). Departments that sponsor Green Teams include the Athletics department, School of Education, and the Kelley School of Business. The entire directory of teams can be found on the Indiana University Office of Sustainability's Website.

Communication and Use of IT

These groups are largely autonomous and independent from one another. However, they have regular meetings, usually monthly, in which representatives from each group have the opportunity to share ideas, elicit feedback, and offer support. These meetings, although helpful, are difficult for many people to attend for multiple reasons. For example, the location may be inconvenient for some individuals or others may have conflicts in their schedules because the meetings occur during a regular work day. Until recently, the Green Teams have not had an efficient mode of communication outside of the monthly meetings and e-mail correspondence. In January 2011, the Indiana University Green Teams blog was created at http://iugreenteams.wordpress.com/ in an effort to improve communication among Green Team members. The following statement describes the purpose and significance of the blog:

> "When it comes to campus sustainability there is much to discuss. Although eager to address a broad range of issues, we have limited time to meet with others engaged in on-campus initiatives. A convenient forum needs to exist, then, that allows green team participants and others within the IU community to join in the conversations, start new conversations, and stay informed on sustainability efforts taking place at IU.

> There needs to be a space in which we can stay in correspondence with one another. This blog aims to do just that. Here, ideas can be shared, inquiries can be posed and responded to, and accomplishments can be publicized and celebrated. When inspiration strikes, take advantage of this convenient forum and share that inspiration with others" (Indiana University Green Teams Blog, 2011).

Blog Structure

The Green Teams intern acts as the administrator for the blog. While any Green Team participant can become an author, all posts are first submitted to the intern, who reviews the posts prior to publishing them (Harmon, 2011). Although the intern-administrator is the only individual authorized to publish posts, anyone interested may easily share feedback and ask or

answer questions by leaving a comment on the appropriate post. The subject matter of posts has thus far consisted of information about Electronic Waste Collection Days, Earth Week, and sustainability efforts at the Little 500.

Also located on the Green Teams blog Website is an open forum on "Best Green Team Practices." However, no individuals have posted comments or suggestion in this space. In addition, the blog's search function helps individuals go directly to topics in which they are particularly interested. Posts are also categorized to make it easier to search the Website. The categories thus far include Events, Peer Institutions, and Uncategorized. Also on the Website are links to other informational sites, including those of the Indiana University Office of Sustainability and the Sustainability Tracking Assessment and Rating System (STARS).

Recommendations

The Green Teams blog is a useful, straightforward tool for communication and education. However, a few additional features to the Website may further enhance functionality. It may be helpful to have a separate forum for each Green Team to post news specific to their departments. In addition, a calendar tool should be added to the site as a way for Green Teams and the Office of Sustainability to post events in a more organized and concise manner. While a forum for best practices already exists, no one has commented here. It would be helpful for the blog administrator to structure this component, dividing it into categories of best practices. This strategy could make it easier and more approachable for participants, increasing the likelihood of participation in this discussion. Finally, Green Team leaders from all groups should be sure to advertise this site to their participants and encourage them to participate in discussions or ask questions by commenting on posts or submitting their own posts.

Online Course Evaluations

Introduction

One initiative that is currently underway at Indiana University is a campus-level integration of online course evaluations. From a sustainable computing perspective, online course evaluations would improve University resource management as well conserve paper in an effort to be more environmentally friendly. Conducting course evaluations electronically would be an improvement in terms of cost containment, course assessment, management, and feasibility.

Methodology

Online course evaluations have several advantages including the following (Perry, 2002:8):

- Online evaluations eliminate the need to distribute paper forms, including major cost savings at the administrative level for schools that opt to key-in written responses (to preserve respondent anonymity), store paper files, and analyze results.

- Online evaluations offer flexibility with item selection at the departmental level, while also providing for randomization and other forms of eliminating survey bias.

- Standardization of some items allows for a relatively quantitative analysis, used during faculty consideration for promotion and tenure.

- Many students already use electronic methods to complete coursework, whether through Oncourse or other methods, such as Survey Monkey. In fact, student buy-in was measured by administering a survey to approximately 1,900 students, which indicated that over 89 percent of students would support an online system.

- Online course evaluations provide accessible feedback for instructors, often faster than paper forms.

- Class-time can be utilized for teaching and learning, rather than submission of evaluations.

There are also some barriers to implementing an online system including the following:

- Concerns exist regarding student response rate, as enforcing required responses presents a challenge at the policy level.

- A centralized response data bank presents issues with data security.

The campus must recognize survey bias problems. For example, will students regard online evaluations as seriously as in-class evaluation forms? Will students skim over key questions in an effort to minimize survey time? Will interpretation of items vary by the type of course offered (required versus elective)? Will the survey vehicle create bias of its own, such as order of questions and accessibility?

We conducted two interviews with IU Bloomington staff members who cited that the time saved in simply transcription of written responses would amount to a full work week (40 hours) at the departmental level. Considering that IU houses 14 different schools, as well as interdisciplinary departments within, a modest estimate shows that cost savings in employee hours could be measured at around $9,000 per semester, assuming an average hourly pay rate of $16/hour. Note that this savings merely addresses the staff resources needed to transcribe and file paper evaluations, and does not consider document management, instructor feedback availability, or time spent analyzing responses (SPEAGRAD, 2011).

In 2009, Indiana University Bloomington created a task force specifically designed to implement online course evaluations across the University system by academic year 2013. This task force is comprised of members of the Faculty Council, as well as several vice provosts from Undergraduate Education, Information Technology, and Research Methods. After attending this semester's task force meetings, our group is able to report on the status of implementation thus far.

The task force is comprised of two committees: the Evaluation Committee, charged with survey design and content, and the Information Technology Committee, which addresses technological issues such as vendor selection, data storage, and security. Each committee has various subcommittees tasked with planning and piloting a vehicle that will be tested for academic year

2012, and then implemented in full by 2013. The President's Office plans to use these online evaluations in a fairly standardized format for dual purposes: at the departmental level, as a formative analysis for providing instructor feedback, and at the campus level, as a summative report included in dossiers for consideration for promotion and tenure. In addition, a standardized system for instructor evaluation is required by IU's accreditation agency, the Higher Learning Commission (Higher Learning Commission, 2011). IU will be evaluated in 2013 for this purpose.

Several departments across campus are already using online vehicles including the School of Education, which is conducting a pilot study, the School of Music which is distributing class-level evaluations, and the Bloomington Evaluation Services and Testing Office (BEST) that is offering optional evaluations. Testing these mechanisms against the current system has yet to occur, mostly due to the fact that course evaluations are conducted at the departmental level rather than the campus level.

Technological Considerations

From a technological standpoint, it will be important for the University to choose a vendor product that allows for maximum functionality. Some considerations mentioned during the sub-committee meetings were with regards to data security, anonymity, and student access (window of time available to complete the survey, username and password access, e-mailing notifications and reminders, and a centralized "to-do" list similar to the list currently available through OneStart).

While Oncourse certainly deserves merit consideration because of its usability, the system is limited in terms of its data reporting capabilities. Another highly recommended software vendor, Quizsite, allows for greater customization and reporting, but requires a renewable license and a considerable up-front expense. Additionally, Quizsite is a third-party vendor product, and would require a separate username and password to access the site, which generates administrative burden. The Information Technology committee is presently researching the most affordable option for IU that still addresses the major priorities highlighted above. Engineers with UITS are also researching an institutional vehicle that is designed in-house, which would be fully customizable but require significant resource allocation for design.

Moving Forward

In the short term, the task force is charged with presenting five to seven global items for consideration to be included in every online evaluation form, in order to promote standardization and centralization. Once these items are determined, they will be tested using cognitive interviewing at the departmental level, and then a pilot study will be conducted. Again, a primary concern with the actual survey mechanism is bias – will students who opt to respond to the pilot study represent high-achieving (or, alternatively, low-achieving) outliers in the response group? For example, current course evaluation research suggests that students who perform poorly academically often rate instructors more unfavorably than high-achievers (Spencer & Schmelkin, 2002). The task force must be certain to conduct this pilot study using statistically sound methods, and evaluate it as such.

Once the survey vehicle is created, the President's Office and Faculty Council will move forward with determining appropriate policy for use of the evaluation responses. At present, course evaluations represent about one-third of the teaching component rated by promotion and tenure committees. Other promotion and tenure components are research and experiential (Harris, *Course Evaluation Reliability and Validity*:2). The governing body must consider variation in student responses from year to year so as not to bias its decisions regarding promotion and tenure. Research will need to be conducted to ensure that the transition to an online mechanism is not unjust in any way.

The Information Technology task force will continue its work with electronic vendors, under guidance from the President's Office. As such, this step would take place after the appropriate policy is drafted, and it will be the final piece of implementing online evaluations by 2013.

Energy Dashboard

Uses and Features

Building an energy dashboard may be one way in which Indiana University could use information technology to promote sustainability on campus. The dashboard would provide students, faculty, and staff with an accessible tool that allows them to see energy consumption patterns in the buildings in which they live and work. The dashboard could also be used to supplement other sustainability initiatives, such as the Energy Challenge, by facilitating competitions between buildings. The main benefit of installing an energy dashboard is the expectation that by bringing attention to energy usage and costs it would decrease energy consumption and related costs to the university.

Lucid Design

Lucid Design Group is a company that designs innovative "building dashboards" for large companies, local governments, and universities. These dashboards have many features and potential uses. For this reason, the company refers to its product as "a social network for the buildings in which we live and work" (Lucid Design Group, 2011[1]). In addition to displaying interactive graphs tracking energy usage for a building, the dashboards break down usage by purpose and display different units of consumption (such as kilowatt-hours, CO_2 emissions, or dollars). They also display local weather in a way that relates it to consumption patterns. Institutions such as Indiana University Bloomington are also able to incorporate a dashboard for each building on campus into the system. Thus energy and water consumption for one building can not only be compared to the previous day or month, but also to another building in the network.

In addition, apps can help define terms to make the information more easily understood by the user, and integrate campus sustainability into social networking sites. Widgets can help facilitate energy reduction competitions and foster the competitive edge among participants. Widgets may also be added to a dashboard to promote events, facilitate discussions, and share information on how individuals can reduce their consumption.

City of Bloomington

The City of Bloomington currently uses a building dashboard designed by Lucid Design Group (Lucid Design Group, 2011[2]). This dashboard is installed only in City Hall and therefore is not able to use the comparison feature. Expanding the dashboard network to additional government buildings will require added charges to the city. Bloomington, however, has experienced other benefits from this technology. Most importantly, the city now has more detailed information on its energy usage and, as a result, has seen cost savings. Jacqueline Bauer, Sustainability Coordinator, noted that these cost savings have not yet been analyzed because the system was implemented only a few months ago.

In addition to the initial installation costs, challenges of implementing the building dashboard in Bloomington were relatively limited. The most significant barrier to implementation was scheduling an installation time. Because hookup required the building's entire electrical system to be shut down, this task proved difficult for city administrators (Bauer, 2011). Another cost that the city will incur is that of obtaining a data downloader. This device will allow analysts to have more flexibility in viewing data and to conduct detailed analyses of patterns on an hourly basis (Bauer, 2011).

Other Universities

Unfortunately, the metering system that Indiana University currently uses is not compatible with Lucid Design's products. However, it is possible for the university to build its own custom dashboard as other universities have done. Included among these are Purdue University, the University of Iowa, and the University of California San Diego.

Purdue's dashboard system displays data in the form of line graphs, showing historical data on heating, cooling, and electricity use for each building individually. This system does not have as many features as the Lucid product; however it communicates relevant, timely data on the Website. (Purdue University, 2010)

The University of Iowa's energy dashboard tracks real-time energy consumption for each building (University of Iowa Facilities Management, 2009). Users have the option to view data for either the past 30 days or the last 24 hours. Data is available for chilled water, electricity, or steam.

The UC San Diego energy dashboard, created by its Microelectronic Embedded Systems Laboratory, similarly shows real-time energy data for buildings across campus (University of California-San Diego, 2010[1]). Unlike those of Purdue or Iowa, this system shows aggregate data from the campus as a whole, in addition to breaking up information by school or department. This dashboard also features an interactive map that can be used to search for a particular building. Rather than comparing all buildings, as Lucid Design does, UCSD identifies "Interesting Campus Meter Comparisons," which compare a few buildings selected by the system designers.

UCSD has conducted studies on energy use based on the dashboard design and has identified various opportunities to save energy. For example, the researchers found that IT equipment is one of the largest consumers of energy (University of California-San Diego, 2010[2]). As a result, they were able to make recommendations to students and staff on how they can conserve energy when using personal computers or other energy hogging devices.

Recommendations

Although the purchase of a Lucid Design product may be the most convenient and user-friendly option for Indiana University implementing an energy dashboard system, it is not feasible at this time due to technological limitations. The best option for Indiana in going forward with this initiative is to build a system in-house that is compatible with the metering system. The Iowa design is a relatively good example to follow, as it provides real-time data in easily readable graphical form. The UCSD is also a good model from which to learn because it couples instant, user-friendly information with more in-depth research.

Most importantly, a dashboard built at Indiana University should be customized to the university's sustainability needs and activities. Dashboards should be displayed prominently in each building, encouraging all students, faculty, and staff to learn about their impact on the environment and on the campus. In addition, the dashboard system should be unified across campus, more readily facilitating recognition and aiding comparisons and competitions across buildings and departments. Finally, the dashboard system should be automated, providing real-time data directly from each building's meters.

GoGreen Gadget

Introduction

The GoGreen Gadget was developed by the Department of Education to help bring down the cost of energy from the hundreds of desktop computers in their department that are constantly on. The Gadget configures the computer to go into a deep sleep after it is idle for a given amount of time, saving both energy and CO_2 emissions (Hanks et al. 2008). These savings are then reported back to a central location, so that the savings of each department as well as the entire university can be tracked.

The Gadget was made available to the entire Bloomington campus almost a year ago, yet only the School of Education and the School of Health Physical Education and Recreation use it currently. The Sustainable Computing Group, therefore, requested information which would help with the dissemination of the GoGreen Gadget.

Methodology

We were tasked with designing a marketing plan for the GoGreen Gadget. This was discussed at the Sustainable Computing Working Group, with confusion about how to best get the gadget onto campus computers. There were suggestions of monetary incentives, stressing that "doing

the right thing" was the imperative motive, and we were not really sure of what the obstacles were. Should the marketing effort be taken directly to the Deans and chairs of departments?

We first met with Susan Coleman to get an idea of what was needed in this marketing plan. She suggested that we need to get faculty support while also figuring out the barriers of IT managers for implementation. We therefore decided to speak to as many IT managers as we could while trying to find avenues in which to get faculty and staff involved and excited about the project, therefore putting pressure upon IT managers.

Findings

We went to Jana Wilson, Director of Marketing and Communications at the School of Public and Environmental Affairs. She had some insight on the way that decisions are made at the University, saying that marketing to Deans of departments was not much different than marketing to IT managers, logistically. She did suggest however that with this kind of program, pressure must come from the top. This makes logical sense, as financially it is not individual departments that save money from energy costs. As explained earlier in this paper the University has one energy bill which gives no incentives for individuals to conserve energy. Even there were $21.95 estimated saved by each computer, this would not seem like much of an incentive for all except the largest of departments. However a campus-wide $360,000 plus would be enough incentive for the financially pressured campus on a whole (Hanks et al., 2008).

Ms. Wilson recommended that we talk with John Applegate, Executive Vice President for University Regional Affairs, Planning, and Policy. We sent an e-mail asking for his assistance and were told we would hear from a more relevant person. We hear that a chain of e-mails was started between Vice Presidents, but have not heard from anyone at the time of printing.

When speaking to IT professionals throughout campus it was clear that they all were in favor of the GoGreen Gadget in theory. This was partially for environmental concerns, but most believed that implementation was inevitable due to fiscal policy and the rising cost of energy. The main challenge seems to be equalizing the ease of installing and using the Gadget and resources IT staffs have. Since these gadgets are not essential to teach, research, or function administratively the IT professionally would understandably balk if they thought implementation of the Gadget could cost them time, money, and have the potential to create problems in the future.

At SPEA, and other smaller departments, there are some technical barriers to "deployment"[17], where teams have little experience with the process and may need technical assistance. There was also concern about having an official policy, or which group of customizations would best fit all the users in the building.

The Chemistry Department has about 2,000 computers which they believe could use this technology, and though they like are in favor of the idea, their current stand is that for now they are not going to implement it. Their chief concern is that if STC has not used it then it is not fit for production and that their stamp of approval is what is needed. They believe there are bugs in the program that could be disastrous, especially in classroom laboratories. They are also very

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[17] Where all computers are updated at once as opposed to machine by machine

willing to collaborate with STC to use some of Chemistry's STC machines to test out the Gadget and use the results of this trial to implement the Gadget in both the Chemistry Department and STC.

The HPER staff, where the Gadget has already been used for about a year, is still using the program with few hindrances. However, when they first installed the Gadget they had problems with waking up sleeping computers remotely, public documenting reporting – where only the last computer which was installed with the Gadget was being reported for all of HPER, and they also had a difficult time finding support to help them when these problems arose.

When speaking to the Student Technology Center, we got a firmer idea of the hurdles which one can expect to encounter when implementing the Gadget for the first time. The estimated that about 80 hours of STC time was spent on the School of Education's pilot, and though some lessons were learned from that, the same template could not be applied to all projects. Some of these challenges include reconfiguring the network, different brands of hardware and Bios systems, and resuming the system as opposed to rebooting it. STC is responsible for roughly 5,000 campus computers, 2,000 of with they share with various departments. STC was open to the proposition of partnering with Chemistry to pilot the Gadget in some areas and then expand, though no official commitment could be made.

Though is it true that many students use laptops which could not benefit from the Gadget, there is probably still some energy to be saved by desktops on campus property. It is also useful to have popular sentiment behind the Gadget and promote that the application is "cool". Marketing this to the entire campus, therefore, would not hurt the cause. Therefore, it would be a benefit to make stories available to the IDS, the *Herald Times,* WFIU, etc. There should also be an easy-to-find consumer-friendly Webpage with useful statistics, pictures and bulleted language.

Recommendations

1. Pursue the possibility of an STC collaboration

2. Clearly communicate ways for technical support, and any resolved issues which may add to the perception that the GoGreen Gadget is bugged.

3. Talk to individual IT managers to understand their concerns and offer them help for their specific concerns.

4. Use basic marketing channels to increase awareness of the GoGreen Gadget throughout campus.

5. Seek support from higher levels of university staff

Using Smartphones to Conserve Energy and Water

Introduction

Smartphones are quickly becoming ubiquitous, particularly on college campuses. These devices have yet to be tapped as a resource to enhance sustainability. This pilot project aims to address smartphone use by enabling students to report leaky faucets and running toilets from their mobile phones. Smartphones can now act as barcode scanners, and the square "Quick Response," or QR code, has seen increasing use, especially in the advertising arena. These codes allow phones quick access to a phone number or Website, which appears on the screen once the QR code is successfully scanned.

Currently, many buildings on campus have a "Leak Line" sticker with a phone number that students, faculty, and staff can call to report. The stickers were installed in late 2010 and resulted in a large increase in the number of reported leaks. In total, the Leak Line has saved an estimated $19,321.87 since the fall of 2006 (Utilities Information Group 2011). This pilot project intends to bring the Leak Line into the 21st century with a Web-based interface that can be accessed from mobile phones.

Current Study

For this pilot project, fliers containing QR codes were placed in bathrooms in both buildings of the School of Informatics and Computing. The fliers contained a short amount of text letting visitors know that they can now report issues by scanning the QR code with their smartphone. Once scanned, the user is presented with a link to a short form that asks what they would like to report, where they are, and for additional comments. An additional choice stating that the user has nothing to report but likes the idea was included on the form and the flier. The fliers were posted for a period of three weeks.

Although there were only three responses and all had nothing to report, they were supportive of the concept To put this in perspective, the central Leak Line had only 123 responses representing 24 buildings in 2010 (Indiana university Utilities Information Group, 2011), or just over five responses per building per year. When compared to three responses in three weeks, this seems promising. It is plausible to note that the QR method may be more desirable as a reporting system because of its ease and novelty. There are, however, some caveats to these results. First, the fliers were posted in the School of Informatics, which may have a slight bias with regards to technological savvy. This may have skewed the results slightly, and the response may vary in other buildings. Additionally, these results represent only two buildings during a short period of time and therefore cannot be considered wholly representative of the rest of campus.

Looking Forward

This pilot has positive future implications. It showed that people may be willing to use their phones to report facilities-related issues. This platform can be scaled up to include lights left on in empty rooms, air conditioning or heating issues, or any other general maintenance issues. From these data, it would be possible to divine trends with regards to problem areas in buildings and even behaviors. For example, if there are multiple reports of lights left on in a particular

room, that room might be a candidate for signs reminding occupants to turn the lights off or automated occupancy sensors.

We recommend that this pilot be scaled up to include multiple facilities to thoroughly test its effectiveness and utility. Fortunately, this project is relatively inexpensive to implement. Once the Web interface and backend are developed, fliers or stickers can be printed at minimal costs and posted in the desired facilities. This also takes some burden off of the Utilities Information Group, as the Web-based reporting system is operable 24 hours a day and won't require any staff to continuously monitor.

If this pilot is scaled up and implemented on a larger scale across campus, this will also help UITS decision-makers decide whether incorporating a similar feature into the IU Mobile App might be appropriate. If such a path were chosen, additional features could be included, such as the ability to GPS-tag a problem's location and to attach a picture of the purported issue. These additional features, while not required, would provide maintenance staff with more information regarding the reported problem and potentially lead to more timely repairs.

Conclusion

Indiana University has already undergone multiple initiatives to use IT in to increase sustainability. Many of these, however, are held up due to organizational problems or red-tape. Motivation to increase utilization of these services could include broader public awareness, support/pressure from schools and the university as a whole, and dialogue between IT manager and the working group. Leadership is also needed to help prioritize initiatives and help create incentives for applying more sustainable computing techniques.

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Best Practices

Introduction

Though interest in campus sustainability has been growing rapidly over the past decade, we are just beginning to see universities and colleges specifically address the field of sustainable information technology. The first step toward achieving implementation of any effective sustainability initiative is seeking out information regarding current best practices.

The Best Practices committee consists of five people: One person was designated the "coordinator;" responsible for directing research areas within Best Practices and coordinating our efforts with the other groups, and the other four were assigned to liaise with each of the other capstone groups and compile their data. During the preliminary research period, each group member engaged in literature review and Best Practices, assisted with research on the topic specific to our assigned groups, and attempted to obtain a larger view of the field of currently utilized and innovative sustainable information technology. Our research into these best practices was divided among three areas of focus: the private sector, the public sector, and academic institutions.

The Best Practices committee conceptualized our group's research plan as having three main goals. The first two were unique to Best Practices owing to the wideness of the scope of the reviews we had planned, and the third was more specifically related to our capacity as "compilers" of the other groups' data.

> **Goal 1**: Establish the fundamentally "key" sustainable information technology practices used in business, governmental, and academic environments.
> **Goal 2**: Determine whether these practices had been or could be implemented at Indiana University.
> **Goal 3**: Identify best practices applicable to IU in the areas of e-waste, duplex printing, reduction in printing, use of IT to enhance sustainability, and data center energy use.

Through the data we have gathered and here report, we hope to provide IU with the means to improve its STARS and Campus Sustainability Report Card scores and effectively utilize information technology to achieve some of its sustainability goals (as stated in the Office of Sustainability's 2020 Master Plan). We have also attempted to identify both gaps in the university's current technology-related policies and practices which could be improved.

Methodology

The Best Practices group used the three goals listed above to form our methodology. Our research began with a literature review focusing on the best practices in the fields of e-waste, duplex printing, and data centers, as well as gaining familiarity with both IUB's approach to sustainable computing and the existing literature. As we conducted our literature review and

research into best practices, we chose three separate areas of focus: academic institutions, the public sector, and the private sectors.

For our academic institutions, we utilized AASHE's Sustainability Tracking Assessment & Rating System (STARS) and the Campus Sustainability Report Card (CSRC). With STARS we originally focused on colleges and universities that received a "Gold" rating and thus are considered top of the field. As the research was conducted, we concluded that STARS' areas of focus compromised the usefulness of the rating system for our purposes. However, the top rated schools were researched in the areas of waste and purchasing because both categories were identified as related to sustainable IT and were areas in which Indiana University could raise its score. Using the Campus Sustainability Report Card, we compared IUB's practices in several similar categories in more depth against seven institutions that received overall grades in the "A" range (see Appendix BP-2 for detailed spreadsheet). We supplemented this research through online research into institutions' sustainability programs. In order to better understand IUB's own sustainable IT practices, the list from the IUOS site and the goals from the 2020 Master Plan were compared.

As we explored practices in the private sector, the research team mainly focused on businesses that encouraged green computing. Three best practices were identified that sustainable businesses were using, as well as three other practices worth noting.

Our methodology for research in government included looking at policy at the federal, state, and local government levels. At the federal level, agencies that publicly responded to President Obama's Executive Order 13514, calling for the sustainability of government agencies were researched. At the state level, Indiana's Greening the Government and Greening Initiatives were examined. At the local level, ITS Director Rick Dietz was interviewed on what efforts the City of Bloomington is pursuing in regards to sustainable computing.

Best Practices in Electronic Waste

Several universities around the country are using sustainable and cost efficient practices for minimizing and disposing of electronic waste. After identifying practices that IUB is not currently using and discussing them with our client, there are several potential practices for IUB to consider adopting.

Virtual Desktops

The average owner of a personal computer rarely uses more than five percent of its computing capacity even though it is built with high-performance memory and dual-core processors (Wengroff, 2008). The rest of the computer's memory is wasted. Virtual desktops allow excess power not being used to be shared among multiple users. There are several environmental and cost saving benefits associated with virtual desktops. They are reliable and inexpensive because they do not have memory, fans or other moving parts, or a central processing unit. They also consume between one to five watts of electricity, significantly less than the 110 to 200 watts consumed by a PC. The central device's performance is dependent on the PC and therefore they do not require upgrades. If an upgrade is needed it is only for one of the shared PCs. This saves time and reduces IT support costs. Additionally, virtual desktops usually weigh around 0.15 kg

where a PC's average weight is 9.5 kg. NComputing, Inc., the leading provider of desktop virtualization hardware and software, claims the adoption of virtual desktops would eliminate around 6.7 million metric tons of electronic waste (Wengroff, 2008). The University of Michigan currently uses virtual desktops and IUB is currently undergoing a pilot program (Stuenkel, 2009). IUB started the program after learning of the cost saving benefits from the ability to extend the life of older hardware; the central unit lasts at least six years, and it allows for increased security (Potchanant, 2011).

Purchasing

The University of Michigan (UM) believes the majority of its savings, cost and environmental, come from the type of machine they decide to purchase and by positioning purchasing based on need. They purchase computers that are Energy Star-compliant and EPEAT-certified. EPEAT is the Electronic Product Environmental Assessment Tool and it looks at more than just how energy-efficient a computer is. EPEAT takes into consideration criteria such as the amount of hazardous materials in the machine, its material selection and composition, end-of-life design and management, and life cycle considerations. UM makes its computer purchasing decisions so that the machines they obtain can be easily reused or refurbished, contain the least amount of hazardous materials possible, and are of high quality to last longer. Chris England, the head of IT for SPEA, stated that at IUB, after three years professors can have their computers replaced whereas UM determines replacement based on need. UM focuses on more than disposing of e-waste but they try to minimize the amount (Stuenkel, 2010).

Green Clean Day

The University of Michigan has a "Green Clean Day" for all departments once a year. The day is entirely dedicated to cleaning out office space and determining what is recyclable, reusable or waste. The "Green Clean Day" guide (See Appendix BP, BP-1) is also distributed to all departments. The detailed guide contains information on e-waste, how to recognize e-waste, and how to store and dispose of e-waste. Moreover, the guide has a checklist for departments to follow which consists of creating teams so all tasks are performed, setting goals, and informing constituents on how to properly sort items. The Waste Management department at UM intends for Green Clean Day not only to create a venue for proper disposal of items but to help departments recognize the amount of waste they create and opportunities for reuse (University of Michigan, 2010).

E-Waste Dispensers

Ohio University's Campus Recycling and Refuse department teamed up with its Facilities department to convert old file cabinets into drop-off bins for electronic waste. The bins are located around campus to allow students, faculty and staff to dispose of PDAs, digital cameras, printers and toner cartridges, computers, batteries, and CDs. The cabinets have different slots marked for the different types of waste and are kept locked (Schaffhauser, 2010). IUB currently pays $500 for each cell phone disposal bin on campus. There are currently file cabinets at IU Surplus that could be reused to save money and resources.

Best Practices in Duplex Printing

Summary

Duplex printing (DP) is a fundamental aspect of sustainability that needs to be better understood by Indiana University (IUB). As members of the Best Practices in Sustainable Computing team, we set out to thoroughly research the practices and policies of duplex printing and related facets of sustainable printing to assist the Duplex Printing Team in their original research and overall recommendation to IUB.

It is evidenced by the extensive research of duplex printing and related facets of sustainable computing that the benefits of duplex printing are considerable, that they far outweigh the costs, and that therefore they should be set as the default printer setting. DP reduces paper consumption, which results in both financial and environmental benefits. Decreasing paper consumption at IUB leads to cost savings from reduced paper purchases and less waste disposal while lowering paper production and CO_2 emissions. Additionally, it is clear from the research that liquid printing ink has various toxins detrimental to the environment and personal health, and solid ink may be more health and environmentally friendly However, no conclusion can be drawn on the level of threat these toxins carry, and it is recommended that a cost-effectiveness or cost-benefit analysis be conducted using the printing-ink alternatives discussed in the duplex printing sections.

Findings

The consensus among academic research provides that printer default settings should be set to duplex rather than simplex. Making DP the default setting will not only reduce energy and paper costs, but will also reduce the overall life cycle environmental impacts (James & Hopkinson, 2008). Paper reduction from DP can be by as much as 30 percent, thus decreasing the costs of both paper purchasing and waste disposal (Environmental Stewardship Systems Team, 2008). In 2001, the Penn State Green Destiny Council published an extensive study on sustainable practices referred to as "the Mueller Report." The study found that using duplex printing for every document printed will result in a 50 percent paper savings and, accordingly, recommends that duplex printing be set as the default setting (Penn State Green Destiny Council, 2001).

Furthermore, the paper savings from DP on printers printing over 40 pages per day can recoup the added investment cost of duplex printing within five years (Environmental Stewardship Systems Team, 2008). The 2008 study conducted by Michigan State University found that replacing its 88 large capacity E-token printers with duplex-capable printers would save the university $21,750 in five years, reduce paper consumption by nine tons per year, decrease energy use in paper manufacture and disposal by 330 BTU per year, and reduce greenhouse gas emissions by 20 metric tons of carbon equivalent (Environmental Stewardship Systems Team, 2008).

Along with efficiency, another factor that must be considered is the environmental impact of duplex printing. CO_2 emission levels are reflective of energy consumption: the more energy

used, the more CO_2 emitted (Thompson, 2009). Considering this, one would assume that printing duplex causes more harm to the environment than simplex because it requires more energy consumption. In actuality, this is not the case. The actual production of paper emits substantially more CO_2 than merely printing (Morse, 2009). Therefore, DP is far more environmentally friendly than simplex printing because if duplex printing increased the demand for paper would decrease and, subsequently, paper production would decrease at a similar rate resulting in sizable reductions in CO_2 emissions. Finally, the benefits of DP are further enforced by a 2009 study from the University of Alberta's Office of Sustainability which credits the University's 23.2 percent decline in overall paper consumption to a 20 percent increase in duplex printing usage (Clark & Davidson, 2009).

To be thorough and precise in our research, we explored the disadvantages of duplex printing and overall found very little evidence that suggested DP has unworkable flaws. IUB does not use duplex printing as the default setting largely in part to a survey that revealed faculty members were not "fond" of grading on double-sided pages (Hanks, 2008). We question the feasibility of using this reason as a justification to keep simplex as the default setting for all printing jobs. If students are required to print something out for a professor who prefers single-sided pages, why not allow the student to choose that option?

Conventional duplex imaging systems may have various disadvantages which stem from the receiver and passing the paper through the system multiple times (Marsh et al., 2008). This often leads to paper jams resulting in increased maintenance costs. According to a 2008 study by the University of Michigan, "[when] analyzing printer malfunctions, Michigan saw a 200-500 percentage increase in jams associated with duplex printing. These jams are the leading reason why system-wide duplex printing is not a viable model for our current environment." According to that same study, DP takes over twice as long to process than simplex printing which results in longer queues and more abandoned jobs and an estimated cost between $150,000 and $375,000 to address the "jam" problems. With that said, the study was conducted three years ago on only one model of machine (the HP 4300/4350) and should not carry significant weight when determining the best practice for duplex printing in the year 2011. We also find it hard to believe that paper jams are nearly as costly as the study indicates given that the majority of machines are staffed by student workers and find no explanation of the methodology used in the study that led Michigan to reach this conclusion. Michigan is currently moving towards a new printing model, the HP 4515, and ascertains this newer model is more reliable (University of Michigan Information and Technology Services, 2011).

According to a study by Indiana University's Office of Sustainability (Coleman, 2009), DP consumes more energy in terms of Kilowatt Hour (KWH) than simplex printing. The results of the study are indicated in Table 1 below.[18]

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[18] Table was taken directly from the study

Table 1. Results of the Study

Duplex	HP LaserJet P4515X	HP LaserJet 4350dtn	HP Laser Jet 8150dn
Total KWH	0.14	0.12	0.21
Total Time	11:43.7	13:10.5	20:31.2
Simplex	HP LaserJet P4515X	HP LaserJet 4350dtn	HP Laser Jet 8150dn
Total KWH	0.11	0.11	0.18
Total Time	08:57.7	09:09.0	15:57.2

While these results clearly demonstrate that DP consumes more energy than simplex printing, it is not by a significant amount for any of the printers. Although the time required to print duplex is notably higher than printing simplex, we believe that perhaps this could ultimately be beneficial in assuring that students edited carefully before printing. In addition, as explained above, the costs stemming from the additional energy required for duplex printing is overshadowed by the potentially substantial benefits incurred through the reduction in paper production.

Emerging Technologies

The Synchronous Duplex Systems using directed charged particle of aerosol toner development (Marsh et al, 2008) is designed to synchronize imaging of both sides of the paper at one time, removing multiple pass-through problems. The paper feed apparatus for duplex printing provides a more cost-effective and effective way to automate duplex printing (Wu et al., 2009). According to the patent, duplex printing runs into trouble because of the friction created when the paper reverses sides. The paper feed apparatus is designed to overcome this deficiency of duplex printing.

To overcome problems of printer malfunctions stemming from DP, the Detour Printing Solution on the OpenPrint Platform (DETOUR) allows print jobs to be re-routed from the jammed printer to another printer "close-by" printer. They can thus guarantee print output even though printers are down.

Printing Ink Best Practices

The National Emissions Inventories (NEI) ranks the U.S. printing industry fifth in terms of volatile organic compounds (VOC) emissions among major industries; just ahead of the automobile industry which ranks sixth (Miller, 2008).[19] According to a 2007 article in Medical News Today, a study by the Australian Department of Sustainability finds that, "indoor particle levels in the office air increased fivefold during work hours due to printer use. Printers emitted more particles when operating with new toner cartridges, and when printing graphics and images that require greater quantities of toner," (Bernstein, 2007). There are four primary components of printing inks that may be detrimental to the environment: varnish sometimes referred to as the

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[19] It should be noted this statement was not cited in the report nor could we locate the NEI source of this claim

"vehicle", which is the greatest source of emissions from the printing industry solvent; colorant that may include heavy metals; and additives (Miller, 2008).

Solid printing ink does not use the known highly toxic metals such as lead, arsenic, selenium, mercury, cadmium and hexavalent chromium (NAPIM). The National Association of Printing Ink Manufacturers provides the following breakdown of the environmental impacts of printing ink:

Table 2. Breakdown of the environmental impacts of printing inks.

Ink Type	VOC Composition	Typical % VOC	On-Press Emission Controls
Liquid Inks			
Flexo-Gravure Solvent	Various solvents	40-70	Afterburners
Flexo-Gravure Water	Alcohol (if present)	0-2	Venting to atmosphere
Gravure Publication	Toluene	40-70	Recapture
Inkjet Solvent	Various solvents	40-90	None
Inkjet Water	Water	0-5	None
Solid Inks			
Dry Toner	None	NA	NA
Hot Melt	None	NA	NA

While solid inks are prevalent in Xerox machines, Xerox claims that not only has it eliminated "nearly" all lead and mercury from its products, its dry inks are non-toxic and do not generate hazardous waste (Bozeman et al., 2010). The 2010 Bozeman et al. study (commissioned by Xerox) finds that, "over the product life cycle, the solid ink printer studied exhibited approximately 30 percent lower Cumulative Energy Demand and Global Warming Potential than the laser printer and created approximately 90 percent less post-consumer waste." Given that Xerox is obviously a private, for-profit company; we were concerned that there might be a conflict of interest in the study. However, the study clearly indicates that the analysis was peer-reviewed by college professors.

Conclusions

Based on the above research, it is clear to us that setting duplex printing as the default print setting is a best practice in sustainable computing as it will work to reduce paper consumption, paper purchasing costs, and may serve to be very beneficial for the environment as well as promoting sustainable behavior change. In addition, any extra cost of buying additional computers with duplex printing capabilities will pay for itself in five years or less (Environmental Stewardship Systems Team, 2008).

Our research was not limited to duplex printing practices but extends to the best practices in all aspects of sustainable printing. Although the Mueller Report was published in 2001, we find many recommendations proposed in the "Mueller Solutions" represent best practices. By simply changing the margins on Microsoft Word from the default setting of 1.25" to 0.75", IU can reduce paper consumption by an additional 19 percent (Penn State Green Destiny Council,

2001). For example, a 100-page document under the current 1.25" margin setting can be reduced to 81 pages with a 0.75" margin.

In terms of best practices in printing inks, we recommend that additional research be done on various emission control techniques which include the following: Alternative inks, such as vegetable oil/ water-based inks, and radiation-curing inks, as well as ink optimization software. Vegetable oil-based inks can reduce or even eliminate mineral oils in inks, thus conserving non-renewable reserves, and also reduce VOC emissions and water-based inks can significantly reduce solvent emissions (Miller, 2008). Finally, reducing the ink film thickness on paper also introduces less ink into landfills and lowers the amount of solvents needed to de-ink paper in the recycling process (Miller, 2008).[20]

Best Practices in Data Centers

Introduction

Within a large computing network, the data center is the largest and possibly most important component. At the most basic level, a data center stores the systems backup power along with security filters, cooling systems for the processors, and large amounts of data and secure information. Cooling is necessary within a data center to keep temperatures and humidity low to keep the equipment from malfunctioning. Data centers can also house equipment required for such advanced processes like cloud computing and virtual computer servers (discussed below). For these reasons, data centers tend to function at the center of any computing network (WiseGeek, 2011). Since data centers can vary in size, ranging from a single room to a large building, the amount of energy used by any given data center can be extreme. The ability to reduce energy use by a data center can save millions of dollars in electricity costs every year. This section highlights some of the best practices being used in reference to data centers to reduce energy costs by improving data center efficiency.

Public Sector - Government

The United States Environmental Protection Agency (EPA) and Energy Star Program spearheaded a joint study to compile information on the best practices to increase energy efficiency within data centers (U.S. Environmental Protection Agency, 2007). This study concluded by identifying three areas of opportunity for efficiency improvements that all data centers can comply with: improved operations, best practices, and state-of-the-art technology.

Improved operations are considered the "low hanging fruit" or the most easily achievable energy efficiency improvements that could be reached by all data centers. The activities in this category are essentially operational in nature and can be achieved by simply operating the data center in a more efficient way. Some suggested actions under this category are server consolidation, elimination of unused equipment, power management, and improved airflow. Ultimately, implementing improved operations could save as much as $1.6 billion dollars (2005) across all three sectors (Energy Star, 2011).

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[20] An example of ink optimization software is FineEye Color Solutions' ICEsaver software.

Best practices are defined as "efficiency gains that can be obtained through the more widespread adoption of the practices and technologies used in the most energy-efficient facilities in operation" (Energy Star, 2011). The main constraint on these recommendations is that they can only be implemented if the data center is under construction or undergoing major renovations. Actions within this category include moderate server and storage consolidation, adopting energy-efficient equipment, purchasing efficient pumps, fans, and chillers, and utilizing free cooling. Overall, the EPA and Energy Star Program determined that these actions could save up to $4.1 billion dollars (2005) across the three sectors (Energy Star, 2011).

Finally, the state-of-the-art section presents the best available technologies in use today. By using only the best technology and best practices to manage this technology, maximum energy efficiency can be achieved (Energy Star, 2011). Practices within this category include aggressive server and storage consolidation, power management of all equipment, servers, and applications, direct liquid cooling, and combined heat and power. The consolidation of servers and storage in this section are cloud computing and virtual server technology (Energy Star, 2011). Overall, these measures can save $5.1 billion dollars (2005) but also require a substantial investment for equipment (EPA, 2007).

Public Sector – Indiana University

The Indiana University Data Center is a facility constructed to house the university's computer servers and computer data storage units. There are many features that were built into the data center to improve the buildings operation as well as its sustainability. Unique design elements for the building include the following: the ability to withstand an F5 tornado, security-enabled entrance, fire suppression ability, and single story bunker design. Additionally, any data stored in the facility is redundantly stored in an Indianapolis facility to serve as a backup for any data (Biagioli, 2009).

There are both design elements and computing elements in the data center to increase sustainability within the building. The entrance hall is the most ornate part of the building with bamboo paneled walls and shined concrete floors. Bamboo and concrete were used because they are relatively sustainable materials, both readily available and renewable. The rest of the building is very sparse in decoration, emphasizing the functionality of the environment.

In addition to the sustainable materials used to construct the building, the data center itself has the capacity to determine CPU, memory, and storage needs monthly. This is beneficial during the months when school is not in session, and energy is not used unnecessarily. Additionally, the data center uses hot and cold isles together to help keep the machines cool as well as circulate the air using minimal energy requirements. Finally, there is increased utilization of server capacity through the use of virtual equipment (Biagioli, 2009).

Many of the practices being utilized by Indiana University are considered best practices according to the EPA and Energy Star. They have consolidated much of their storage and server space in order to make room for additional machines. Additionally, the use of alternating hot

and cold isles allow for the best possible air circulation within the building. This helps the data center run at high energy efficiency.

Private Sector

This section focuses on three private sector companies that serve as models for the cutting edge of computing technology; Google, Intel, and Hewlett Packard. Their best practices are identified and can be used in both the public and government sector.

Google
Google has implemented practices to improve the efficiency and sustainability of its data centers. Instead of using large power distribution units (PDUs), Google actually equips its individual servers with 12-volt batteries. This increases efficiency from 92-95 percent to about 99.9 percent. Although this seems to be a small increase, there is an increase in efficiency where there is a small window available for improvement. Additionally, Google uses outside air for as much free cooling as possible. This allows for cool air to be brought in from the outside to supplement air needed to be cooled by the computer room air conditioners (CRACs), which are large and energy intensive. Finally, Google generates its own energy, on site, to run its data centers. This reduces energy costs for the company as well as transmission losses from the energy generating companies. Google has recently applied for a license from the Federal Energy Regulation Commission (FERC) in order to be able to purchase clean energy on the open market (Samson, 2010[1]).

Intel
Intel has embraced an advanced system to reuse the heat generated from the data center. By using heat recovery chillers (HR chillers) in a heat recovery system, enough heat is created by the data center to heat the building and water for kitchen and bathroom use throughout the building. Ultimately, the HR chillers remove heat from one of the two water loops within the building and use the removed heat to heat the building. Some drawbacks of Intel's HR chiller system are that it is slightly less energy efficient and more expensive than some other chillers available on the market. However, if HR chillers are purchased, then water heaters, piping, boilers and other amenities do not need to be purchased, thereby offsetting some of the price disadvantages. Ultimately, money is saved by not having to pay boiler fuel costs and through energy savings (Intel, 2007).

Hewlett Packard
Hewlett Packard has developed two innovative ways to make a data center more sustainable. First, there is a proposal to use cow-excrement to power the data center. "Biogas derived from the cow manure could generate electricity for the data center while the heat waste from the data center could warm other facilities on the farm -- including the digester, which extracts biogas from the manure" (Samson, 2010[2]). This decreases the amount of methane released into the atmosphere as well as reduces energy costs for both the farm and data center. The data center could use the excess methane to power the data center. The farm could supply a constant form of clean, renewable energy to the data center as well as use the excess heat from the data center to heat buildings on the farm (Samson, 2010[2]).

Secondly, HP has developed a flexible data center. This data center consists of four data center halls that can be constructed from premade sheet metal. This type of simple construction allows for quick and easy assembly of data centers. The company also offers different options for powering and cooling the data center. This allows for greater flexibility by the purchasing company as well as options for more energy efficiency equipment if it is desired. As capacity increases within the data center and more computing power is required, more quadrants can be added. On average, the flexible data centers operate with a power usage effectiveness (PUE) of 1.2, which is considered very low and indicates that the power being supplied is being used efficiently. This type of data center is ideal for large companies using virtualization technology (Niccolai, 2010). A main drawback from this type of data center is that the security might be less than desirable for companies who rely on their information being very secure. However, if the companies are highly virtualized, certain security measures can be taken.

The EPA and Energy Star Program consider many of the above best practices state-of-the-art technology. The practices require aggressive consolidation as well as the use of free cooling and combined heat and power. Although these practices are some of the best in the field, not all are feasible for all data centers. Many of the practices require new facilities and resource investment. However, the energy and cost savings associated with the new technology can often justify a new data center being built or retrofitted to accommodate new and emerging technology.

Survey of Best Practices in the Private Sector

Introduction

Sustainable practices are not only better for the environment but can save costs. There are several practices used to make computing in the private sector more sustainable that businesses adopt. Below, we discuss the top three best practices as well as three other common practices and how each improves sustainability in computing. The section concludes by identifying what practices can be implemented at Indiana University (IUB) for its continuing improvement in the sustainability field.

Top Practices

Cloud computing is the ability to have every piece of information needed, instantly. Data then becomes mobile, transferable, and instantly accessible to anyone (Tadjer, 2010). Cloud computing is considered a best practice because it allows for needed data to be stored in one central location and does not utilize unnecessary space. This function provides the most efficient consolidation of data available. Cloud computing is ideal for smaller businesses or private users to access data because information is stored through a vendor. Since IUB is a large public university with secure information and research storage needs, they may not want any information stored through a vendor and instead use virtualization to keep information within the university.

Virtual computing, also known as virtualization, is very similar to cloud computing but is more ideal for an institution like IUB. Virtualization of a computing system means that one central server feeds all computers connected to it. This allows for all the computers to be connected while the computing power is maximized and power usage minimized. This best practice provides opportunities for energy savings, maximization of computing power, and a central storage area, away from the computer, for data storage. Since the data is stored away from the computer, at a separate site, it provides higher data and information security. Additionally, monitoring can be done of the computing and storage equipment at the off site location to ensure energy savings maximization.

The final best practice identified is improving data center technology. Improving data center technology can range from updating the equipment being used in the data center to improving the cooling within the data center to help increase performance and energy efficiency. If a data center is utilizing old and out-of-date technology, the processing time of the machines is slower, and there is less space in which to store the data. Due to these factors, the data center uses excess energy. Additionally, updating the arrangement of computer room air conditioner (CRAC) units can allow for air flow to be more optimal and reduce the amount of energy required to cool the units. This can reduce costs of electricity and improve efficiency of the data center.

Other Recognized Practices

We identified three further private sector green computing practices while researching best practices. We feel that these additional practices should be acknowledged as "best practices" although they are not utilized as widely within the private sector. These practices are: IT energy measurement, power management software, and IT asset disposal and recycling (Samson, 2009).

IT energy measurement is the practice of businesses measuring their energy use from computers, printers, and other computing products. Quantifying the amount of energy used allows a business to determine its carbon footprint, energy costs and savings, and overall energy consumption. This information helps serve as a starting point for businesses to set energy usage goals and as an incentive to implement cost-saving practices that increase sustainability.

Power management software is the practice of managing computers power usage when they are not in use. This increasingly common practice saves on energy and costs. Placing a computer into a sleep mode uses less energy and does not require the computer to be completely turned off.

More and more businesses are learning that electronic equipment is highly toxic and must be disposed of differently from regular trash. Businesses are learning how to properly dispose of this material at the end of its use or to try to give the equipment a second use by fixing, donating, or selling the parts. Proper disposal and recycling of this equipment allows for businesses to make money off of unused equipment and frees up space so equipment is not just sitting in an empty office.

Best Practices and Indiana University

Based on the information we found about best practices within the private sector, it is evident that Indiana University is implementing all of these options, in whole or in part. Indiana University uses virtualization technology and strives to improve data center technology. University Information Technology Services (UITS) is currently conducting a pilot program of virtualization technology with select employees, and in 2009 IU unveiled a brand new state-of-the-art data center to meet the University's needs. Cloud computing and virtualization are both common practices in the private sector to increase sustainability. The practices are very similar, but virtualization was determined to best meet the needs of IUB. Virtualization is more effective for larger institutions because the servers are in constant use and there is little time when servers are not being used. Virtualization is also considered more secure than cloud computing, which is important for IUB because of the amount of personal and sensitive information stored by both students and faculty.

In addition, Indiana University is actively engaged in measurement of its data center's energy expenditure to help identify how much energy the computer equipment is using. The University practices storage optimization by making sure all storage space is utilized before a new storage device is used. Power management software is currently installed in computers around campus to help save energy while the computer is not in use. The Go Green Gadget is software that Indiana University developed to help put computers into a deep sleep when they are not being used to help save energy. Finally, the e-waste program to recycle old, broken, and out of date technology fully embraces the idea of asset disposal and recycling. Overall, we find that Indiana University is utilizing all of the best practices being used in the private sector to improve green computing.

Survey of Best Practices in the Public Sector

Introduction

Sustainable IT has become increasingly important at all levels of government. With that in mind, it is important when analyzing the best practices of sustainable IT in the public sector, to keep in mind the difference in agendas and resources that the levels of government have available. Whether local, state, or federal government, it is easy to see that sustainability is on the mind of IT directors.

Federal

In October 2009, President Obama passed Executive Order 13514 stating that, "in order to create a clean energy economy that will increase our Nation's prosperity, promote energy security, protect the interests of taxpayers, and safeguard the health of our environment, the Federal Government must lead by example" (Exec. Order No. 13514, 2009). This executive order mandated that the federal government and its agencies pursue energy efficient practices and create agency-specific strategic sustainability performance plans.

The Office of Technology and Electronic Commerce in the U.S. Department of Commerce's International Trade Administration is one agency department that is actively pursuing their sustainability efforts in IT. The department published a Green IT To-Do List, listing ten easy, low/no cost ways to save IT energy and cut CO_2 emissions. The list includes simple ways to begin the process of greening IT, including:

- Using free energy calculators/tools to determine your IT electricity consumption and carbon footprint and to help establish a green IT plan for the agency

- Unplugging or responsibly retiring unused servers, PCs, monitors, and printers

- Unplugging laptop and telephone chargers when not in use

- Employing power management techniques by adjusting settings to "standby or sleep" mode when PCs and printers are inactive during business hours

- Turning off PCs and peripherals at the end of the day

- Connecting computers to a power strip and turning off the strip after shutting down components

- Setting printer settings to default duplex and black and white copies; using print preview and "shrink to fit," switching to draft mode to increase printing speed

- Increasing use of the Internet and your Website by placing information on Web pages, wikis, and blogs instead of creating paper copies.

- Periodically deleting unwanted or duplicated e-mails, removing attachments from e-mails, and emptying out the deleted items folder to reduce storage space required and thus the energy consumed by computer storage.

- Allowing each employee to telecommute one day a week (Miles, 2010).

The Office of Technology and Electronic Commerce used statistics from the Department of Energy to complement its To-Do list. For example, the DOE states that power management will reduce electricity consumption by at least 20 percent and could result in an average savings of $50 per PC (Miles, 2010).

The Government Printing Office, though not held responsible to the Executive Order, has been notable in its pursuit of efforts to green its departmental operation. These efforts include use of alternative flex-fuel delivery vehicles, installation of a green roof, and an in-house recycling program. The GPO is responsible for the majority of agencies' printing and previously printed on presses that only used solvent once and then discarded the hazardous fluid. Through the GPO's greening efforts, the GPO now can reuse up to 90 percent of the solvent after its first use (Yehle, 2010). The GPO has also begun pursuing options for offering environmentally friendly paper and ink, though there are certain standards that are regulated within the government that makes options limited (Yehle, 2010). While this does not directly align with sustainability in IT, it is a

close cousin and might be another venue for the Office of Sustainability to pursue with Indiana University's publishing function.

State

The past several Indiana state administrations have encouraged the ongoing efforts of the Greening the Government plan. The state's Greening the Government Plan includes five major categories: (1) Employee Education, (2) Source Reduction and Recycling Collection, (3) Environmentally Preferable Purchasing, (4) Pollution Prevention and Energy Efficiency, and (5) Employee Transportation. This plan encompasses many of the best practices supported by Best Practices' conducted literature review including: a sustainable purchasing plan and addressing energy efficiency and the greening of state buildings (IDOA, 2011[2]).

Indiana created a Greening the Government Taskforce to carry out the greening initiatives. Unfortunately not much information concerning their initiatives could be found published nor was the research team able to get a response from agencies contacted. The Greening Initiatives Website did state that the government encourages duplex copying and printing, as it saves agencies money and paper. Though the policy does recognize that some agencies may not have technology capable of this function, it mandates that whenever possible this capability be activated. Indiana is a member of the U.S. EPA's Energy Star Partnership, and the government is working towards reducing its energy consumption. This includes such measures as using the power saver and sleep features on PCs and unplugging electronics when not in use (IDOA, 2011[1]).

The State of Indiana has been applauded for its greening efforts. In 2005, the Indiana Office of Technology was founded with three goals in mind: (1) improve IT service, (2) reduce costs, and (3) employ green initiatives wherever possible (Brandel, 2009). Some progress IOT has made in terms of sustainable IT using best practices of the field include the consolidation of seven data centers into one and reducing server count by one-third through virtualization (Brandel, 2009). By 2009, IOT "upgraded 30,000 desktops to Dell machines using Intel Corp.'s vPro chip. That resulted in $400,000 in savings from a reduction in electricity use and an increase in productivity while reducing carbon-dioxide emissions" (Brandel, 2009). This purchase was also Energy Star compliant. The IOT offers a unique program to incentivize its employees by using metrics for greening into performance-based pay and producing a monthly newsletter highlighting its sustainable activity (Brandel, 2009). The efforts of IOT toward sustainable computing have been so successful, that they have been encouraged to start a pilot program in which other governments might take part, sharing resources in an effort to reduce inefficiencies and equipment load (Brandel, 2009).

Local

In order to analyze public sector best practices at the local level, the research group interviewed Rick Dietz, ITS director for the City of Bloomington (COB). In collaboration with the city's new Sustainability Director, the ITS department is pursuing many efforts to enhance their

sustainability in IT. Many of these efforts align with the best practices promoted by the literature review conducted, UITS, and IUOS.

In keeping with the best practice of virtualization, the COB is currently in the process of virtualizing as much of their system as possible. Because of the nature of some of the city's systems, virtualization is not possible for everything; for example, the utilities department, whose system is too integrated.

The COB has looked into the best practice of duplex printing, but for the city, this presents some practical challenges. There is little uniformity in the printers currently in use by the different departments, and therefore the printers are not universally capable of duplex printing in an efficient and effective manner.

There is a similar problem in pursuing efforts of power management. Not all of the city's computers are capable of going into a deep sleep and wake-on-LAN, meaning the computer is able to awake from the sleep with a network message. While deep sleeps present challenges for the COB, the ITS department has replaced all the computer's supply bricks with more energy efficient options, an alternate means of addressing sustainability through power management. The city has also switched all CRT screens to the more efficient LCD screens.

The city has collaborated with campus on Electronic Waste Collection Days. There are plans for at least one E-Waste Day, if not two possible days in the coming year. The ITS department also has its own policies in place for dealing with e-waste. The COB replaces about one-fourth of its computer equipment each year to keep up with new technology. Registered 501(c)(3) non-profit organizations can apply to receive this equipment free of charge.

The City of Bloomington is currently drafting a sustainable purchasing plan. As the city pursues LEED certification for many of its buildings, the purchasing plan will obviously play a big role in the construction and equipping of those buildings. It is important to note that certification is not only based on the structure itself but also the practices within—including purchasing. The proposed purchasing plan encompasses ongoing consumables, such as printing and copying paper, toner cartridges, and batteries, as well as durable goods, a category which includes office equipment such as computers, monitors, printers, copiers, fax machines, etc. The proposed plan also encourages the purchase of electronics that are Energy Star qualified when available, which will reduce unnecessary energy usage in city departments.

Indiana University is thoroughly integrated into the City of Bloomington. It is because of this reason and the close-knit quality of the community that it is only natural for the city ITS department to be in communication with the university's IT efforts particularly because the University has more resources available to pursue sustainable practices (Dietz, 2011).

Greening IT in the Public Sector: Literature Review

Other literature found beneficial in the field of greening IT in the public sector includes A How-To Guide for Greening IT in Government. The Guide outlines methods for sustainability in the areas of data center power and cooling, server consolidation, virtualization, storage management, data management, and recycling and disposal (Government Technology, 2009). While much of

the information was duplicated by what has been covered in other sections of this report, the report was found beneficial as a consolidated source of information and could be useful in the creation of any such guide for IT departments at Indiana University.

Survey of Best Practices in the Academic Sector

AASHE's STARS

Introduction

This section examines the Sustainability Tracking, Assessment & Rating System (STARS), a platform in which higher education institutions (HEI)[21] can advertise and share their sustainability policies and practices with other institutions across the nation, as a way to determine the best practices in sustainable computing. STARS rates these sustainability policies and attaches a grade to them, which other HEIs can then use as inspiration for their own sustainability policies. This section provides an overview of STARS and compares the policies pertaining to sustainable IT of some highly-rated HEIs to the practices utilized at IUB.

STARS Overview

The Association for the Advancement of Sustainability in Higher Education (AASHE) was founded in 2006 to promote sustainability practices in higher education institutions (HEIs). AASHE believes that social, environmental, and economic factors are the fundamental principles of sustainability; thus, proper sustainable policy practices must be designed to enhance the health of the environment, social health and welfare, and the wellbeing of future generations (Matson, 2008). To carry out its mission of endorsing their unique definition of sustainability in HEIs sustainability policies, AASHE created STARS. The system's extensive ratings criteria and categories have made it the benchmark for sustainability across the country (Matson, 2008).

There are five levels of STARS ratings available: Bronze, Silver, Gold, Platinum, and Reporter[22]. Only positive ratings, Bronze through Platinum, are accessible through their Website; however, no school has received a Platinum rating to date. Out of the 43 total submissions, 9 have received Gold, 21 Silvers, 11 Bronze, and 1 Reporter. Major categories include Education and Research, Operations, Planning, Administration and Engagement, and Innovation. Each category carries equal weight except for Innovation which is graded out of four possible points. An institution's STARS score is based on the average of the percentage of applicable points it earns in each of the three categories.

STARS is comprised of two main types of credits: Performance ("Tier One" credits), which can be worth one or more points, and strategy ("Tier Two" credits), which are worth less than a point (Matson, 2008). It is understandable why performance credits carry more weight than strategy

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[21] Higher Education Institutions includes all colleges and universities, college and university systems, community colleges, research universities, and any other post high school educational institution
[22] A "Reporter" is a school that wishes to remain anonymous.

credits as performance is the outcome of strategy. The results are, obviously, quantifiable and therefore provide for a more concrete grading system. Additionally, awarding more credits to performance measures acts as an incentive for HEIs to follow through with their strategies and not just keep implementing new strategies as a way to earn a better rating for publicity purposes.

Improving IUB's STARS Rating

Indiana University Bloomington (IUB) received a Silver rating with an overall score of 52.23; a 45.42 percent for Education and Research; a 39.3 percent for Operations; a 59.95 percent for Planning, Administration & Engagement, and the full four possible points for Innovation. Though IUB reported specific information on its use of many sustainable IT practices, programs, and technologies, STARS generally allows discretionary reporting of these initiatives where HEIs choose how much, or little detail to provide. This made STARS somewhat difficult to utilize as a data mine and impeded on our ability to compare programs across different schools. However, there were a few specifically delineated areas in which sustainable information technology solutions were clearly applicable. The "Operations" category, specifically the Waste and Computer Purchasing subcategories, are most closely related to our focus of sustainable computing (IUB also received its lowest of all of its STARS scores in the Operations category); thus, are where we focused our best practices research. . The breakdown of IUB's Waste scores is as follow:

Table 4. Indiana University Bloomington Waste Scores.

Category	Score
Waste Reduction	**0.00 / 5.00**
Waste Diversion	**0.94 / 3.00**
Construction/Demolition Waste Diversion	0.00 / 1.00
Electronic Waste Recycling Program	1.00 / 1.00
Hazardous Waste Management	1.00 / 1.00
Materials Exchange	0.25 / 0.25
Limiting Printing	0.25 / 0.25
Materials Online	0.25 / 0.25
Chemical Reuse Inventory	0.25 / 0.25
Move-In Waste Reduction	0.25 / 0.25
Move-Out Waste Reduction	0.25 / 0.25

We were pleased to see that IUB received full points for reporting its sustainable programs of providing online materials through Oncourse and E-Reserves, limiting printing through quotas and online submissions, "materials exchange" through IU Surplus, and e-waste recycling. The Tier 1 credits of Waste Reduction and Waste Diversion which together account for eight of the category's 12.5 possible points are areas in which IUB has a major opportunity to improve.

Waste Reduction

The following comments were given by Steve Akers, IU's Associate Director of Environmental Operations, in IUB's Waste Reduction section: "A waste reduction plan is in planning stages to further reduce waste and increase recycling amounts by unification of different waste and recycling systems on the IUB campus," (AASHE-STARS, 2010[2]). Best Practices encourages IUB's active pursuit of this plan. Obviously, if the university were to implement a formal waste reduction policy, it would receive credit for this step in its STARS report.

Waste Diversion

Waste Diversion was where IUB received its second lowest score. The category is broken down by; Materials recycled, composted, reused, donated, re-sold, or otherwise diverted ("Materials Recycled") and Materials disposed in a solid waste landfill or incinerator ("Materials Disposed"). The following portrays several of the Gold-rated schools' Waste Reduction scores:

Table 5. Gold-Rated Schools Waste Reduction Scores

School	Waste Diversion Score	Materials Recycled (Tons)	Materials Disposed (Tons)
IUB	**0.94 / 3.00**	**1,188.80**	**2,617.60**
American University	1.57 / 3.00	815.00	739.00
Duke University	0.99 / 3.00	4,853.92	9,928.10
Middlebury College	1.91 / 3.00	745.91	428.62
New York University	0.95 / 3.00	1,609.31	3,456.95
Oregon State University	1.08 / 3.00	1,396.80	2,480.00
Portland State University	0.86 / 3.00	849.20	2,107.36
University of CO-Boulder	1.11 / 3.00	1,895.96	3,246.72
University of South Florida	2.30 / 3.00	1,511.15	464.12

As seen above, American University (AU) has a Waste Diversion score far greater than IUB's; therefore, we looked deeper into its waste reduction policies. AU has set up an e-mail address (AUSurplus@american.edu) for use by students, faculty, and staff who need to discard old electronic equipment for both reuse and recycling. Both personal and university-owned electronics are accepted. In the case of computers, AUs OIT Asset Management Team pick them up and decide whether to reuse or recycle the equipment. In either case, data is wiped from hard drives and then the machine is either redeployed or sent to their contractor, 2nd Solutions, for recycling. (2nd Solutions specializes in electronics waste management and attempts to reuse equipment as a first priority and recycle it as a last resort.) AU also provides cell phone collection bins which are located in common areas around campus to enable easy recycling of this common electronic waste.

The University of South Florida (USF) also uses a licensed contractor to take away electronic waste for the purpose of recycling and disposal. According to their contracting policies, the contractors that work with USF are required to follow environmental guidelines for recycling and disposal as per the EPA mandates. USF also operates two trucks dedicated to pick-up and

transportation of electronic recyclables and to promote cost-competitiveness, works with multiple local recycling partners.

Given that Portland State University was the only school given a score lower than IUB's for Waste Diversion, we felt it would be worthwhile to investigate why it wasn't given full credit. Portland State University currently does not have a program in place to recycle, reuse, and/or refurbish electronic waste generated by students, nor do they take other measures to ensure that the electronic waste is recycled responsibly.

Although the STARS "Purchasing" category consists of six subcategories, we identified only three as being relevant to sustainable technology (all are Tier 1): Computer Purchasing, Office Paper Purchasing, and Vendor Code of Conduct. For computer purchasing, STARS requires an institution-wide stated preference to purchase EPEAT Silver or higher computers and monitors; for office paper, an institution-wide stated preference to purchase recycled content office paper; and for vendor code of conduct, an institution vendor code of conduct or equivalent policy that sets expectations about the social and environmental responsibility of vendors with whom the institution does business that is acted upon (STARS, 2011). Below is the breakdown of this category:

Table 6. STARS purchasing categories

Institution	Operations Grade	Total "Purchasing" Score	Computer	Office Paper	Vendor Code of Conduct
Indiana University	**39.30%**	**4.59 / 7.50**	**1.21 / 2.00**	**1.03 / 2.00**	**1.00 / 1.00**
American University	52.62%	6.45 / 7.50	2.00 / 2.00	0.97 / 2.00	1.00 / 1.00
Duke University	49.48%	4.77 / 7.50	1.92 / 2.00	0.56 / 2.00	1.00 / 1.00
Middlebury College	50.31%	5.41 / 7.50	2.00 / 2.00	1.48 / 2.00	0.00 / 1.00
New York University	56.01%	3.98 / 7.50	0.50 / 2.00	1.12 / 2.00	1.00 / 1.00
Oregon State Univ.	48.33%	4.99 / 7.50	1.78 / 2.00	0.93 / 2.00	1.00 / 1.00
Portland State Univ.	46.34%	5.14 / 7.50	1.92 / 2.00	1.80 / 2.00	0.00 / 1.00
U. of CO-Boulder	48.48%	3.54 / 7.50	0.00 / 2.00	2.00 / 2.00	1.04 / 2.00
U. of South Florida	44.11%	2.00 / 7.50	0.50 / 2.00	0.50 / 2.00	0.00 / 2.00

As indicated by the highlighted sections, American University (AU) and Middlebury College (MC) earned the highest two scores for the "Purchasing" category and received full credit for computer purchasing. Several notable elements of AU's and MC's sustainable purchasing policies are as follows:

American University
- "Acquisition of all goods and services [are] based on consideration of total cost of ownership, product lifecycle impacts, human health and equity concerns, product quality and performance, and vendor quality of service," (American University, 2010).
- Aims to eliminate waste by reducing consumption and shifting to products with less harmful lifecycle impacts

- Has a focus on total cost of ownership rather than low purchasing prices when evaluating the financial competitiveness of procurement contracts
- Requires sustainability standards and certifications whenever available; preferably earned from a third party
- Requires the university's licensees and/or sourcing companies to meet a code of conduct that is consistent with FLA and WRC codes. (American University, 2010)

Middlebury College[23]
- Maintains a policy to purchase computers and other electronics that are EPEAT-certified. 99 percent of the desktops, laptops and computer monitors purchased at MC in 2010 were EPEAT-certified.
- Stresses course material be provided online (much like IUB's Oncourse) and offers instructions to the faculty on how to utilize and post course material online as well as in developing their own procedures for long-term storage of their online course materials.
- MC emphasizes the efficiency and cost minimization of its online storage space by maintaining a policy to remove online course materials after two years (from the end of the course) (Middlebury College Handbook, 2010).

STARS Conclusion

When researching STARS and the STARS Technical Manual, we had some disagreement on the validity of this resource when developing best practice recommendations for IUB. STARS offers a disclaimer on page two of the Version 1.1. Technical Manual (the most recent manual) which reads, "Although the information provided herein is believed to be accurate and reliable, none of the parties involved in development of the Technical Manual, including AASHE, its members, and its partners, assume any liability or responsibility for the accuracy, completeness, or usefulness of any information contained in the Technical Manual," (AASHE-STARS, 2011) In addition, AASHE states on page eleven of the Version 1.1. Technical Manual, "While AASHE has strived for a fair and consistent approach to allocating points and ratings, this is an inherently subjective exercise," (AASHE-STARS, 2011).

We debated as to whether it was appropriate to provide best practices recommendations based on a source that clearly admits its ratings are "inherently subjective," and incorporates a disclaimer stating it is not responsible for accuracy. AASHE in no way attempts to maintain that its rating system is based on original research but is rather designed to enable meaningful comparisons over time and across institutions. With that said, we do think it is important to note the disclaimer and the "subjective" statement, but only to help establish the purpose of STARS. Our goal is to provide meaningful insight into the best practices in sustainable computing at similar institutions, and while STARS is limited in its information regarding details of sustainable computing, it certainly is an effective source for best practices in sustainability at comparable colleges and universities to IUB, and does provide some beneficial information regarding sustainable computing as outlined above.

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[23] Access to MC's official "Computer Use Policy" was unavailable. The policies noted here come from the MC Handbook's "Computing Policies - Faculty and Staff." page.

The Campus Sustainability Report Card

Summary

What follows is an examination of the areas of the reports related to sustainable technology in which we felt IUB had the most room to improve. With the CSRC, which is focused more on the minutia of campus sustainability than the STARS reports, we began by creating a spreadsheet of the areas which were believed were most likely to have some relationship through solutions involving information technology or computing (see Appendix BP, BP-2). Once that was completed, we chose for comparison against IUB seven institutions that had received overall grades in the "A" range – Brown University, Oberlin College, University of Wisconsin-Madison, California Institute of Technology, Arizona State University-Tempe, Cornell University, and Princeton University. The schools were chosen from the CSRC list with the intention of getting a mix of differently sized, public and private, research and non-research institutions, but due to possible differences in energy expenditure concerns we also wanted to stay roughly within the same climate for the majority (our two outliers were Caltech and ASUT) (see Table 1).

Table 1. Campuses chosen for CSRC report

Name	Location	Student Pop.	Pub./Priv.		Other	Grade
IUB	Bloomington, IN	42,464	public	research	"Public Ivy"	B
Caltech	Pasadena, CA	2,175	private	research		A-
Oberlin	Oberlin, OH	2,970	private			A
Princeton	Princeton, NJ	7,567	private	research	Ivy League	A
Brown	Providence, RI	8,649	private		Ivy League	A
Cornell	Ithaca, NY	20,939	private		Ivy League	A-
U of WI-Madison	Madison, WI	42,099	public	research	"Public Ivy"	A
ASU-Tempe	Tempe, AZ	50,397	public	research		A-

We examined these other universities' sustainable information technology practices in the sections of activity and policy which fell under the categories of Administration, Energy Efficiency, Green Building, and Recycling for comparison against IUB's and found them to be extremely illuminating. IUB currently has a "B" grade in Administration, Green Building, and Recycling and if the proposed steps are taken to implement some of the best practices identified at other schools, we are confident we can raise IUB's overall CSRC grade and ensure that its score continues to improve as per the administration's goals.

Administrative Best Practices

<u>Purchasing Policy</u>

Examination of IUB's purchasing policy showed that apart from the recommendation, "All energy consuming products, appliances and equipment purchased by the University shall be Energy Star-qualified whenever possible or practical," in policy No: P - 19.0 *Procurement of*

Appliances and Electronics, the current formal purchasing policy does not contain other references to sustainable or environmentally friendly technology purchasing.[24]

Along with the other seven CSRC universities, IUB answered "Yes" to the question, "Does your school have a formal green purchasing policy?" but did not indicate that it either encouraged or recommended this green purchasing in the object categories of Appliances, Computers / Electronics, or Lighting (which we determined as being most relevant to our sustainable technology focus). However, we must take this lack of information with a grain of salt since we can clearly see from No: P-19.0 that the policy *does* technically encourage the purchase of more environmentally friendly technology and, as we see in the Energy Star and EPEAT sections below, a sizeable percentage of technology purchases are in some way already being influenced by energy efficiency concerns.

Best practices in the area of purchasing policy are by far represented by Arizona State University-Tempe (ASUT) which has developed its green purchasing policy based on concern for both environmental and social justice. The section devoted to energy reduction, which is therefore specifically applicable to sustainable computing and IT, is as follows:

1. All electrical products shall meet EPA Energy Star certification when available and practicable. When products with this certification are not available, products in the upper 25 percent of energy efficiency as designated by the Federal Energy Management Program shall be used.
2. All desktop computers, notebooks, and monitors purchased must meet all EPEAT environmental criteria designated as "gold" as contained in the IEEE 1680 Standard for the Environmental Assessment of Personal Computer Products.
3. Copiers and printers purchased shall be compatible with the use of recycled content and remanufactured products.
4. When acquiring vehicles, the university shall purchase/lease less polluting alternatives to diesel, such as compressed natural gas, biobased fuels, hybrids, electric batteries, and fuel cells, as available and suitable for the use intended.
5. When acquiring or replacing inefficient interior or exterior lighting, energy efficient equipment shall be purchased. (University Policy Manuals Group, 2007)

- *Energy Star products*
    Though, as we have seen, IUB's purchasing policy clearly does not mandate green technology purchasing, the CSRC report does note that the school *has* recently made Energy Star-certified purchases. For Energy Star, the categories of Appliances, Computers/Electronics, Heating and Cooling, and Lighting and Fans were determined to be the most relevant to the sustainable IT topic. IUB reports that purchases have been made (percentages unreported) in all of those categories except for Lighting and Fans.

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[24] Apart from policy No:P – 10.0 which is about protection of old growth forests by avoiding furniture wood and paper products made from the trees of those forests.

Best practices in use of Energy Star products are represented by the University of Arizona-Tempe and Princeton which each reported that 100 percent of their campuses' recently purchased Appliances, Heating and Cooling mechanisms, Lighting and Fans, and Computers/Electronics (including desktop computers, laptops, monitors, printers, etc.) were Energy Star-certified. At both campuses these numbers are very likely to be correlated to their thorough and detailed green building codes, which are discussed below.

- *EPEAT-certified products[25]*
In the case of computers and other electronics, Oberlin and Cornell joined Princeton and ASUT in claiming that 100 percent of recent Computer/Electronics purchases were EPEAT-certified. IUB reported that only 80.35 percent of its computers were EPEAT-certified (percentage not given for miscellaneous electronics) though this percentage is expected to rise because of industry trends toward creation of more sustainable products, the vendor contract renegotiations discussed below, and IUB's commitment toward environmentally friendly building policies.

Encouraging Sustainable Behavioral Change: University Employee Outreach

Once again, the University of Arizona-Tempe is at the forefront of encouraging sustainable behavior change among faculty and departments as well as staff and offices. The CSRC's criteria for determining this were to ask the universities to report on (1) the existence of sustainability liaisons for the academic departments, (2) whether green office tips were posted online or on office bulletin boards, (3) if green office certification programs existed, (4) whether sustainability issues were addressed in new employee orientation, and (5) if the school were running any other program aimed at this goal.

While Arizona is five for five in meeting these criteria, IUB is the only school of the remaining seven to go four for five – failing only to address sustainability issues in new employee orientation. IUB was the only campus apart from ASUT to offer a green office certification program and was given credit for its Campus Energy Challenge in the "Other" category. An additional noteworthy best practice in the "Other" category came from Brown where a monthly environmental tip is e-mailed to faculty and staff through their Department of Facilities Management. The California Institute of Technology does not have an office certification program but maintains a "Green Office Checklist" page at its procurement site. The most intriguing entry in the "Other" category comes again from Arizona which claims that, at ASUT, the sustainability of departments and offices is a factor on which staff and administrators are graded during their annual performance evaluations. In the administrative recommendation section, we discuss how we believe this information can be used to helpfully address IUB's weakest point in this area which is failing to ingrain the idea of sustainability in employee culture from the start of their employment.

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[25] **Note**: As of 2010, a product which is EPEAT-certified is also Energy Star-certified at the same level. Should the Energy Star standards rise, the EPEAT technology has six months to rise to the same standard (EPEAT, 2010).

Administrative Recommendations

The first step toward increasing the role of sustainability in employee culture at IUB is to increase visibility and awareness of the existing sustainable behavior initiatives and opportunities available to employees. To accomplish this, we have created three complementary recommendations that could be viewed as a three part strategy or pursued independently. Though they are mutually supportive, implementation of one is not dependent on success or conclusion of the others. Each is based in use of and aimed at increasing awareness of sustainable information technology use at Indiana University.

Redesigning the Green Teams Information Site

We were very excited to find that ASUT and IUB were the only campuses of the eight in our sample that offered green office certification programs. To promote and highlight this laudable initiative, we recommend re-wording of the "Green Teams" link on the IUOS homepage's "Quick Links" box so that it somehow includes the words: employee, office/departmental, or faculty/staff. Though obviously the Green Teams are the basic units which make up the certification program, the majority of the IUOS's home page is student-focused and a link which simply says "Green Teams" does not obviously signal to the seeker that this is the place to go for non-student oriented sustainable activity.[26]

We would also recommend a minor redesign and simplification of the official Green Team page so that the information can be more quickly and easily understood. The logo and the quote (if desired) should stay near the top of the page, but we believe a series of expandable bullet points or a wiki-style table at the top of the page with links to information further *down* the page would more effectively present information and engage the viewer on a page where frame-imposed width restrictions force the content several "scrolls" downward. Example formatting follows:

- What is a Green Team?
  - ▼ expand to existing page's opening paragraph
- How is a Green Team formed?
  - ▼ expand to existing page's path diagram
- Does my office or department already have a Green Team?
  - ▼ expand to existing page's table*
- Why isn't my office listed?: Starting a new team
  - ▼ expand to existing page's text and link to New Green Team Guide.
- Where can I learn more about existing Green Teams?
  - ▼ Link to the newly-created Green Teams blog

* We would also recommend doing away with the "Green Team Members List" page here: http://www.indiana.edu/~sustain/Green_Teams/green_teams_dynamic.html. As

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[26] Despite what we would characterize as average familiarity with the IUOS's Website, some members of the Best Practices committee was unaware that this program was taking place until informed of it by the CSRC.

none of Teams have yet created individual Websites the only new information presented on this page is the occasional additional team member, names which could easily be added to the existing table if deemed necessary.

Following these clarifications, we would recommend the IUOS release a statement about office certification through IUB-issued newsletters highlighting the offices and departments which have achieved high levels of sustainability. Securing a spot on the IUB.edu homepage would be ideal. It is hoped that by drawing increased attention to the program via the easy-to-navigate Green Teams site more offices and departments will be inspired to join, leading to a fundamental restructuring as the practical and reputational benefits of greening their workspaces are realized and rewarded. It is also hoped that this expansion of implementation might provide IUOS with more leverage to pursue the second recommendation (below).

<u>Pushing for Sustainability Scores in High-Level Performance Reviews to Create Sustainability Emphasis at Ground Level</u>

If a campus-wide renewed interest in greening office space is sparked, it would become logical to follow this up by work with Human Resources to include mention of sustainability efforts during employee orientation sessions. Unfortunately (for human services but happily for the environment!), employee orientation at IUB consists of nothing more than an e-mail sent to the new employee which contains information on their benefits packages. As this "e-orientation" has been an HR goal for years, there are currently no plans to change the process into anything more involved (Borne, 2011). Though IUB may have to write off those points as lost on its report card, it is possible that there may yet be opportunities to influence individual departments' movements toward sustainable practices that would "catch" these new employees at the start of their working relationship at the university.

Instantly instituting sustainability scoring in all high-level (Associate Vice President / Dean upward) performance reviews would be ideal, but is not likely to be practically within the grasp of the IUOS until the president can be persuaded to make an explicit, personal commitment to the sustainability movement (for example, by signing American College & University Presidents' Climate Commitment or the Talloires Declaration). Continuing with their practice of decentralization, as of 2011 IUB does not have a single standard employee performance review form and each department or office decides which measures they will use to evaluate employees (IU Human Resource Services, 2005). Annual performance reviews between the vice presidents, deans, and the university president obviously do not take the same form as performance reviews at the lower levels, but if the promotion of IUB's green office certification receives positive media attention, gains popularity as an on-campus movement, and there is acknowledgment of the progressive work of the staff and their engagement with their workplace, administrators should proudly be reporting this to the higher authorities who should then have a vested interest in their continuing to pursue these efforts. In this way, green office certification program promotion may be the foothold to formally incorporating sustainability in reviews of administrator performance and thereby ingraining sustainability mindfulness among new employees.

Formalizing a Sustainable IT Purchasing Policy

This recommendation would be well supported by implementation of the first two but could also be pursued independently. The Office of Procurement Services, through which the purchasing policy is constructed, acknowledges that, "it is time that Indiana University, as a leading institute of higher education, move[s] towards sustainability" (IU Office of Procurement Services, n.d.) but, as noted above, enforces no formal standards or requirements within the policy itself. According to the information recorded in the STARS report, IUB has commendably recently renegotiated the terms of its contracts with Dell and Hewlett-Packard to ensure that the computer "bundles" that are offered to the university, "meet or exceed industry standards in efficiency such as Energy Star 4 or EPEAT Gold" (AASHE-STARS, 2010[1]). However, these standards do not apply to all smaller-scale purchases made from individual departments for electronics or appliances.

As we can see by the efforts made to renegotiate contracts and the reporting of Energy Star and EPEAT purchases, the groundwork for standardizing a sustainable technology purchasing policy has been laid. The choice to continue purchasing more sustainable computing and electronic equipment will only become more of a given as IUB continues to expand and renovate its facilities, since it has committed to building these new additions to LEED Silver specifications. To begin to scout out what would be involved in formalizing these existing efforts into a sustainable technology purchasing plan commensurate with the best practices seen at Princeton, ASUT, and Oberlin, we recommend a conversation be initiated with the Associate Vice President for Procurement, Jill Schunk, as the policy-setter for the purchasing policy. Reaching out to the following specific contract managers for input would also be advisable:

> Tom Ellis (Appliances)
> Nathan R. Smith (Computer Hardware & Peripherals)
> Karen Coopersmith (Office Equipment, Copier Equipment & Supplies)
> Michelle Duggar (Telecommunications Infrastructure)

Energy Efficiency Best Practices

Encouraging Energy Efficient Practices/Energy Use Reduction in the Campus Community

The CSRC questions in the energy efficiency category which were judged most likely to be amenable to sustainable technology improvements had to do with (1) the percentage of possible campus building spaces in which specific energy-saving technologies had been implemented, and (2) specific programs to encourage the campus community members to reduce their energy usage. Though IUB reported that a number of energy-saving technologies were indeed in use on campus, the percentages were not reported. This limits our ability to draw detailed conclusions about the pervasiveness of this technology. However, we can be somewhat more certain of the information provided for the programs encouraging reduction of energy usage aimed at the campus community.

Energy-Efficient Technologies

As with most questions that requested percentages, the ability of universities to be thorough in their reporting for this section was varied.   (The University of Arizona-Tempe was the only other school not to report percentages, however we feel it safe to assume that based on their building codes and overall scores in the areas of physical infrastructure the percentage of their campus buildings which utilize energy-efficient technologies is quite high.) The technologies which IUB did *not* report utilizing were: LED lighting, timers for temperature control, and vending machine sensors.

In Table 2 below, we record how many (out of the eight) schools reported use of each of the sustainable technologies for which CSRC requested information, and the best practices columns display the highest recorded percentages (based on the schools that provided percentages):

Table 2. Technology breakdown by school

8 of 8	Best Practices	7 of 8	Best Practices	6 of 8	Best Practices
Energy management systems (e.g., automation or energy info. systems) integrated into campus buildings	CIT 100% Cornell 95% Brown 80% UWM 80%	Metering - chilled water	CIT 100% Cornell 100%	Timers for temp. control	Cornell 90% Brown 75%
				LED lighting	Oberlin 10%
Heat recovery systems	CIT 80%	Metering - steam	CIT 100% Cornell 100%	**3 of 8**	**Best Practices**
Lighting sensors	Brown 90%	Variable speed drives (reduce energy flow to machines not in use)	UWM 100% Cornell 95%	Vending machine sensors	Princeton 100% UWM 80%
Metering - electric	All 100%				
Other energy-efficient lighting	UWM 95% Oberlin 90+% Brown 90% Cornell 90%				

As we can see, energy management systems, heat recovery systems, lighting sensors, electricity metering, and use of (non-LED) energy efficient lighting were best practices common to all eight campuses.

Schools were given the option of "other" to report energy-saving technologies not mentioned by the CSRC. Some of the interesting ideas mentioned in this category follow: ASUT reported that

its buildings were cooled to no lower than 78°[27] and heated to no more than 68°, Cornell and Princeton both reported implementation of occupancy sensor-based laboratory air ventilation controls, and CIT has begun re-roofing some of its buildings with reflective materials to prevent excess heat from being absorbed and increasing demand on their cooling systems.

Energy Use Reduction Programs Aimed at the Campus Community

The six types of energy use reduction programs which could be related to information technology for which the CSRC requested information were (1) audits or investigations of individual energy use, (2) permanent energy monitoring sites or dashboard displays for buildings, (3) energy reduction competitions among departments and/or offices, (4) green IT policies, (5) PR campaigns (newsletters, signage, pledge drives, etc.), and (6) trade-in or rebate programs for inefficient appliances. Here too, there was an "other" category where schools could report programs they had created with the intention of serving the same purpose.

Though not one of the eight universities in our sample could report that they had done all six of the programs, the California Institute of Technology, Cornell, and Brown[28] reported that they engaged in five (CIT and Cornell left out the trade-in/rebate for inefficient appliances program). Brown's score is set to rise even higher next year since its EcoReps team "field-tested" an energy competition model on some of their dorms in spring of 2010 with an eye toward campus-wide implementation.   Princeton, UWM, and Oberlin could all claim four of six programs leaving IUB and ASUT as the only two schools to only have completed three of six.

Interestingly, the two programs which were common to all schools were related to greening IT and PR campaigns. Showing up as another clear sector best practice was the use of energy dashboards. Five of the eight schools[29] made significant use of energy dashboards: Brown and Oberlin using the services of BuildingDashboard.Net, CIT partnering with the California-based Phoenix Energy Technologies, and ASUT utilizing an in-house creation called "Campus Metabolism." (Though Princeton reported that it utilized energy dashboards on its campus, as of April 2011 it currently has only one [unnamed] monitoring system in place for its newly built chemistry building. Their sustainability report claims that they plan to expand implementation to a sustainable living-focused dorm complex [Princeton University Reports, 2010].)

The two schools that elaborated on the other programs they reported were Brown and Princeton. Brown emphasized its priority on communication by reiterating its daily e-newsletter, its weekly student-run newsletter, and its "Green Schools" discussion list which focuses on campus sustainability issues for those "working on institutional change" (AASHE, 2010). Taking these

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[27] The ASUT Division of Facilities Development and Management claims buildings are cooled to no lower than 80°.

[28] At the time of their survey submission to CSRC in July of 2010, Brown did not report usage of a dashboard, however, they partnered with BuildingDashboard.Net in Nov. 2010 to begin monitoring the campus.

[29] The University of Wisconsin-Madison does not currently employ a dashboard, but its satellite campus in Milwaukee uses BuildingDashboard.Net.

efforts into consideration alongside their monthly e-tip for faculty and staff, we commend Brown's proactive approach to communication and information resource provision to its community.   The various projects undertaken by Princeton's EcoReps and EnergyCorps programs seem comparable to the ones in place at IUB being manned by IUB's Sustainability Advisory Board, student interns, and Green Teams. Information on their "Sustainability Ambassador" program appears to be still in development.

Energy Efficiency Recommendations

As far as IUB's implementation of energy-efficient technology on its campus buildings goes, again we expect to see the different types used rise and the percentages become more easily estimable in the next ten years. We feel this is especially probable because the use of technologies *like* timers for temperature control, LED lighting, etc. are compatible with several prerequisites for LEED certification and credits toward the LEED Silver certification (U.S. Green Building Council, 2008) which IUB's building/renovation policy pledges to pursue.

We must also bear in mind that our small sample size was chosen to allow us to easily compare and contrast IUB's CSRC position among A-rated institutions and therefore may not necessarily provide us with an accurate determination of whether or not a particular technology is a worthwhile investment in terms of energy conservation and sustainability. The low count of a particular energy-efficient technology such as vending machine sensors in our eight school sample does not mean the sensors' impact is insignificant. Case studies of the Energy Star "Vending Miser" sensors have shown that installation of one sensor on one machine is able to reduce a university's CO_2 emissions by 1.12 tons and provide electricity savings of $200-$300 (Priebe, 2009).

Regarding recommendations for the energy reduction outreach programs, we must note that IUB is well on its way to shoring up these numbers.[30] Within the body of this report, the feasibility of dashboard implementation is being considered (see Sustainability in IT section, p. 120) and taking into consideration the programs that Princeton listed as "Other," IUB would be justified in including information about its Green Teams program. We very much admire the specialized communications outreach Brown does through its e-mail tips for employees, newsletters for the entire community, and discussion lists for its entire campus community and believe that our previously mentioned recommendations for improved communication re: sustainability issues between IUB and its employees are also applicable to this section of the report.

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[30] Note: Though it is one of the programs in which IUB did not participate, we would not advise focusing too heavily on the "Trade-in or Rebate Programs for Inefficient Appliances" category. It will be interesting to see if it is cut from the next CSRC program list since it appears that as of mid-2010, the stimulus money from AARA which had funded most of the state programs had been exhausted and as of early April, 2011 all but sixteen programs (including waitlists) had been closed (U.S. Department of Energy, 2011).

Green Building Best Practices

Green Building Policies

In this category, we found a high degree of synchronicity existed among the schools.   Most of their differences were in the number of existing buildings which meet LEED criteria or have been LEED-certified. At one end of the spectrum was IUB which was the only school of the eight which does not yet report having any certified/eligible buildings[31] and at the other was ASUT which has a total of thirty-two certified/two eligible.

Each of the eight report green building practices mandated in their formal building codes and seven of eight require all new construction or major renovations to meet LEED Silver standards (the outlier is CIT which has a goal of LEED Gold).

Though operating off of LEED Silver as a base, some of the universities' policies incorporate environmental considerations above and beyond this standard. For example, ASUT's is committed to having each new building or renovation receive at least 10 percent of its energy from the sun, wind, or an otherwise renewable source. Cornell's building policy includes the requirement that new projects achieve 30 (ideally 50) percent reductions in energy usage compared to an ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) baseline energy model for building types. Brown has taken Rhode Island's GHGE (Green House Gas Emissions) legislation as a guide and requires that new projects come in between 25-50 percent (depending on building type and purpose) below those limits.

Princeton has mandated that each new project be at least 50 percent more energy efficient than comparable off-campus buildings. It has also created one of the most unique ideas we found in our survey which was the application of an internal "CO_2 tax" to each building based on an emission calculation to encourage every attempt at energy efficiency.

Water Conservation Technologies

The CSRC requested information on the existence and percentages of campuses' buildings which included water metering, laundry-related technologies, leak detection and reduction, and also asked if weather-informed irrigation was taking place.

As before, reporting of percentages was hit-and-miss with these universities, but except for UWT and ASUT, all campuses reported building water metering – Cornell and Oberlin were tied for first place with 100%, Princeton in second with 90 percent, and IUB came in third with 33 percent (CIT did not report a percentage). Six of eight universities claimed weather-informed irrigation practices were in place with innovative, desert-bound ASUT reporting on its use of a graywater recycling and condensate-capturing system for outdoor landscaping.   Green laundry technologies were the third most popular water-conserving mechanism with five of eight

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[31] See the Data Center section (p.58) for discussion of getting Energy Star certification for IUB's Data Center.

universities replying in the affirmative. (Different interpretations of the intention of "percentage" make the percentages especially problematic for this category.)

The single specific water conservation technology that IUB (somewhat confusingly) chose to leave blank despite its "Leak Line" sticker campaign was "Leak Detection and Reduction." Fortunately, within the context of this report, a study of an innovative image-capture leak-detecting technology called "QR Codes" is being examined in depth.

Green Building Recommendations

We are happy to report that the sustainable technology solutions we see as being most applicable to improving IUB's green building score and raising it toward sector best practices are currently under review.

IUB's commitment to its green building policy of LEED Silver standards for all new projects will enforce its own restrictions on energy-inefficient technologies. (It is here again that we see the harmony with which this mandate could pair with a formalized green technology purchasing policy.) A dashboard system, as mentioned in the energy-efficiency section of the summary, which was designed to monitor a building's energy usage would also go hand-in-hand with implementation of these technologies.

Obviously IUB has made a good start in implementing water conservation technologies. Based on sector best practices as represented by our sample, we would recommend attempts be made to raise the percentage of buildings with water metering (from current 33%) and those which use green laundry technology (from current 1 percent). Energy Star makes an "intelligent" front-loading machine which can sense the size of the load and match it to the water needed. For our recommendations on using IT to improve leak detection and reduction, please see pages 122-23 for discussion of the implementation of QR codes.

Recycling Best Practices

Electronics Recycling Programs

The primary category in the recycling section of the reports that was most obviously related to technology and sustainability was the electronics recycling program.

The CSRC simply asked whether schools provided recycling opportunities for six types of item: batteries, cell phones, computers, light bulbs, printer cartridges, and "other e-waste." It also asked schools to confirm whether these opportunities were available for institution waste in addition to student waste.

Using this metric, best practices in the area of electronics recycling were represented by the California Institute of Technology and Arizona State University-Tempe. Both of these institutions offered recycling opportunities for each item for both their student and employee populations. Cornell offered recycling opportunities of every type of item to both populations,

except for the "other e-waste" option which was not available to students; Brown offered all types of recycling to both populations except in the case of student computers; and Oberlin offered opportunities for the first five specific item types to both populations but did not provide "other e-waste" recycling to either. Though IUB reported that it promoted and provided recycling opportunities for all of the specific types of electronics (including ways to discard "other e-waste" during the E-Waste Days program) to its *student population*, it was strikingly the only university of the eight to make none of the programs (beyond E-Waste Days) available to its employees.

Recycling Recommendations

Electronics Recycling Programs

With IUB's report of *no* electronics recycling programs in place to reach their employee population, it is easy to see where there is room for improvement. To achieve the standards set by best practices in the sector, swift action is needed to make recycling opportunities available to the non-student population. Fortunately, this is yet another problem being tackled by the sustainable information technology capstone group. For detailed information on the e-waste plan and findings, please see the E-Waste Group section of the report.

Academic Sector Conclusion

Though IUB is obviously not yet "the best it can be" regarding ratings in the STARS and CSRC systems, we were pleased and encouraged by the results of research and comparisons to higher-rated universities. The best practices identified in STARS were common to both systems – a fact which serves to emphasize the importance of IUB's implementation of a formal sustainable purchasing plan for computers and electronics and improved recycling options for e-waste. It is our impression that due to LEED requirements, the university's green building and renovations mandate by itself would naturally do much to improve the scores related to energy efficiency, but merely sitting by and waiting for this to happen is obviously not a best practice. Our observations of the high usage of dashboards, water conservation technologies, and other energy efficient practices lead us to recommend efforts at implementation for IUB. Underlying all these technological recommendations is the realization that ultimately the most important purpose for which we will use this sustainable technology is to change is the way people think. Continuing to promote use of virtual workspaces like Oncourse, changing of printing settings from simplex to duplex, promotion of the green office certification program – these are all aimed at not just reducing IUB's carbon footprint, but at causing a fundamental shift in the collective campus consciousness.

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General Conclusions

When looking at this project as a whole, there were some overarching themes which were consistently observed no matter which sustainable initiative we were examining. We believe that these must be taken in consideration with our recommendations, and will spur discussion about how to go about implementing them.

One consistent problem seems to be a lack of communication between departments, in a complex organizational system. One challenge is to get correct information and policies which are already in place to the persons who need to be implementing them. This does not seem to be due to a lack of technology to deliver communications, but an organizational structure through which to disseminate information.

We also have noted disconnect between the sustainable computing policies of the University and the official purchasing plan. While the current purchasing plan mentions the importance of sustainability, there are not standards or requirements for computers or electronics within the policy itself. If we put consideration and effort into the things we are buying and the way the University spends the considerable sum it does on technology we can make a bigger impact than most other initiatives combined.

We also see that most persons involved with this study seem to be more concerned with financial incentives than sustainable ones. Though not preferable, it may be the largest motivator for departments. This, of course, leads us to the energy billing problem. Since departments are not directly responsible for their energy bills, there is little incentive to implement measures to reduce energy. We know that there are efforts to correct this, but feel the need to emphasize that it is of utmost importance.

We would also like to stress that the solutions to most of these issues fall on the back of the IT managers. Introducing all of these initiatives to IT managers at once could be overwhelming. We would suggest the Sustainable Computing Group take a leadership role in prioritizing these initiatives, perhaps reaching for the lowest hanging fruit first. These priorities may be university-wide, or may vary from department to department.

Finally, we are encouraged by the attitude and initiative of many of the staff we collaborated with. We were, on the whole, granted access and given time by very busy individuals. We believe that with effort and coordination this institution can continue to improve its computing sustainability and become a model for other campuses.