Inventorying Plug Load Equipment and Assessing Plug Load Reduction Solutions on a University Campus

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ABSTRACT

The percent of energy consumed by plug load equipment in commercial buildings is on the rise. Research conducted in the past has included surveying plug load equipment, measuring plug load electricity consumption and equipment operating patterns, and studying plug load reduction solutions in office buildings, but plug load energy use across other building types is poorly understood. A university campus, which houses many building types, presents a unique opportunity to understand plug load profiles across building types. In this study, an equipment inventory was performed in 220 buildings on Stanford University's campus, totaling 8,901,911 square feet of building space and encompassing lab buildings, office buildings, recreation facilities, public space, and service buildings. Within these buildings, 110,529 pieces of plug load equipment were recorded. Energy consumption estimates were developed from published values and used to evaluate the aggregate plug load energy consumption of this equipment by equipment type and by building type. In total, it is estimated that the plug loads from these buildings consume nearly 50 million kWh per year and comprise 32% of the electricity consumption of the buildings surveyed. Energy consumption and savings estimates were also used to analyze effective savings opportunities based on the equipment data gathered. These opportunities, while not yet field-tested, can be used to better target energy conservation efforts throughout multiple sectors.

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1. Introduction

Equipment with non-traditional end uses in commercial buildings in the United States consumed over 7 quadrillion Btu in 2012, and the energy intensity of these miscellaneous loads is expected to increase by 21.4% by 2040 [1]. One reason for this projected increase is that current energy efficiency standards do not cover the majority of this miscellaneous equipment, as they do for equipment with traditional end uses such as lighting and space heating. As heating, ventilation and air conditioning (HVAC) and lighting systems become more efficient, the amount of energy that goes towards these traditional end uses decreases as a percent of total building energy consumption, creating a simultaneous rise in the percentage of electricity that is used by other miscellaneous equipment, hereafter deemed "plug loads" in this paper. Moreover, the increased market penetration of electronic products combined with the increased requirement for new electronic products that aid worker productivity in commercial buildings ensures that the electricity consumed by plug loads will continue to increase [2]. It will be important to address this growing area of electricity consumption to support climate change mitigation, grid stability, and energy security, among other environmental concerns.

Several previous studies have illustrated the energy consumed by plug loads in commercial office buildings. Equipment stock figures were used to estimate that office and network equipment consumes approximately 74 terawatt hours (TWh) per year in the US, or about 2% of total domestic energy consumption [3]. Stock figures were also used to show that the US EPA's Energy Star program had saved about 867 TWh of primary energy through 2006 through office equipment efficiency improvements, with projections to save an additional 1,652 TWh through 2015 [4].

Other studies have estimated the energy consumed by plug loads in commercial office buildings by conducting surveys of select office spaces. Plug loads have been shown to consume 20% of the electricity used in office buildings in California [2]. Due to the metering conducted in studies like this, solutions for reducing plug load energy consumption have also been evaluated. Plug load reduction strategies in one office building resulted in a 47% reduction in associated electricity consumption [5]. Transitioning to energy efficient products has also been identified as a successful energy-saving solution in office buildings [6]. Finally, the savings that can be attributed to "smart" power strips was illustrated in a separate study, with occupancy-sensing power strips saving an average of 134 kWh per strip per year and load-sensing power strips saving 163 kWh per strip per year. Interestingly, because these two types of power strips were tested in two different settings, their savings per device controlled varied significantly from the average savings per strip, at 49.8 kWh per device controlled per year for occupancy-sensing strips and 85.4 kWh per device controlled per year for load-sensing strips [7]. These findings manifest one example of how plug loads and the effectiveness of plug load reduction strategies can vary significantly even within the same type of space.

Fewer studies have evaluated the plug load energy consumption of other building types. When one healthcare facility was surveyed, plug loads comprised 19% of its total energy consumption. The same study also evaluated education buildings and large office buildings and estimated that these loads comprised 18% and 11% of the energy consumed at these sites, respectively [8].

Variability in the density of plug load equipment has been shown to be high, even across buildings of the same type and size [7]. Furthermore, sample sizes have ranged from a single building to 47 sites, but even the larger sample sizes have not been statistically valid enough to represent equipment densities and energy consumption at a state or national level [2]. Despite this, large data sets of miscellaneous equipment have been valuable in understanding the accuracy of sampling; however, the increasing availability of electronic products along with rapid technology improvements creates a constantly changing picture of plug load energy consumption [9]. Because of this, on the campus of a research institution, which naturally houses numerous building types and varieties of equipment, a thorough understanding of plug load equipment could only be gained through the completion of a comprehensive equipment inventory. While Stanford University's equipment inventory is not necessarily representative of that of other commercial buildings, it is the largest inventory conducted to date to our knowledge, and it can shed light on the types of equipment and associated energy consumption that can be found not only in buildings on other college campuses, but also across office buildings, healthcare facilities, and other sectors. Moreover, the findings of this study can inform design for new construction, preventing design teams from overestimating plug loads and, in turn, oversizing cooling systems.

1.1 Study Overview

The purpose of this study was to quantify plug load energy consumption on the campus of a research institution and to analyze the effectiveness of various plug load reduction methods. While Stanford University, like many other entities, has a well-developed understanding of the electricity that goes to traditional end uses, such as hardwired lighting and HVAC systems in its buildings, plug loads manifested the missing piece of the electricity puzzle.

In 2014, Stanford University's data showed that 21% of campus electricity consumption went to hard-wired lighting, 14% went to fans, and 3% went to HVAC pumps. It is important to note that Stanford's campus has central chilled water, so the lack of an on-site chiller keeps HVAC electricity usage low. Thus, a total of 76% of building electricity consumption can be attributed to lab loads, IT loads, office equipment loads, refrigeration loads, and miscellaneous loads, but the breakdown of this electricity could only be estimated by multiplying the square footage of each space type on campus with the estimated energy use intensity of that space type. A comprehensive plug load equipment inventory was therefore designed to better understand the breakdown of electricity consumption on Stanford's campus.

In this paper, plug loads are defined as electricity being drawn from any piece of equipment that is plugged into an outlet, with 55 specific types of equipment categorized in this study. Previous studies identified a need for a standard plug load taxonomy, which now exists [10]. This study incorporates the majority of equipment within the three categories in the standardized taxonomy (electronics, plug loads within traditional end uses, and miscellaneous loads), which in turn captures the categories utilized in other studies, including office equipment, miscellaneous electric loads (MELs), and information and communication technologies (ICTs), including servers.

In this paper, results and analysis are presented from a comprehensive plug load equipment inventory conducted in summer 2014 throughout 220 buildings, or 8,901,911 square feet of building space across Stanford's campus. The thoroughness of this study allowed Stanford to collect a detailed snapshot of its campus-wide plug load equipment, which has opened the door to identifying underlying trends in equipment densities and energy consumption. Those trends can then be compared across building types both internally and externally to benchmark plug load energy consumption on university campuses and measure variability with other sectors. While this study does not capture measured energy consumption data, it does represent the most thorough inventory of plug load equipment conducted to date, which will lead to informed and data-driven plug load reduction strategies, including subsequent metering studies, that will continue to expand our knowledge of plug load equipment energy consumption and reduction in commercial buildings.

2. Methodology

The protocol developed for this inventory was very precise in order to consistently and efficiently capture equipment data. Trained student interns used a smartphone application to collect inventory data on 55 types of equipment, along with predetermined attributes for each type of equipment. This involved visiting every room in each of the 220 buildings that were inventoried, which often required close coordination with building managers to access locked rooms. As the inventory was conducted, energy consumption for each type of equipment, based on the attributes collected for that equipment type, were heavily researched. The final energy consumption estimates were applied to all 110,529 pieces of equipment recorded in our central database in order to calculate aggregate energy consumption estimates and begin to identify underlying trends.

2.1 Study Scope

The 55 types of equipment included in the inventory were divided into eight overarching categories: Audio/Video, Computers & Monitors, Gym & Training Equipment, Laundry Equipment, Office Occupant Comfort, Printers & Scanners, Kitchen & Breakroom, and Lab Equipment. A table showing the types of equipment recorded by category can be found in Appendix A. Appendix A also includes other common categorizations for each equipment type in order to compare the equipment findings in this study with those of other studies. Additionally, Appendix A shows the attributes associated with each type of equipment. Multiple energy consumption values were developed for each type of equipment based on different equipment attributes, which allowed for the development of the most accurate energy consumption estimates possible for each piece of equipment.

Attributes were predetermined and appeared automatically when a piece of equipment was entered into the smartphone application. Previous studies have shown that when conducting inventories, it is common for the individuals collecting the data to forget to record certain pieces of information unless they are prompted to input that information [9]. The automation of prompts for equipment attributes allowed Stanford to avoid this information loss, resulting in the correct recording of attributes for 98% of the equipment captured in the study. In the remaining instances where attributes were not recorded, it was often because they could not be observed. For example, the attribute associated with the equipment type "Desk Lamp" was "Bulb Type,", and in cases where the actual light bulb could not be seen, the attribute was left blank. As a result, there is a very high level of certainty for all energy consumption estimates for equipment with attributes recorded; for the 2% of equipment without attributes accorded, average energy consumption values were assigned.

Finally, Appendix A also includes the definitions and data collection rules associated with each equipment type, since some of the equipment types in this study differ from the categorizations included in previous studies. For instance, rather than dividing printers into laser printers and inkjet printers, this study instead categorized printers as "personal printers" and "shared printers." The goal of this division was to identify how many individuals on campus are using a printer assigned only to them compared to individuals who use shared printers within their office spaces. This also allowed for the identification of spaces where both shared printers and personal printers were in use. While this approach may have led to slightly less precise energy consumption estimates, it provided valuable information regarding printer usage that will more effectively drive targeted plug load energy reduction strategies on Stanford's campus.

It is important to note that this inventory extends past plug loads when considering the resources required for this full effort. The inventory also captured environmental health and safety hazards—or "red flags"—such as hazardous materials caches, fire hazards, and obstructed egresses, in addition to occupancy counts and water fixture data. The data gathered within these additional categories was then shared with relevant groups for remediation. Occupancy data, however, was used directly in this study for calculation of equipment densities and energy consumption per occupant. Subsequent occupancy calculations presented in this paper are based on the number of desks per building, as recorded during the inventory.

2.2 Site Selection

Stanford's criteria for inclusion in this study were on-campus buildings that are served by Stanford's electric distribution system. A total of 220 buildings, comprising 8,901,911 square feet of building space were fully inventoried. At Stanford, each building is assigned a building type according to Stanford's building classification system. For this study, some of these building types have been combined to better reflect standard commercial building types. Table 1 defines these building types and sizes. Overall, this study included 42 lab buildings, 90 office buildings, 34 classroom buildings, 17 public spaces, 13 recreation facilities, and 24 service facilities.

Table 1: Summary of buildings included in inventory

Building Type	Number of Buildings	Gross Square Feet	Occupancy	Rooms	Stanford Building Types Included
Labs	42	3,258,412	7,593	6,417	High Intensity Lab, Low Intensity Lab, Greenhouse
Offices	90	2,008,637	4,412	5,484	Office, Medical Office, Studio
Classroom	34	1,674,265	3,232	3,053	Classroom
Public Space	17	1,268,616	971	1,432	Auditorium, Commons, Library, Museum
Recreation Facility	13	604,664	317	518	Recreation Facility
Service Facility	24	87,317	120	169	Shops, Service Facility, Environmental Facility, Storage, Miscellaneous

As thoroughness was an important goal for the inventory, priority was placed on accessing locked rooms, attics, basements, data centers, IT closets, and all other space in each building, no matter how easily accessible. Building managers supported this effort and commonly walked around with student interns to unlock rooms. Rooms that could not be accessed were logged by interns as "incomplete." Eighty-nine percent of the rooms within inventoried buildings were successfully completed. Partially due to the inventory taking place on a single campus, and partially due to the emphasis on thorough data collection, this inventory pushed the boundary of typical building surveys, which commonly impose limits based on time, number of floors and rooms, and areas deemed inaccessible, especially data centers. Despite this, Stanford's inventory remained as unobtrusive as possible, which was aided by the smartphone application used for data collection, allowing interns to enter equipment data in each room in a matter of minutes, so as not to disrupt anyone's work for too long.

It is worth noting that full inventories could not be completed in 2 of the 220 buildings included in the study. These two buildings represent 354,418 square feet of building space together and could not be inventoried due to time and scheduling constraints and privacy and security issues within these two buildings. It was decided that a portion of each building would be inventoried and data extrapolated accordingly. For both buildings, a number of representative rooms were surveyed, and data was extrapolated based on the total number of offices, wet labs, dry labs, and kitchen & break rooms in each building. The extrapolated rooms were counted as complete, and therefore do not factor in to the number of incomplete rooms. The extrapolated equipment data is included in all calculations in this paper.

The inventory spanned 60% of Stanford's campus. Twenty-six percent of the campus is student and faculty residences, which comprise 4,516,800 square feet of building space. These spaces were excluded for privacy reasons and because the inventory occurred over the summer when the equipment recorded in student residences would not have been representative of the equipment in those locations for the majority of the year. Also, since student populations are transient on a university campus, residential data would not necessarily have remained accurate. Based on this approach, this study ultimately lends itself to primarily informing the commercial building sector, rather than residential.

The remaining 14% of building space on campus that was not inventoried included buildings under construction or temporarily vacant, patient care buildings, and buildings not served by Stanford Utilities. The two buildings that house the campus data centers (approximately 52,397 square feet) were also not included due to security concerns.

2.3 Site Surveys

A total of twelve student interns conducted the equipment inventory over the course of 5 months between April and September of 2014. In total, interns worked approximately 2,760 hours, with approximately an additional 300 hours of staff time during those 5 months devoted to scheduling the inventory in each building, coordinating with building managers, and training and advising interns. Time spent facilitating the inventory by building managers themselves is not included in this estimate and varied significantly by building.

To ensure consistency in data entry, a well-developed data collection protocol was presented to interns during training sessions, which were supplemented by a thorough training guide that interns could carry with them to refer to when questions arose. The training guide contained pictures of each type of equipment, including images illustrating the attributes for each equipment type. Special notes were also included in each training guide to clarify anticipated areas of confusion. After training, interns were given a casual quiz to make sure they had learned the rules presented in the guide. Finally, staff periodically performed physical checks of the spaces inventoried by the interns to ensure that mistakes were not being made.

Interns were able to inventory building space at a rate of approximately 3,228 square feet per hour. Of course, this rate increased slightly in less dense buildings, such as public spaces, and decreased in more dense buildings, such as lab buildings. Stanford's Land, Buildings & Real Estate application systems group developed a smartphone application for data collection. The smart phone application combined electronic versions of all of Stanford's building floor plans, uploaded through ArcGIS, with a web form that could be accessed via the ArcGIS smart phone application with an Oracle database backend for each individual room. The web form contained drop-down lists of the equipment categories and equipment types and automatically populated attributes based on the equipment type selected. There was also a section of the web form in which interns could enter notes for each piece of equipment and an option for changing the count of equipment of the same type present in that room. Once each piece of equipment with its relevant attributes was added to the web form for that room, interns could mark the room as complete, which would change the color of the room from red to green on the floor plan within the ArcGIS application, allowing for easy tracking of progress. Equipment data by room was stored in an online database and could be easily downloaded to Microsoft Excel from the Oracle database through the application. This innovative approach to equipment data collection not only allowed for efficiency gains, but it also improved accuracy, data accessibility, and security.

2.4 Data Analysis Methodology

At the conclusion of the inventory, the equipment data was aggregated and analyzed to quantify plug load electricity consumption and determine the most effective electricity reduction opportunities. First, unit energy consumption (UEC) estimates were developed and applied to each piece of equipment based on its attributes. These estimates were calculated based on published data, industry research, and internal measurements and assumptions. Then, all equipment quantities and energy consumption data were aggregated to determine estimated campus-wide and building-level totals, in addition to totals by equipment type. Microsoft Excel pivot tables were a valuable tool in calculating campus-wide and equipment-wide totals, while the Analytics Express software by Microstrategy was primarily used to determine building-level totals and to generate individual building PDF reports for building managers.

To analyze the most effective plug load reduction opportunities, a full list of all potential opportunities was first created. This included everything from installing load-sensing power strips, timers, and occupancy sensors to upgrading each equipment type to energy efficient models (where applicable), to running behavior-based programs. In total, this list included 93 potential opportunities. Then, each opportunity was assigned a rating based on the following twelve factors:

- Volume of equipment addressed
- Ease of installation of upgrade
- Chance of independent upgrade
- External support required
- Cost
- Return on investment (ROI)
- Potential savings
- Occupant satisfaction
- Magnitude of problem addressed
- Confidence level
- Implications to university policy
- Expected persistence

Based on the balance of ratings, the top opportunities were selected, with the addition of a few other highly visible opportunities, to be categorized into overarching program options that would continue to be pursued at Stanford. In total, the 37 selected opportunities were divided into five programs: basic energy efficiency measures, space heater minimization, energy efficiency for IT equipment and laboratory equipment, and procurement strategies. Cost and savings figures for each opportunity were then aggregated at the program level to easily summarize and justify the development of said programs.

2.5 Limitations of Methodology

The advantage of conducting this study on a university campus was that some centralized oversight of buildings does exist, which facilitated the process of conducting a large-scale, 220-building inventory of 55 equipment types. Of course, there are many additional types of plug loads above and beyond the 55 equipment types captured in this study, so one key limitation of this study is that not all plug loads were captured through the inventory process. This was especially true in labs where specialized equipment is prevalent. Thus, the plug loads discussed in this paper do not necessarily represent the entirety of equipment in the 220 buildings that were inventoried. Furthermore, because many buildings, such as student residences, were also not inventoried, the plug loads discussed in this paper also do not fully represent Stanford University's complete plug load profile.

Also, because the scope of the inventory was so large, and because having a thorough set of equipment data was a priority, metering plug load equipment was not feasible during this study. On the other hand, metering will be conducted as part of subsequent field testing of plug load reduction opportunities, allowing metering to be focused on the equipment for which the data will be most valuable. The results of Stanford's plug load opportunity analysis will be combined with data from previous studies on appropriate sample sizes, sampling intervals, and duration of metering to conduct metering studies with relatively minimal resources and high return [9].

Human error has also been shown to factor into building surveys [8]. While interns underwent a rigorous training process, there remains a high likelihood that some equipment data was recorded incorrectly. For instance, one common mistake that was noted during staff checks of equipment data was that covered compact fluorescent light bulbs were often recorded as incandescent light bulbs. However, any human errors that could have been made during the data entry process itself were likely minimized due to use of the smartphone application.

It is also important to note that this inventory represents a single snapshot of the equipment on Stanford's campus, and this snapshot was taken during the summer months when some buildings may not have been functioning as they would throughout the rest of the year. Thus, any seasonal variations were not captured, although one previous study found that seasonal variation in equipment densities was not significant [7]. Follow-up surveys would help Stanford identify trends in equipment procurement and removal over time, which could be valuable data on a university campus where much of the population is transient, especially if future surveys were to include student plug loads.

Finally, by nature of using energy consumption and savings estimates for each piece of equipment and associated savings opportunities, there will be error in the energy consumption and savings values used in this study. This error compounds across each unit of each type of equipment, so the most prevalent types of equipment on campus are also likely to have the highest potential for error when considering the total energy consumption (TEC) of that equipment type. Ultimately, the value of this inventory is the thoroughness of the study scope and building surveys, which allowed Stanford to identify clear trends in both equipment densities and energy consumption campus-wide and by building type; many of these trends are not predicated upon the utmost precision in energy consumption and savings values.

3. Results and Discussion

The results of this study were first aggregated by equipment type and category to determine Stanford's exact plug load profile and identify underlying trends. Then, savings opportunities were analyzed and prioritized. The results of these efforts are presented below, including detailed results of the survey itself, in addition to a summary of the potential savings identified and descriptions of savings opportunities.

3.1 Survey Results

The results of this survey are presented below at the equipment level and at the building level. At the equipment level, both equipment density and estimated energy consumption are summarized by equipment category, with discussion of the key equipment types that factor into each category. At the building level, results are presented by type of building in order to highlight underlying trends within and across building types to demonstrate the relevance of this inventory to various sectors.

3.1.1 Equipment Density

In total, Stanford collected 132,964 data points during this inventory, 110,529 of which pertained to plug load equipment. The other 22,435 data points pertained to "red flags," water fixtures, and occupancy counts. Based on the gross square footage of building space inventoried and the building occupancy numbers collected during the inventory, this study found that Stanford has an overall plug load equipment density of 12.4 pieces of equipment per 1,000 square feet and 6.6 pieces of equipment per building occupant, excluding pieces of equipment that did not fall into the 55 types of equipment that were inventoried. Table 2 summarizes the quantities and densities of equipment within these 55 equipment types on campus by category. This information can be found at a granular level for each type of equipment in Appendix B, which also captures energy consumption and savings by equipment type, discussed in section 3.1.2.

Stanford's results for number of devices per occupant remain fairly consistent with the data from previous studies. One such study that included small, medium, and large offices, healthcare facilities, and education facilities found an average of 8.9 devices per occupant [8]. Another study that looked exclusively at commercial office buildings of different sizes found average equipment density to be seven devices per occupant [2].

Table 2: Equipment quantity and density by category

Equipment Type	Total Quantity	Percent of Total	Density (units/ 1,000 ft^2)	Density (units/ occupant)	Density (units/ room)
Computers and Monitors	48,112	44%	5.40	2.89	2.82
Audio/Video	17,170	16%	1.93	1.03	1.01
Office Occupant Comfort	16,534	15%	1.86	0.99	0.97
Lab Equipment	15,123	14%	1.70	0.91	0.89
Printers and Scanners	7,192	7%	0.81	0.43	0.42
Kitchen and Breakroom	6,089	6%	0.68	0.37	0.36
Gym and Training Equipment	265	0.2%	0.03	0.02	0.02
Laundry Equipment	44	0.04%	0.005	0.003	0.003
Grand Total	**110,529**	**100%**	**12.42**	**6.64**	**6.47**

Interestingly, the number of devices per square foot on Stanford's campus is less than half the figures found in other studies, which show about 30 devices per 1,000 square feet in commercial buildings [2]. One factor driving this is that a university campus has more open building space (with few to no items plugged in) than standard commercial buildings, which is supported by the Public Spaces and Recreation Facilities data depicted in Figure 1.

Figure 1: Equipment density by category and building type

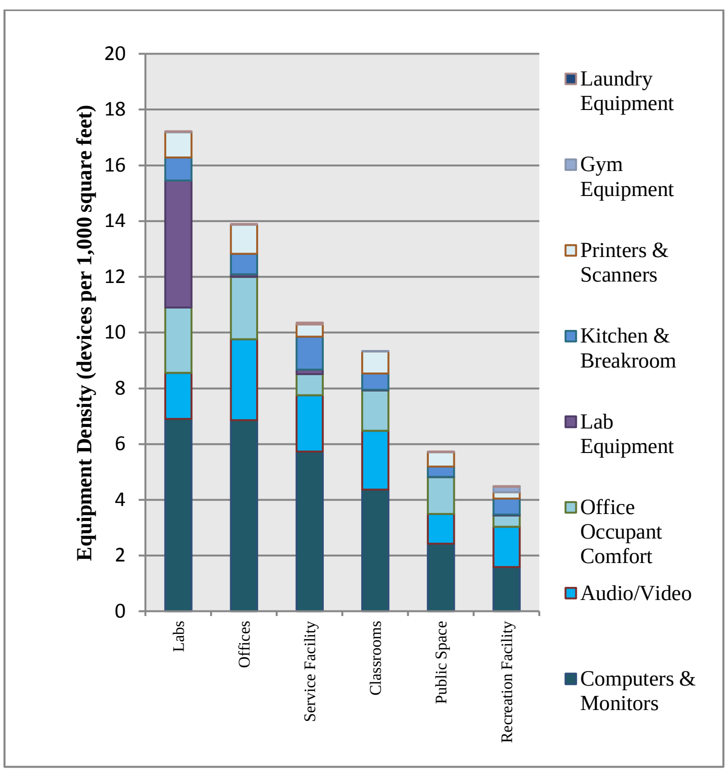


Figure 1 shows Stanford's equipment density per 1,000 square feet by both equipment type and building type. Labs have the highest average equipment density at a total of 17.2 devices per 1,000 square feet, followed by offices at 13.9, while recreation facilities have the lowest equipment density at a total of 4.5 devices per 1,000 square feet. Of course, the density of lab equipment in lab spaces is much higher than in any other type of building at approximately 4.6 devices per 1,000 square feet. This additional equipment is the primary driver of increased equipment density in lab buildings. It is noteworthy that the Computers & Monitors category, including personal computers, monitors, servers, and other computing equipment, is the most prevalent category of equipment in all building types, including lab buildings. In fact, the density of computing and networking equipment in labs and offices is the same, at 6.8 devices per 1,000 square feet. Similarly, the number of computing and networking devices per occupant remains fairly similar among labs and offices, at 3.1 and 3.0 devices per occupant respectively. The most prevalent types of equipment within this category—and overall—are personal computers and LCD monitors, which have overall equipment densities of 2.3 and 2.1 devices per 1,000 square feet and 1.2 and 1.1 devices per occupant, respectively. These findings are further illustrated in Figure 2 and suggest that solutions focusing on computer power management could result in significant savings across all building types.

Figure 2: Quantity of equipment by equipment type

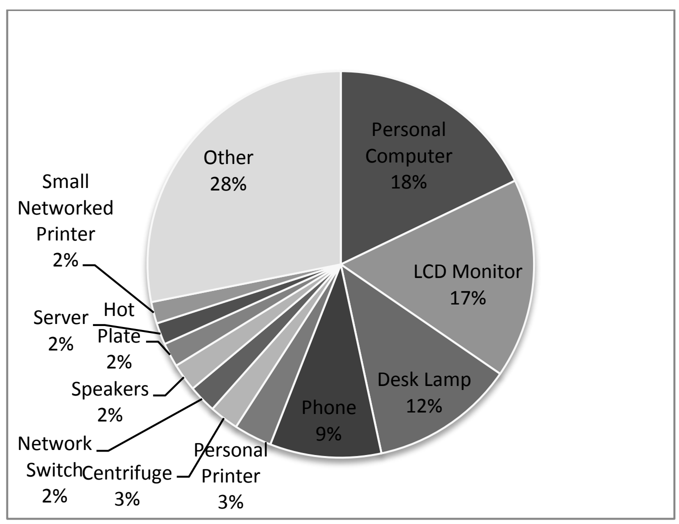


Figure 2 shows the top 11 most prevalent types of equipment on campus. These 11 equipment types together comprise 72% of the total equipment present on campus. A total of 20,117 personal computers were inventoried, along with 18,803 LCD monitors. An additional 402 CRT monitors were also recorded. This brings the number for both personal computers and monitors to a total of 1.2 per occupant. Previous studies have shown computer density to range from 0.53 to 2.18 per employee [8], so the number of computers in Stanford's buildings seems to be consistent with prior findings. Also, 43% of the computers recorded were manufactured by Dell, with 37% Apple, 7% Lenovo and the remainder divided between other brands.

Of the 20,117 personal computers recorded, 13,706 are desktops and 6,275 are laptops. The remaining 136 did not have the desktop or laptop attribute recorded during data collection. Additionally, there were 500 docking stations recorded for which a laptop was not present, so it is safe to assume that at least an additional 500 laptops are being used on campus in the buildings that were inventoried. However, laptop chargers were not included separately in the inventory because of their minute power draw, so it is likely that some computers that were not present at the time of the inventory and that use basic chargers rather than docking stations have been overlooked. Finally, because student residences were not included in this study, the majority of the personal computers that were inventoried are used by faculty and staff, although any personal laptops that belonged to students working in the inventoried buildings at the time of the inventory would have been captured in this data. All other student laptops were not captured.

3.1.2 Equipment Energy Consumption

It is estimated that the energy consumed by the equipment recorded in Stanford's inventory totals approximately 48,214,090 kWh/yr. Based on Stanford's electricity rates, this equates to $6.7 million in electricity costs per year. This electricity consumption comprises 22% of Stanford's overall building electricity use, and 32% of the energy use of the 220 buildings included in the inventory. The average unit energy consumption (UEC) of each equipment type is illustrated in Appendix B. Total energy consumption (TEC) is calculated for each equipment type according to the equation below, where:

N_1= quantity of equipment with attribute 1
UEC_1 = unit energy consumption of equipment with attribute 1
N_2 = quantity of equipment with attribute 2
UEC_2 = unit energy consumption of equipment with attribute 2
N_3 = quantity of equipment with attribute 3
UEC_3 = unit energy consumption of equipment with attribute 3

$$TEC = (N_1 \times UEC_1) + (N_2 \times UEC_2) + (N_3 \times UEC_3)$$

There is a maximum of three attributes per equipment type, and some equipment types were not assigned any attributes. The above equation changes accordingly based on the number of attributes associated with each equipment type.Table 3 summarizes TEC and other energy consumption metrics by equipment category.

Table 3: Total energy consumption by equipment type

Equipment Type	**Total Energy Consumption (kWh/yr)**	**Percent Energy Used of Plug Load Total**	**Energy Use Intensity (kWh/ft^2/ yr)**	**Energy per Occupant (kWh/ft^2/ person)**
Lab Equipment	23,955,761	50%	2.69	1,439
Computers and Monitors	17,261,798	36%	1.94	1,037
Kitchen and Breakroom	2,306,695	5%	0.26	139
Office Occupant Comfort	1,625,419	3%	0.18	98
Printers and Scanners	1,478,357	3%	0.17	89
Audio/Video	1,046,246	2%	0.12	63
Gym and Training Equipment	510,943	1%	0.06	31
Laundry Equipment	28,871	0%	0.00	2
Grand Total	**48,214,090**	**100%**	**5.42**	**2,895**

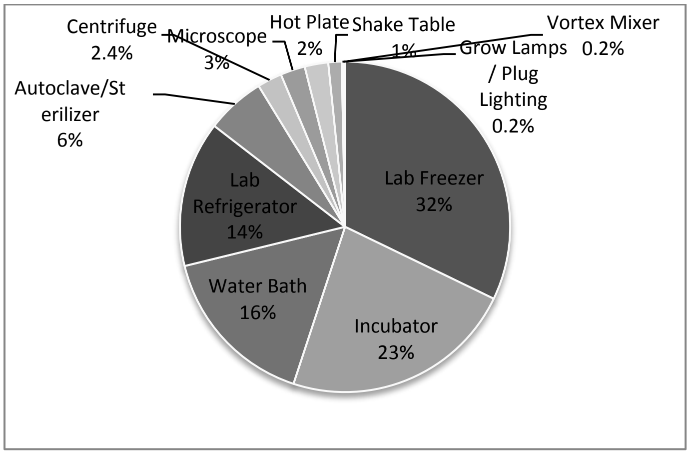
Overall energy use intensity based on the equipment recorded in this study is estimated to be 5.42 kWh per square foot per year. It is difficult to draw a direct comparison to previous studies for overall energy intensity, since this study includes lab equipment and IT equipment, whereas previous studies have not.

Estimated TEC by equipment type is shown visually in Appendix C, which highlights the equipment types that consume the most energy on Stanford's campus and reveals the entire energy consumption spectrum for all 55 types of equipment included in this study. Brief descriptions of the driving factors behind the results for each equipment category are below.

3.1.2.1 Lab Equipment

Lab equipment comprises 50% of the total estimated plug load energy consumption on Stanford's campus, which equates to 11% of total campus electricity consumption and 71% of total plug load energy use in lab buildings. Figure 3 shows the expected breakdown of lab equipment energy consumption by equipment type. As noted above, there are many types of specialized lab equipment that are not included in these totals since they were not included in the inventory. Lab freezers are estimated to consume 7,705,669 kWh per year, which equates to nearly one third of total lab equipment energy consumption and makes lab freezers the 2nd highest consumer on campus, behind servers. A total of 1,520 lab freezers were inventoried, and these alone are estimated to consume 16% of the total plug load energy consumption captured in this study.

Figure 3: Lab equipment energy consumption by type



The temperature and size of each lab freezer were recorded during the inventory. Altogether, there were 847 standard lab freezers, which are typically set to a temperature of -20 degrees Celsius. Three hundred and fifteen of these standard lab freezers are under-counter models, while 528 are full-sized. Additionally, there are 515 ultra-low temperature (ULT) lab freezers on campus, all of which are full-sized and are typically set to -80 degrees Celsius. Within the 3,258,412 square feet of lab building space, there is one ULT freezer for every 2,222 square feet. With each ULT consuming approximately as much energy per year as a single family home, this equipment presents a significant opportunity for lab equipment energy savings.

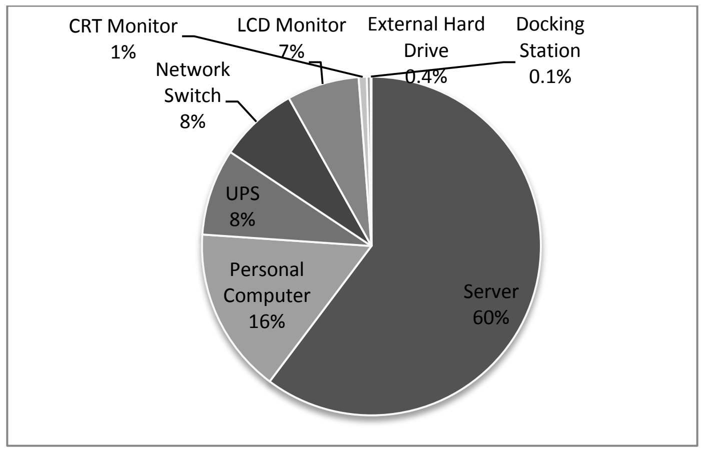
Incubators and water baths were estimated to be the next highest-consuming types of lab equipment and the 3rd and 4th highest energy consumers overall, respectively. One interesting component of these equipment types is that they often remain turned on all the time, but they could be powered down when not in use. It is estimated that simply turning lab equipment (including incubators, water baths, centrifuges, shake tables, hot plates, microscopes, and vortex mixers) off at night could save 758,258 kWh per year.

3.1.2.2 Computers & Monitors

Computers and monitors are estimated to comprise 36% of the plug load electricity consumption captured in this study, which equates to 8% of total campus electricity consumption. Of course, computers and monitors are prevalent in all types of buildings—a supported by this study's density calculations—but the estimated energy use intensity of these devices across various building types varies dramatically, with energy use intensity in office spaces at 3.64 kWh per square foot per year, in labs at 2.16 kWh per square foot per year, and on the low end in both recreation facilities and public spaces at 0.49 kWh per square foot per year.

The biggest reason for this varying energy use intensity for computers and monitors among building types is the presence of data centers. The Computers & Monitors category includes equipment commonly found in data centers, such as servers, uninterruptible power supplies (UPSs) and networking equipment, including both Ethernet hubs and network switches. Figure 4 shows the breakdown by energy consumption of equipment types within the Computers & Monitors category. Despite the high quantities of personal computers and monitors present on campus, they are only expected to consume 16% and 7% of the total electricity consumption of the equipment in the Computers & Monitors category, respectively.

Figure 4: Computer & monitor equipment energy consumption by type



In contrast, servers alone are estimated to consume 60% of the energy consumption within the Computers & Monitors category, which totals 10,399,486 kWh per year. As the single highest electricity consumer on campus, estimated server consumption equals 22% of the total plug load electricity consumption captured in this study. As a comparison, UPSs and networking equipment together are only thought to consume the equivalent of 26% of total server energy consumption. This figure also includes small UPSs, which are more commonly found in offices rather than server rooms. Physical size was recorded as an attribute for servers, with size varying from 1U through 12U, and a separate category for blade servers. Altogether, blade servers, which are typically a more energy efficient server model due to their high storage capacities, represent only 8% of the total servers on Stanford's campus, while 41% of the servers are smaller 1U servers.

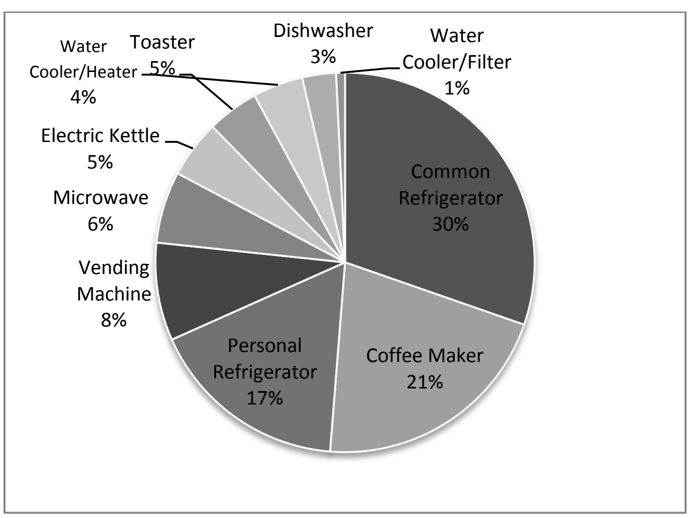
Furthermore, servers require significant backup power and cooling to run optimally, which is not included in the energy consumption estimates listed above. An average server room has a Power Use Effectiveness (PUE) of 2.0, meaning that it uses the same amount of energy for backup power and cooling as it does for the IT equipment itself

[12]. Efficient data centers can have PUEs as low as 1.1 [12], meaning that the energy consumption of many data centers can be cut nearly in half through the implementation of energy efficient cooling strategies, in addition to the savings that can be achieved through IT equipment itself. However, close examination of the locations of servers and networking equipment revealed that much of the equipment is kept in IT closets rather than central data centers, so consolidating servers into central data centers with more efficient cooling systems also represents a significant opportunity, which is currently being addressed through server relocation programs at Stanford.

Kitchen & Breakroom

Kitchen and breakroom equipment comprises 6% of the total equipment on campus and an estimated 5% of the plug load electricity consumption estimated from this study. The entire breakdown of electricity consumption among kitchen and breakroom equipment is depicted in Figure 5. Although this equipment is found consistently in buildings on campus, its overall quantity is relatively low since it primarily resides in shared common areas rather than individual office spaces. One exception to this is refrigerators: there are 919 common refrigerators on campus, which equals one refrigerator for every 18 building occupants. But there were an additional 1,277 personal refrigerators recorded in this study, more than doubling the total number of refrigerators per occupant. Ten percent of common refrigerators were specifically noted as older models during the inventory. Additionally, only 6% of common refrigerators and 3% of personal refrigerators had the Energy Star label. It is possible that some additional refrigerators qualified as Energy Star but did not have a visible label.

Figure 5: Kitchen & breakroom equipment energy consumption by type



A total of 1,022 coffee makers were recorded in the inventory, divided into three categories: single-cup coffee makers, single-pot coffee makers, and multi-pot coffee makers. Of these, the single-cup coffee makers were the most prevalent on campus at 483 units, closely followed by the single-pot coffee makers at 421 units and then the multi-pot coffee makers at 109 units. However, the multi-pot coffee makers are estimated to consume 119,137 kWh per year, whereas the single-cup coffee makers are expected to consume only 51,895 kWh per year despite being over four times more prevalent. Previous studies have found that industrial coffee makers can use as much electricity as a standard refrigerator over the course of a year and that there is high variability in coffee maker power levels, with some reaching a low power level for most of the day to keep coffee warm, while others continually cycle between high and lower power all day [2]. Based on this data, addressing commonly used multi-pot coffee makers could be an effective tactic at lowering energy consumption in kitchens and breakrooms.

3.1.2.3 Office Occupant Comfort

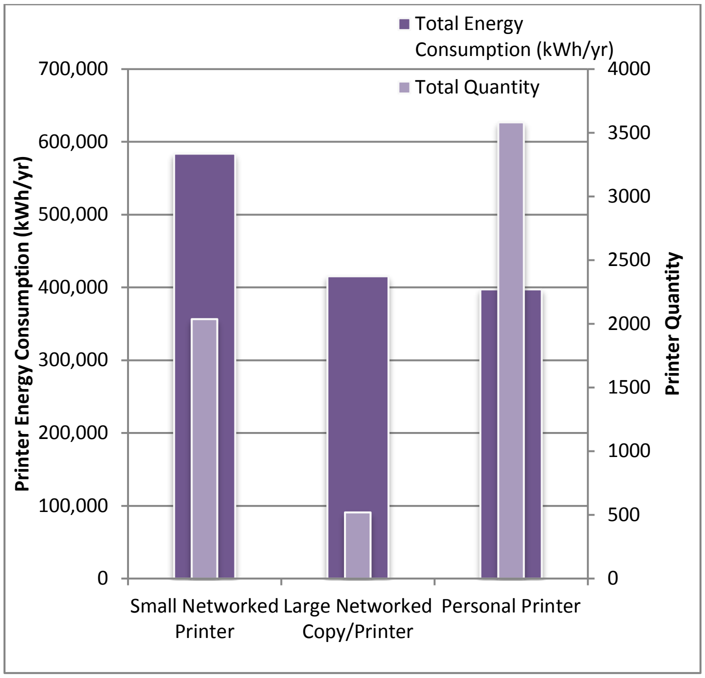
Four types of equipment are included in the Office Occupant Comfort category: desk lamps, space heaters, air conditioning units, and fans. The energy use intensity of these devices stays fairly consistent across building types, with an estimated range of 0.12 kWh per square foot per year of energy consumption in public spaces to 0.24 kWh per square foot per year in lab buildings. The inventory recorded a total of 955 space heaters (approximately one space heater for every 17 building occupants), which in total are estimated to consume 517,634 kWh per year. Space heater energy consumption depends heavily on usage patterns, so the level of uncertainty in this estimate is relatively high.

In contrast, there are only 151 plug-in air conditioning units on campus, which are estimated to consume 47,368 kWh per year. Also, 1,815 personal fans were recorded in the inventory, which together are estimated to consume 119,585 kWh per year—just 2.5 times the energy consumption of air conditioners with 12 times the number of units. Finally, a total of 50 larger gym fans were also recorded in the inventory, which are estimated consume an estimated 36,500 kWh per year.

3.1.2.4 Printers & Scanners

Equipment within the Printers & Scanners category comprises 3% of total plug load energy consumption captured in this study. For the purposes of this study, printers were divided into three categories: small networked printers, large networked copier/printers, and personal printers. The count and estimated energy consumption of printers in this study by type is depicted in Figure 6.

Figure 6: Summary of printer quantity and energy consumption



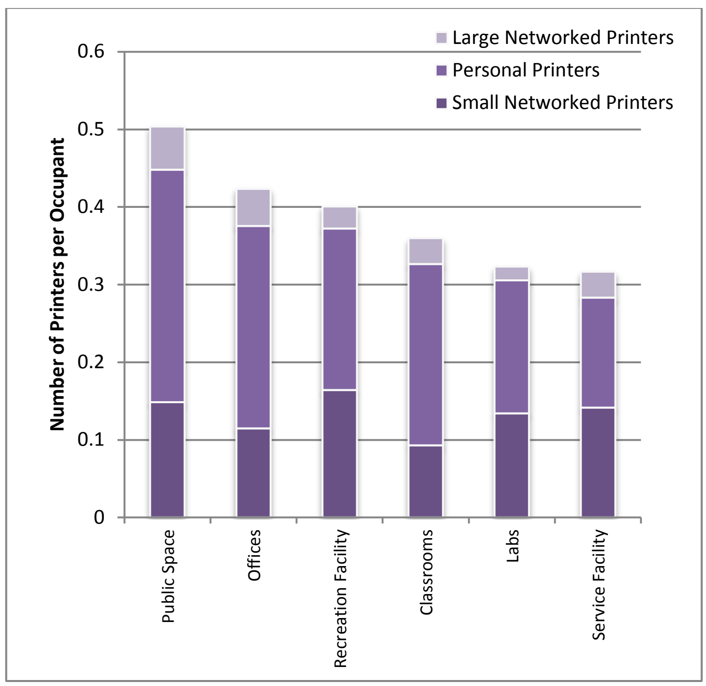
Personal printers were defined as any printer used by only one person; this equipment type comprises primarily small inkjet printers, but printers of any kind could be included in this equipment type if they were used by only one individual. In this study, 76% of the personal printers captured were HP models.

In contrast, small networked printers were defined as any standard-sized printer that is shared among building occupants; within this equipment type, there is more variation between laser and inkjet models, although previous studies have shown that laser networked printers outnumber inkjet networked printers in office buildings by a factor of about three to one [2]. Laser printing technology is more energy intensive than inkjet technology, which has been factored into the energy consumption estimates developed for small networked printers [13]. Overall, 73% of the small networked printers at Stanford were HP models.

Finally, large networked copier/printers are defined as any floor-mounted printing device. These primarily use laser technology and often have additional functionality, such as copying, scanning and faxing. There is more diversity among the common brands of these devices, with 34% recorded as Canon models, 26% Xerox, and 14% HP. In other building surveys, large networked copier/printers are often referred to as multi-function devices (MFDs).

The total number of printers per occupant remains fairly consistent across building types, between 0.32 printers per person in both labs and service facilities and 0.5 printers per person in public spaces. Figure 7 captures printer density per occupant by building type and by printer type. Office buildings have a fairly high printer density at 0.43 per occupant as well as the highest density of personal printers at 0.26 per occupant. This means that approximately 1 in 4 people have personal printers in office buildings on Stanford's campus. On the other hand, the presence of small networked printers is lower than average in office buildings at 0.11, or one small networked printer for every 9 people, suggesting that personal printers may replace shared printers in *some* spaces rather than supplement them. Finally, public spaces have the highest printer density per occupant overall and among the majority of printer types. One reason for this may be that public spaces often have small administrative units with only a few occupants, but those occupants still require the same printing functionality as occupants in larger administrative units.

Figure 7: Summary of printer density



Other devices in the Printers & Scanners category include scanners, fax machines and plotters. Together, these devices are estimated to consume 81,951 kWh per year, which is 17 times less than the combined energy consumption of printers included in this study. These items often have redundant functionality to new multifunction printing equipment (which were recorded as printers in this inventory), but there are still a total of 1,053 of these various devices on campus. Findings from previous studies have suggested that increased procurement of multifunction devices do correlate with a decrease in copiers, but do not necessarily correlate with decreases in other types of equipment, which may help explain why so much redundant single-function equipment remains on Stanford's campus [8].

3.1.2.5 Audio/Video

Audio/Video equipment comprises 16% of the total plug load equipment included in this study but only an expected 2% of the total estimated plug load electricity consumption, mainly because the majority of equipment types in this category are low energy consumers. Cable boxes and subwoofers are among the top equipment types in this category by UEC, but their relatively small numbers on campus keep their TEC to an estimated 52,824 and 66,824 kWh per year, respectively. Older models of overhead projectors and TVs also use a significant amount of energy per unit. There were 126 older cart-mounted projectors found in the inventory that together are thought to consume 52,245 kWh per year. Additionally, the 257 CRT TVs captured in the inventory are projected to consume 36,878 kWh per year. Eliminating or replacing these older units could be one energy-saving opportunity in this category.

3.1.2.6 Gym & Training Equipment

Gym & Training equipment had a very low TEC, largely because many types of equipment present in Stanford's gyms are battery-operated rather than electrically powered. This was true for ellipticals, stationary bikes, and even some treadmills. Ice machines were recorded in this category, although they were found in many types of locations across campus. A total of 125 ice machines were recorded in this inventory, 20 of which were located in recreation facilities, 86 in labs, and the remainder divided among on-campus cafes and the student health center. Together, these ice machines consume an estimated 358,125 kWh per year. Because ice machine energy consumption cannot be attributed only to recreation facilities, the total energy consumption for the Gym & Training equipment category is artificially high.

3.1.2.7 Laundry Equipment

The quantity of laundry equipment recorded in this inventory was very low, with only 25 dryers and 19 washing machines. This energy consumption represents an insignificant portion of plug load energy consumption on campus at an estimated total of 28,871 kWh per year, 74% of which can be attributed to dryers. A shortcoming of this study is that the majority of washing machines and dryers on campus are located in campus residences, which were not inventoried. Future work could focus on integrating the number of washing machines and dryers in student residences into this inventory in order to paint a more accurate picture of laundry equipment energy consumption on a college campus.

3.1.3 Results by Building Type

The analysis of data by building type helps not only to relate the densities and estimated energy consumption to various sectors, but also to understand the breakdown of equipment and energy consumption among building types on a university campus, which can be extrapolated upon by other institutions. Table 4 illustrates relevant equipment quantity, density, energy consumption, and energy intensity figures by building type. It is worth noting that due to a few cases of data inadvertently being captured without an associated building, the totals by building type do not align perfectly with the totals by equipment type.

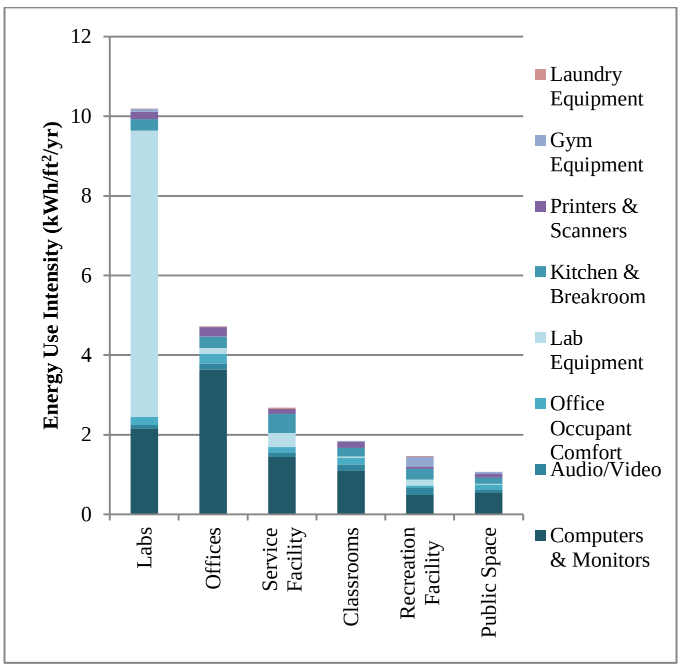
Table 4: Equipment quantity and energy consumption estimates by building type

Building Type	Total Count	Total Energy Use (kWh/yr)	Average Plug Load Electricity Use as Percent of Total Building Type Electricity Use	Plug Load Energy Use as % of Total Campus Electricity Use	Average Energy Use Intensity ($kWh/ft^2/yr$)	Average Power Density (W/ft^2)
Labs	56,110	33,189,649	36%	69%	10.19	1.16
Offices	27,900	9,473,215	39%	20%	4.72	0.54
Classroom	15,618	3,084,001	31%	6%	1.84	0.21
Public Space	7,273	1,344,297	13%	3%	1.06	0.12
Rec Facility	2,714	880,505	11%	2%	1.46	0.17
Service Facility	905	234,189	24%	0%	2.68	0.31

Lab buildings and office buildings together consume 89% of the estimated plug load electricity consumption in this study. However, plug loads in lab buildings are ultimately much more significant than those in office buildings; labs consume an estimated 69% of the total plug load electricity, while offices are projected to consume only 20%. The next highest building type is classrooms at an estimated 6% of total plug load electricity consumption, which have a similar plug load profile to offices but are fewer in number. A 2004 study that surveyed high school buildings found that a large driver behind plug load electricity consumption in classroom spaces was computer labs [8]. Power management settings in computer labs in Stanford's classroom buildings could be evaluated as a next step based on this data.

Lab buildings also contain the highest quantities of equipment at 51% compared to offices which contain only 25% of the total plug load equipment captured in this study. Tellingly, equipment within the Computers & Monitors category had the highest energy consumption among all building types except labs, but overall lab equipment energy consumption is estimated to surpass that of computing equipment by over 6.5 million kWh per year. Perhaps the most telling variable is energy use intensity, which is estimated to be 10.19 kWh per square foot per year in lab buildings, while office buildings are projected to use less than half of that at 4.72 kWh per square foot per year. This estimated value lies within the range of measured values found in previous studies for office energy intensity, although this spectrum is fairly broad, ranging from 2.19 kWh per square foot per year [11] to 5.15 kWh per square foot per year [7]. In fact, office energy intensity has been found to be as high as 10.5 kWh per square foot per year in space deemed to be "computer intensive" [7]. Estimated energy use intensity for all building types by equipment category is summarized in Figure 8.

Figure 8: Energy use intensity by building type and equipment category



This study also allowed Stanford to estimate the average plug load power density of its buildings. As a whole, Stanford's average power density is estimated to be 0.62 watts per square foot for the equipment types included in this study, but of course there is significant variation by building type. On average, lab buildings have an estimated power density of 1.16 watts per square foot, while office buildings are projected to use 0.56 watts per square foot.

On the low end of the spectrum, plug loads in public spaces consumed an estimated 0.12 watts per square foot. One important note is that this study more fully captured data on equipment in office buildings, since a high percentage of office equipment can be categorized into the 55 equipment types included in this study, whereas it is more likely that lab buildings would contain specialized plug load equipment that was not included in this study. Thus, estimated plug load power density can be estimated more accurately for office buildings than for lab buildings. In fact, the estimated plug load power density for office buildings in this study aligned well with measured plug load power density figures from Stanford's submetered office buildings, as illustrated in Table 5. While it is important to note that this study only takes average power density into account and cannot determine peak plug load power draw, this study has further substantiated the case built in previous studies that electrical infrastructure and cooling systems in office buildings are often oversized due overestimated plug loads [14].

Table 5: Comparison of measured and calculated plug load power densities in Stanford office buildings

Building	Gross Square Feet	Plug Load Energy Use (kWh/yr)	Measured Average W/ft²*	Measured Peak W/ft²*	Calculated W/ft²
Office Building 1	115,110	249,598	0.23	0.41	0.25
Office Building 2	49,360	45,736	0.3	0.64	0.11
Office Building 3	83,130	151,535	0.16	0.42	0.21
Office Building 4	26,326	55,295	0.4	1.08	0.24
Office Buildings 5,6,7	113,644	134,860	0.28	0.63	0.14

*Data published in Sheppy et al 2011

The four buildings with the highest plug loads based on this inventory consume 40% of the total estimated plug load electricity in this study, and the top 10 are projected to consume 55% altogether. Moreover, all four of the buildings with the highest overall plug load consumption also fall within the top 10 buildings with the highest plug load energy intensity. Ultimately, this data suggests that a targeted approach to plug load electricity reduction in the buildings with the highest plug loads could be an effective strategy in decreasing this consumption.

Observing plug load energy intensity among individual buildings also revealed some underlying trends. For instance, some of the buildings with the highest plug load energy intensity turned out to be small buildings with unusually high amounts of energy-intensive equipment, such as shops and small IT buildings. In fact, the building on campus with the highest plug load energy use intensity—an estimated 36.25 kWh per square foot per year—was a small building that is listed in university records as an office. However, further evaluation revealed that there are actually 130 servers in that building grouped into approximately three data centers and 2 IT closets. This highlights another identified trend: servers tend to be the primary driver in increasing plug load energy consumption in buildings due to their high UEC. In fact, servers have the highest TEC of all equipment in four of the six building types on campus.

Building-level analysis also provided an easy mechanism for communicating results to building managers, who each received plug load report cards as a result of this study. The report cards compared each building's plug load electricity consumption to that of other buildings of the same type and provided building managers with recommendations for reducing plug load electricity consumption in their buildings.

Finally, low numbers of Energy Star equipment were found across building types, so it does not appear that any one sector places more preference on purchasing Energy Star equipment than another. Of all equipment on campus for which the Energy Star attribute was recorded, only 16% contained the Energy Star logo. In offices, this figure is 17%, in labs it is 15%, and in classrooms it is 12%. While it is possible that some equipment qualified as Energy Star but did not have a visible logo or that some equipment was Energy Star certified but Energy Star was not collected as an attribute, this overall number is lower than expected and represents a significant opportunity for improvement in purchasing habits. The consistency across building types also suggests that no particular departments or schools have policies regarding the purchasing of Energy Star equipment.

While this study captured a large range of equipment types and building types, it still does not holistically show Stanford's total plug load electricity consumption, and future work could focus on completing this picture. For instance, on-campus residences should be inventoried in order to fully capture the number of computers, printers, personal refrigerators, desk lamps, and other relevant plug load equipment types on campus, although these loads are subject to change more rapidly than other loads due to the transient student population. Future work could also focus on developing a better understanding of how much aggregate loads in student residences truly fluctuate year to year.

Additionally, it is likely that lab loads and IT loads are underrepresented due to the need to exclude certain sensitive buildings. For instance, Stanford's two largest data centers were not inventoried for security reasons, and several School of Medicine buildings were not inventoried in order to maintain patient privacy. Furthermore, the exclusion of specialized equipment means that a higher proportion of lab and IT equipment, which tends to be more specialized, may not have been recorded in the inventory compared to office equipment. Because of the large UEC of both lab equipment and IT equipment, the equipment not captured in this study could represent a significant portion of Stanford's plug load electricity consumption, and developing an even more comprehensive understanding of this equipment should be a priority.

3.2 Savings Opportunities

The savings analysis performed using data from the equipment inventory represents one of the most comprehensive analyses of plug load reduction opportunities to date; whereas several studies have thoroughly reviewed savings opportunities such as power management for office equipment, installation of Energy Star equipment, and the use of various types of load-controlling devices, this is one of the first studies to our knowledge to analyze all solutions together in order to compare and contrast their efficacy. However, it is important to note that these solutions were not field-tested, which would be the next step in confirming the impact and effectiveness of the programs.

Analysis of the plethora of potential savings opportunities identified 37 viable measures to cost-effectively reduce campus plug loads. These 37 measures have the potential to reduce plug loads at Stanford by an estimated 27%, which would reduce the electricity consumption of the entire campus by 6% based on the equipment captured in this study. It has been estimated that 40% of the electricity used by plug loads is wasted [15], so this analysis methodology prioritized opportunities that addressed energy waste by weighing occupant satisfaction heavily in the rating for each opportunity, since solutions that address energy waste would not typically significantly affect an occupant's direct experience.

The top 37 measures center around 5 primary opportunity categories: basic energy efficiency measures, space heating, information technology, labs, and procurement. The overall potential savings to Stanford and return on investment from implementing the opportunities within each of these five categories is illustrated in Table 6. Estimated adoption rates were taken into account when developing the savings figures in this table. More thorough explanations of the individual measures that comprise each category are below.

Table 6: Savings and ROI from plug load reduction programs

Program	Expected Annual Savings (kWh/yr)	Average ROI	Percent Plug Load Savings
Basic Energy Efficiency Measures	1,934,744	2.7	3.9%
Space Heater Minimization	288,377	1.7	0.6%
Information Technology Measures	5,261,199	4.4	10.6%
Lab Measures	5,053,609	10.5	10.2%
Procurement Strategies	613,737	0.0	1.2%
Total	**13,151,666**	**3.9**	**27%**

3.2.1 Energy Efficiency Measures

The 15 measures in the energy efficiency category involve both direct energy efficiency upgrades to products and installation of hardware-based methods to reduce wasted energy. This study suggested that these measures would be some of the easiest to implement based on their low cost, ease of installation, and estimated aggregate payback period of 2.7 years.

3.2.1.1 Smart Power Strips

Estimates for load-sending “smart” power strip—or smart strip—savings were based on estimates for the individual savings of each device controlled according to the totals collected in the inventory. For instance, a smart strip that controlled every peripheral device could save up to 281 kWh per year, but a smart strip with only an LCD monitor controlled would save 42 kWh per year. If one smart strip were installed for every computer on campus, this estimate averages to 56 kWh of savings per smart strip per year, which is a lower figure than those measured in previous studies. Table 7 summarizes the savings per smart strip and per device and ROI based on whether the strip is installed with a computer as the “control” device or a TV as the “control” device. The most effective way to lower the ROI for smart strips will be to only install them in select locations where high numbers of peripherals are present.

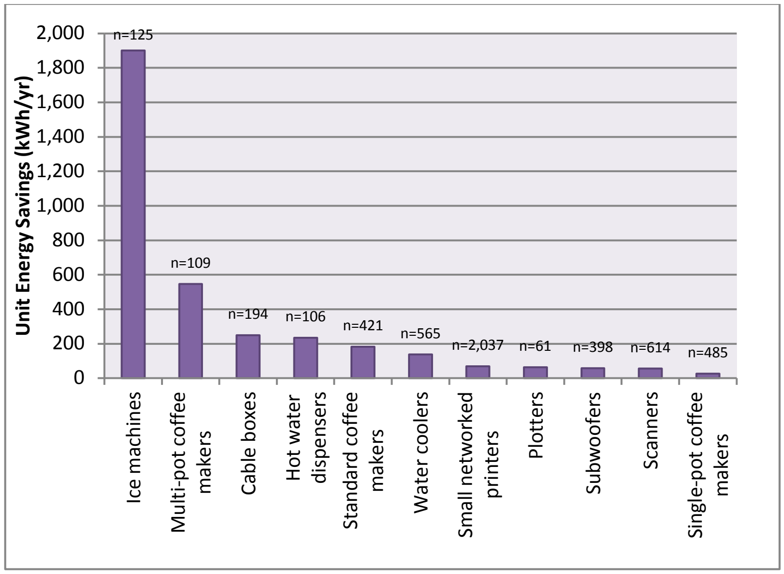
Table 7: Smart strip savings for various equipment types

Control Device	All possible peripheral devices	Average saving per smart strip (kWh/yr)	Average savings per device controlled (kWh/yr)	ROI (years)
Computer	LCD monitors, external hard drives, personal printers, speakers, stereos, subwoofers, and scanners	56	41	4.9
TV	Cable box, DVD player, VCR	37	82	7.5

3.2.1.2 Timers

This study evaluated the potential savings of installing programmable appliance timers on individual types of equipment on campus using assumptions regarding the number of hours of standby or idle load saved, primarily at night. The standby and idle load figures for each type of equipment were either measured or pulled from published data. Figure 9 shows the unit energy savings (UES) for all types of equipment where timer control is a viable solution, and equipment quantities are highlighted for each equipment type. The average ROI of these methods is projected to be 1.2 years. One concern regarding the use of timers is their persistence; to make them a truly viable savings opportunity, they would need to remain functional for a longer period of time than their payback period.

Figure 9: Summary of estimated timer energy savings



3.2.1.3 Vending Machines

There are several measures that can be taken to improve the energy efficiency of vending machines, many of which have been the topic of previous research. A total of 81 vending machines were recorded in Stanford’s inventory. Based on this number, two of the five energy efficiency measures considered for vending machines were determined to be viable. In fact, of all 37 viable actions, the measure with the highest rating was installing vending misers on the 53 vending machines that are not currently equipped with them. This is estimated to save 1,000 kWh per machine per year [16] and to pay back in 1.4 years. This measure achieved a high rating primarily because installation is easy, ROI is low, potential savings is high, and it is not an inconvenience to building occupants. Additionally, delamping of vending machines was determined to be another effective measure. One reason for this is that delamping applies to both refrigerated and non-refrigerated vending machines, so there is a larger scope. Several vending machines were observed to have 18 watt bulbs, and the energy associated with these bulbs could easily be eliminated through delamping at no additional cost to the university.

Many vending machines—especially those that are Energy Star certified—have onboard controls that have a similar function to vending misers. It was not immediately clear during Stanford's equipment inventory which vending machines had onboard controls, and which did not, so clarification discussions with vending machine owners and distributors should be held. For those machines that do have onboard controls, the controls can easily be activated, if they're not already, to reduce the machine's energy consumption. One drawback of onboard controls, vending misers, and delamping is that darker machines can sometimes be perceived as out of order [16]. Testing of this assertion should be conducted to better understand any economic consequences to the owner/distributor of performing vending machine energy efficiency measures.

3.2.2 Space Heating

The options to address space heating energy consumption on Stanford's campus all address the same type of equipment: electric space heaters. While these do come in many forms, the most common type is convection space heaters, which fairly consistently draw approximately 1,500 watts when running. Many do also have low speeds, which reduce the draw to about 700 watts, which is also the approximate draw of radiant space heaters. With 955 space heaters on Stanford's campus, all four options for reducing that energy consumption—and especially any wasted energy consumption associated with space heater use—fell into the final 37 program options.

Table 8: Energy savings and ROI estimates for space heater energy reduction programs

Measure	UES	ROI (years)
Phase out space heaters	542	0
Install occupancy sensors on space heaters	361	3.9
Install timers on space heaters	271	0.5
Upgrade convection space heaters to radiant space heaters	217	1.7

Table 8 shows the savings and ROI for these four measures. One interesting factor involving occupancy sensors is that other equipment could also be plugged into the occupancy sensor, so there would likely be additional savings benefits beyond just space heater savings, which have been shown in previous studies. For instance, one study showed that occupancy sensors connected to all types of office equipment led to an average of 19% savings on weekdays and 28% savings on weekends [7]. The decision of which of these measures to apply should ultimately be site-specific, taking into account how often space heaters are being used and why, how much of their energy consumption is useful versus wasted, and whether HVAC adjustments can be made that would allow space heater use to naturally subside and how cost effective that strategy would be.

3.2.3 Information Technology

Addressing plug load consumption among IT equipment has by far the highest potential savings among all five plug load reduction programs. The total expected plug load savings of implementing all measures within this category equates to an 11% reduction of the total plug load electricity consumption calculated in this study. These measures apply to both sophisticated IT equipment, such as servers, UPSs, and network switches, and basic computing equipment, such as computers, monitors, and large networked copier/printers, for which power management will be an effective solution.

3.2.3.1 Servers

The most effective strategy in reducing data center plug loads is to address server energy consumption. Stanford's analysis showed that the best method for reducing server energy consumption is to virtualize servers. Many physical servers have a utilization rate of less than 5%, meaning 95% of their capacity is not being used, despite the fact that the server is constantly drawing enough power to do so [5]. Through virtualization, all of these physical servers can be consolidated to reach much higher utilization rates while reducing the amount of hardware that needs to be powered, which in turn reduces electricity and maintenance costs [17]. One office facility was able to consolidate a series of 1U and 4U servers with under 5% utilization into a 10U blade server chassis that holds up to 16 individual servers that each hold approximately 20 virtualized servers. These blade servers require a maximum of six UPSs and ten cooling fans, which is also a significant reduction from the amount of power and cooling necessary for individual 1U and 4U servers [5].

Energy savings from server virtualization on Stanford's campus were estimated based on the strategy above, assuming 75% of the servers included in the inventory can be successfully virtualized. Moreover, the university has encouraged server virtualization for several years, so existing data was also used to inform potential server virtualization savings. Stanford's equipment inventory revealed 1,690 servers that could be virtualized to achieve an expected savings of 3,766,987 kWh per year. This alone would reduce Stanford's estimated plug load energy consumption by 8%. Of course, this would also come with immediate reduced power and cooling needs, which would likely be nearly equivalent to the equipment energy savings. Moreover, if the university took additional measures to improve cooling systems in IT closets and data centers in conjunction with server virtualization and consolidation, savings could increase by another 12,405,600 kWh per year, assuming Stanford's data centers could achieve a PUE of 1.1, which is considered to be the target for energy efficient data centers [12].

Because this study also collected data on the number of UPSs and network switches on campus, estimates could also be generated on potential savings from measures that address this equipment. Both UPSs and switches are included in the Energy Star product labeling program, and Energy Star upgrades to this equipment would be associated with an estimated 415 kWh in savings per year per UPS and 74 kWh in savings per year per switch. It is worth noting that the savings data for network switches represents average savings across all network switches of various sizes included in this study and would be higher if considering only 24-port Ethernet hubs or above. Ultimately, the relatively low UES values for this equipment suggests that upgrading backup power and networking equipment gradually in conjunction with server relocation, consolidation and virtualization is the only way these efforts could be considered cost effective.

3.2.3.2 Computing and Printing Equipment

Substantial research exists on the importance of power management strategies for computers, monitors, and printing equipment. One study estimates that complete saturation of power management in the US has the potential to save 47 TWh per year, with an additional 7 TWh per year of potential savings through complete shutdown at night [3]. Another study estimated that power management could save 56% of the energy consumed by monitors and 96% of the energy consumed by printers [8]. Finally, a third study found that by enabling power management, energy use in non-business hours can be reduced by 60%, while idle energy use can be reduced by 50% [18].

Stanford tracks its computer usage numbers through software installed on all university computers. At Stanford, computers are active 13.5% of the time, idle 27.8% of the time, in standby mode 33.8% of the time, and powered off 24.9% of the time. This varies slightly from figures found in other studies, such as one study from 2007 that found that computers spend 70% of their time in idle mode and only 4% in sleep mode [4]. One explanation for this could be that newer computers often come with more aggressive default power management settings out of the box, so computers at Stanford today are more likely to leave idle mode and enter standby mode than computers in 2007. In this paper, "active" is defined as turned on and in use; "idle" is defined as ready to use but not actually in use; "standby" is defined as having entered a sleep mode (without a screensaver); and "powered off" is when the computer is shut down.

This study uses Stanford's usage figures to estimate computer and monitor energy consumption and savings potential. Previous studies have emphasized the need for more effective power management in office buildings. For instance, one study found that existing built-in lower power modes need to be used more effectively [6]. Another study concluded that technological innovation should focus on lessening the inconvenience of power management in situations such as computers needing to remain powered on at night in order to conduct work remotely [18]. This study estimates that successful power management strategies could save an average of 18 kWh per year per computer and 23 kWh per year per monitor. The reason for the lower average computer savings is that the figure includes laptops, which are estimated to use 58% less energy overall than desktops. Despite relatively low UES, these savings add up quickly across the 20,117 computers and 18,803 monitors on Stanford's campus; if 75% of computers and monitors recorded in this inventory were able to successfully employ power management, an estimated potential savings of 603,700 kWh per year could be achieved. When the estimated savings from power management for large networked copier/printers is included, the expected savings from all power management strategies increases by another 132,101 kWh per year. The university is already seeing a portion of these savings through existing power management strategies, but the savings have not been fully realized.

Finally, a total of 402 CRT monitors were recorded in this study, which are estimated to use approximately 77% more electricity than LCD monitors. This study projects that upgrading the CRT monitors on Stanford's campus to LED monitors would have an estimated payback of 4.6 years. However, it is possible that some of these monitors are rarely used but remain plugged in, so developing a better understanding of CRT monitor usage patterns would be beneficial. Finally, transitioning from desktops to laptops would be another way to potentially reduce the total number of monitors on campus. However, although this measure was estimated to achieve a 51% savings in the energy consumption of personal computers, the cost and payback period were too high to make it a viable measure on a large scale. On the other hand, purchasing laptops instead of desktops in the future could be implemented as a university-wide procurement preference to achieve significant energy savings.

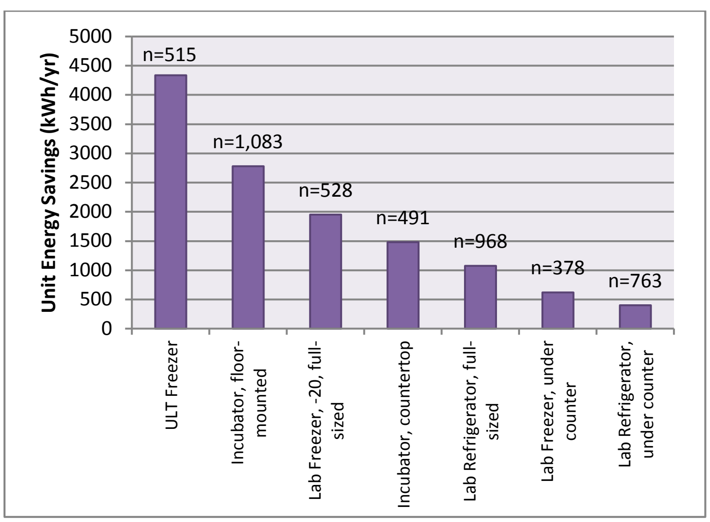
3.2.4 Green Labs

The "Green Labs" concept has become popular within higher education as a method of addressing sustainability in one of the most challenging sectors of a university campus: laboratories. As this study demonstrates, lab equipment likely uses more energy on the campuses of research institutions than any other category of equipment; at Stanford, lab equipment was estimated to consume 50% of total plug load electricity consumption. The need for attention to detail and consistency in labs can make them difficult to penetrate from a sustainability standpoint; however, many institutions have worked on developing Green Labs programs that make sustainability and energy efficiency more appealing to labs. This study seeks to inform those efforts by presenting findings on the most cost effective tactics for energy conservation in labs.

3.2.4.1 Lab Equipment Upgrades

Some types of lab equipment available on the market today are more efficient than older models. For instance, lab freezers are available today that use nearly half the energy of older lab freezers, but encouraging upgrades to the more efficient freezers can be a challenge. A significant first step can be ensuring that all new lab freezers that are purchased are energy efficient models. The same can be done for lab refrigerators and incubators, which are also becoming more efficient over time. Figure 10 shows the UES for each type of equipment from upgrading to more efficient models and includes the quantity of equipment within each type recorded in this study.

Figure 10: Summary of unit energy savings from lab equipment upgrades



However, the upfront cost of lab freezer upgrades is also high, and this study estimates the payback of replacing an existing lab freezer with a newer model to be 24 years, which is longer than the life of the freezer. However, when purchasing a new ULT freezer, the additional cost of purchasing the most energy efficient model would be a few thousand dollars, which would pay back much more quickly than a replacement freezer.

On the other hand, replacing incubators with energy efficient models actually has an estimated ROI of only 3.2 years, and the total expected annual savings is actually 38% higher than that of upgrading ULTs since there are about 4 times as many incubators on campus as there are ULTs and incubators are less expensive. To date, little research has been done in the field on the energy consumption and savings potential of incubators, so this should be an area of continued study.

3.2.4.2 Lab Behavior

Identifying and eliminating plug load waste in labs should be a priority, rather than attempting to affect the way the equipment is used, which could interfere with the research being conducted. Also, because the energy use of many types of lab equipment is high, its potential for wasted energy is also high. For instance, this study identified approximately 2% of lab refrigerators and freezers that were completely empty but still plugged in. Although this is a small percentage, the minimal effort it would take to unplug that equipment could save an estimated total of 222,473 kWh per year.

Additionally, autoclaves were estimated to be the eighth highest energy consumer of all 55 types of plug load equipment inventoried, and there is just one autoclave for every 160 lab occupants. Anecdotal evidence suggests that many individual occupants or labs run autoclaves with only their dishes and materials, rather than waiting for the autoclaves to be full. This study estimates that if lab occupants were to run full loads in autoclaves, which would often mean sharing space with other labs in order to fill up the machines, an estimated total of 519,448 kWh per year could be saved. Incidentally, water savings would also be high due to running fewer loads.

Finally, energy consumption in labs could be reduced dramatically simply by turning equipment off when not in use. In some cases, programmable timers might be appropriate to ensure that equipment is successfully turned off, although the use of lab equipment cannot always be predicted, so the ability to set predetermined turn on/turn off times would be inhibited. Thus, ensuring proper turn off of lab equipment when it is not in use becomes the obligation of the lab occupants. Equipment that can easily be turned off and unplugged when not in use includes centrifuges, incubators, water baths, shake tables, hot plates, microscopes, and vortex mixers. Some of this equipment uses energy even when turned off but still plugged in, so unplugging the equipment is the safest strategy to ensure that the equipment's draw reduces to zero. Of course, this equipment could also be plugged into a standard power strip that would cut power to all equipment when turned off. Regardless of how this idle or standby power is reduced, this study estimates that an average savings of 77 kWh per year per device controlled could be achieved.

3.2.5 Procurement Strategies

Several viable strategies involving equipment procurement actually involve phasing out equipment that is redundant. The equipment included in this analysis are personal refrigerators, personal printers, and fax machines. The UES metrics for each type of equipment can help to frame why this equipment should be avoided from a procurement standpoint, and the total energy savings (TES) metrics help build a potential case for eliminating this equipment altogether. However, these strategies can be difficult to achieve on a large scale due to policy implications.

Rather than fully phasing out this equipment, it is also possible to influence occupant purchasing habits that could aim to both bring less equipment onto Stanford's campus and procure energy efficient equipment when applicable. The inventory revealed that there are currently 7,975 pieces of office equipment on campus that are not Energy Star qualified. If all of this equipment were Energy Star qualified, the university could be saving an estimated 709,522 kWh per year. Similarly, there are 4,752 pieces of lab equipment on campus that do not meet energy efficiency standards, which is adding an estimated 6,012,842 kWh per year of unnecessary load to Stanford's consumption. On average, it is estimated that 222 kWh/yr could be saved per piece of office equipment brought on to campus if the Energy Star qualified model were purchased. Similarly, an estimated average of 1,571 kWh/yr could be saved per piece of lab equipment purchased. While directly replacing most of this equipment was not shown to have a justifiable payback period, new equipment brought on to campus as population grows and older equipment breaks down or naturally phases out should certainly meet high energy efficiency standards, and procurement strategies should focus on encouraging this purchasing behavior.

3.2.6 Barriers to Implementation

There are many challenges to implementing large-scale plug load reduction programs, especially on a university campus. While the many building types that are present on a university campus allow for streamlined plug load data collection, they also present unique challenges to reducing plug load energy consumption. First, the university's research mission is always the highest priority, so it is essential to mold all energy reduction initiatives into the academic mission, rather than introduce competing priorities. This can affect the selection of measures that are implemented at a research institution, as well as the messaging around their implementation, to ensure that the mutual benefits are highlighted. Furthermore, the programs and messaging need to be flexible enough to adapt to differing cultures among various departments, schools, and building types. Finally, building occupancy on a university campus—even within buildings deemed as office buildings—can vary significantly from that of commercial office buildings. With students coming in and out of many buildings at all hours of the day, routine shut off of appliances at night is not always an option. With unpredictable hours of operation, it can be a challenge to consistently reduce loads, which is a key difference between buildings on a university campus and other commercial buildings and highlights the need for studies focused specifically on plug loads at universities.

3.3 Sensitivity

The electricity consumption and savings estimates listed throughout this paper are entirely dependent on assumptions regarding power draw and time spent in various power states. Inherent in using assumptions to develop estimates is a level of uncertainty. To quantify and address the level of uncertainty in this study, a sensitivity analysis was performed. To determine the sensitivity of the energy consumption and savings estimates, key inputs were adjusted to determine minimum and maximum estimates for both energy consumption and savings. For consumption, assumptions were adjusted for every type of equipment by attribute. For savings, assumptions were adjusted for every savings opportunity identified and aggregated based on the opportunities selected as viable measures, discussed above. Overall, by applying minimum and maximum estimates, the plug load electricity consumption captured in this study could range from 12% to 40% of total building electricity consumption at Stanford.

Table 9 shows the percent variation of minimum and maximum estimates from the best estimates included in this paper for both consumption and savings. The range for savings estimates is slightly higher than that for consumption estimates because the minimum and maximum savings values were calculated based on the respective minimum and maximum consumption values. Ultimately, the sensitivity analysis revealed that in the minimum consumption and savings scenario, plug load savings could comprise 31% of the plug load consumption captured in this study, whereas in the maximum scenario, plug loads savings could comprise 28% of plug load consumption. Finally, in the “worst” case scenario of minimum savings paired with maximum consumption, plug load savings could comprise 9% of plug load consumption, which in this case would still equate to over 8 million kWh of savings per year.

Table 9: Percent increase and decrease from best estimates

	Percent Increase, Maximum Estimate	**Percent Decrease, Minimum Estimate**
Consumption	82%	46%
Savings	89%	38%

4. Conclusion

This study was designed to comprehensively collect data on the types and quantities of equipment that are present on Stanford’s campus to understand plug load electricity breakdown and reduction strategies. Specifically, the plug loads analyzed in this study were estimated to comprise 32% of the total energy use of the 220 buildings included in the inventory, with lab equipment consuming the highest portion of electricity and computers and monitors as the most prevalent types of equipment on campus. Additionally, this study estimates that plug loads could be reduced by 27% using cost-effective, off-the-shelf technologies combined with behavioral changes. Server consolidation and virtualization initiatives were found to have the highest savings potential of all plug load reduction strategies, while simple energy efficiency measures like installing timers and vending misers were found to be the most feasible and have relatively low ROIs. The findings from this study would be complimented by future research into equipment operating patterns, ease of implementation of savings methods, and actual energy-saving potential.

The bottom-up strategy employed in this study aligned well with submetered plug load data, suggesting that surveys can be good indicators for plug load energy consumption. However, measured energy consumption data would be preferred, and in fact, building codes like California’s Title 24, which now requires substantial submetering in buildings, are already helping to achieve this. Several previous studies have included equipment metering at the outlet, but additional testing of this equipment, especially regarding the equipment’s operation on a university campus, would be beneficial. Moreover, the large amount of effort required to attach a meter to every piece of equipment included in plug load studies severely limits the scale of the studies. As metering technology improves in this regard, more equipment can be included in these studies, and energy consumption patterns of various types of plug load equipment on a larger scale across multiple building types can more easily be tested.

More advanced load disaggregation technologies also have the potential to facilitate plug load data collection. As load disaggregation technologies develop to be able to identify the specific signatures of various appliances and other types of plug load equipment, those services can be used to predict what type of equipment is being used in a building and when without having to conduct physical building surveys. Stanford’s equipment inventory provides a baseline with which this this data can be compared in the future. However, because this study only captured a snapshot in time of the equipment on Stanford’s campus, there is currently no mechanism built in to this study for tracking changes over time. While some prior studies have included multiple building surveys, they have primarily done so in order to track seasonal changes in the presence of various types of equipment [7]. However, to our knowledge, robust surveys have not been conducted to date to track equipment presence and/or operation over time. This information would be extremely informative so that organizations could predict trends in their long-term plug load energy consumption patterns.

Finally, many of the plug load reduction strategies determined to be effective as a result of this study rely on changes to human behavior. There would be significant value in developing a better understanding of how best to bring about sustained behavior change. Studies of behavior programs to date have shown that various types of behavior programs have varying results over time. For instance, one study found that regular emails to occupants reduced plug load draw during unoccupied hours by 4% [7]. Another study found that while behavior campaigns did result in immediate savings, the savings could not be sustained over time [19]. More robust data on the effectiveness of various types of behavior change strategies would be invaluable in formulating effective plug load energy reduction programs across sectors. Studies that include a focus on university campuses would be particularly helpful since there is such high variation in both population types (faculty, staff and students) and building types at universities.

As plug loads continue to increase as a percentage of energy consumption in commercial buildings, it will become more and more important to understand how to effectively manage them, especially in reducing energy waste. Ideally, future studies will combine with developing technology to continue to make it easier to measure, track, and reduce plug loads over time. In the meantime, building surveys—though they involve significant effort—are an effective method for collecting plug load data at a granular level and can continue to inform the constantly changing realm of plug loads across many building types.

Appendices

Appendix A: Equipment Classification

Category	Equipment Type	Attributes	Equipment Rules	Common Categorization
Audio/Video	Overhead Projector	Cart/ceiling		Miscellaneous Equipment
	TV/LCD Screen	Brand Energy Star Status		Miscellaneous Equipment, Electronics
	VCR	Energy Star Status	VCR/DVD combination recorded as VCR	Miscellaneous Equipment, Electronics
	DVD Player	Energ Star Status	VCR/DVD combination recorded as VCR	Miscellaneous Equipment, Electronics
	Phone	VOIP/No VOIP		Office Equipment, ICTs, Electronics
	Speakers		Any stand-alone speakers	Office Equipment, Electronics
	Stereo			Miscellaneous Equipment, Electronics
	Subwoofer			Miscellaneous Equipment, Electronics
	Cable Box			Miscellaneous Equipment, Electronics
Computers & Monitors	Personal Computer	Brand Laptop/Desktop	Apple desktops combine monitor and personal computer into one device; these were listed as Apple desktop computers	Office Equipment, ICTs, Electronics
	LCD Monitor	Brand		Office Equipment, ICTs, Electronics
	Server	Physical Size	1U is approximately 1. 5 inches	Office Equipment, ICTs
	UPS	Size	Small UPSs are plug-in power supplies for standard workstations; small and medium UPS are more likely to be found in data centers	Office Equipment, ICTs
	Network Switch			Office Equipment, ICTs, Electronics
	External Hard Drive			Miscellaneous Equipment, ICTs, Electronics
	Docking Station	Laptop Present/Not Present		Office Equipment, ICTs, Electronics
	CRT Monitor			Office Equipment, ICTs, Electronics
Gym & Training Equipment	Treadmill		Only record electrically-powered machines	Miscellaneous Equipment
	Stationary Bike		Only record electrically-powered machines	Miscellaneous Equipment
	Elliptical		Only record electrically-powered machines	Miscellaneous Equipment
	Ice Machine	Ice Storage Capacity		Miscellaneous Equipment
	Whirlpool	Volume	Only record electrically-powered machines	Miscellaneous Equipment
Kitchen & Breakroom	Vending Machine	Vending Miser/No Vending Miser		Miscellaneous Equipment
	Personal Refrigerator	Brand Energy Star Status	Any refrigerator used only by one person, no matter the size	Miscellaneous Equipment, Traditional End Use

	Common Refrigerator	Brand Energy Star Status	Any residential-style refrigerator (usually combined with a freezer)	Miscellaneous Equipment, Traditional End Use
	Coffee Maker	Single cup/single pot/multi-pot		Miscellaneous Equipment
	Water Cooler/Heater	Hot only/cold only/both	Any water dispenser, whether tanked or tankless, under counter or stand alone	Miscellaneous Equipment, Traditional End Use
	Microwave			Miscellaneous Equipment
	Dishwasher	Energy Star Status		Miscellaneous Equipment, Traditional End Use
	Toaster	Slot/Oven		Miscellaneous Equipment
	Electric Kettle	Auto-off/No auto-off		Miscellaneous Equipment
Lab Equipment	Lab Freezer	Brand Full-sized upright/full-sized chest/under counter Temperature	Any freezer inside a lab, or marked "lab use only" or "no food"	Miscellaneous Equipment (Laboratory/Medical)
	Autoclave	Floor mounted/countertop		Miscellaneous Equipment (Laboratory/Medical)
	Centrifuge	Mini/countertop/floor mounted		Miscellaneous Equipment (Laboratory/Medical)
	Lab Refrigerator	Brand Full-sized/under counter	Any refrigerator inside a lab, or marked "lab use only" or "no food"	Miscellaneous Equipment (Laboratory/Medical)
	Microscope	On/Off In use/not in use		Miscellaneous Equipment (Laboratory/Medical)
	Incubator	Floor mounted/countertop Shaking/not shaking Temperature		Miscellaneous Equipment (Laboratory/Medical)
	Grow Lamps/Plug Lighting		Grow lamps that are NOT hardwired	Miscellaneous Equipment (Laboratory/Medical)
	Vortex Mixer			Miscellaneous Equipment (Laboratory/Medical)
	Shake Table	Floor mounted/countertop	Any device that is a shake table only. Shaking incubators, water baths, etc. should be recorded as those items with the "shaking" attribute.	Miscellaneous Equipment (Laboratory/Medical)
	Hot Plate		Any device that acts as a hot plate or burner, including heat blocks	Miscellaneous Equipment (Laboratory/Medical)
	Water Bath	Temperature Shaking/not shaking Volume		Miscellaneous Equipment (Laboratory/Medical)
Laundry Equipment	Washing Machine	Front-loading/Top-loading Energy Star Status		Miscellaneous Equipment, Traditional End Use
	Dryer			Miscellaneous Equipment, Traditional End Use
Occupancy	Occupant Count			N/A

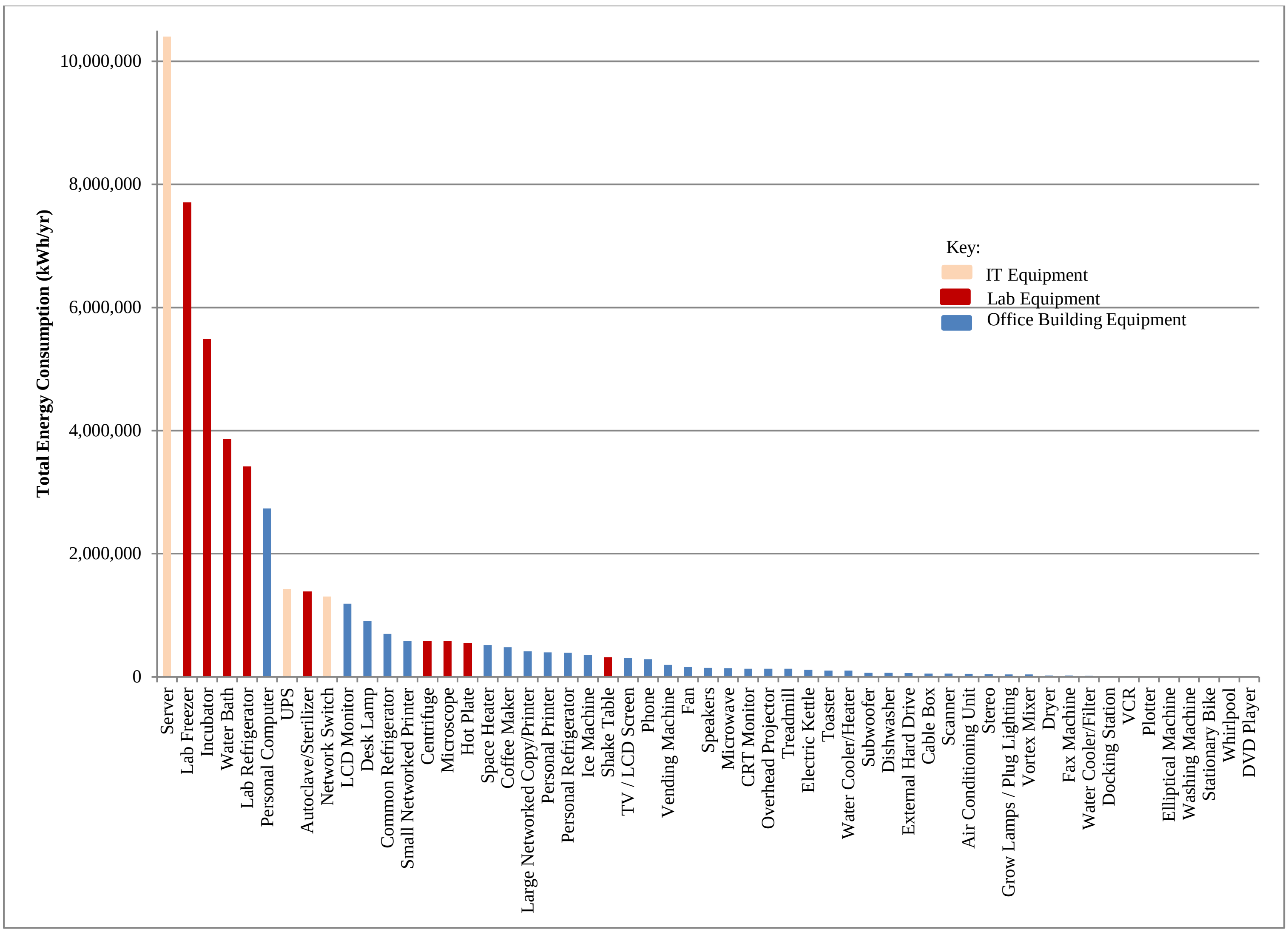
Office Occupant Comfort	Space Heater	Exposed Coils/Non-exposed coils	Space heaters recorded even if not plugged in	Miscellaneous Equipment, Traditional End Use
	Fan	Box/rotating/gym	A gym fan is any fan that is NOT hardwired that is larger than a personal fan	Miscellaneous Equipment, Traditional End Use
	Desk Lamp	Incandescent/Halogen/Fluorescent/LED	Any lighting that is NOT hardwired, including lighting attached to desks	Miscellaneous Equipment, Traditional End Use
	Air Conditioning Unit	Energy Star Status		Miscellaneous Equipment, Traditional End Use
Printers & Scanners	Personal Printer	Brand Energy Star Status Fax Capability	Any printer used by a single person, no matter the size or functionality	Office Equipment, ICTs, Electronics
	Small Networked Printer	Brand Energy Star Status Fax Capability	Any printer used by multiple people	Office Equipment, ICTs, Electronics
	Large Networked Copy/Printer	Brand Energy Star Status		Office Equipment, ICTs, Electronics
	Plotter			Office Equipment, ICTs, Electronics
	Scanner			Office Equipment, ICTs, Electronics
	Fax Machine		Devices that are fax machines ONLY. If a printer has fax functionality, it is recorded as a printer.	Office Equipment, ICTs, Electronics

Appendix B: Equipment Count and Energy Consumption

Category	Equipment Type	Total Count	Percent Count of Total	Average UES (kWh/yr)	Percent Energy Used of Total	Number per 1000 SqFt	Number per Occupant
Audio/Video	TV / LCD Screen	1734	1.57%	175	0.63%	0.19	0.10
	Phone	10485	9.49%	27	0.59%	1.18	0.63
	Speakers	2620	2.37%	55	0.30%	0.29	0.16
	Overhead Projector	759	0.69%	175	0.28%	0.09	0.05
	Subwoofer	398	0.36%	168	0.14%	0.04	0.02
	Cable Box	194	0.18%	272	0.11%	0.02	0.01
	Stereo	398	0.36%	112	0.09%	0.04	0.02
	VCR	257	0.23%	42	0.02%	0.03	0.02
	DVD Player	325	0.29%	19	0.01%	0.04	0.02
Computers & Monitors	Server	2049	1.85%	5075	21.57%	0.23	0.12
	Personal Computer	20117	18.20%	136	5.67%	2.26	1.21
	UPS	1416	1.28%	1009	2.96%	0.16	0.09
	Network Switch	2631	2.38%	495	2.70%	0.30	0.16
	LCD Monitor	18803	17.01%	63	2.47%	2.11	1.13
	CRT Monitor	402	0.36%	333	0.28%	0.05	0.02
	External Hard Drive	1326	1.20%	47	0.13%	0.15	0.08
	Docking Station	1368	1.24%	9	0.02%	0.15	0.08
Gym & Training Equipment	Ice Machine	125	0.11%	2865	0.74%	0.01	0.01
	Treadmill	64	0.06%	2044	0.27%	0.01	0.00
	Elliptical Machine	50	0.05%	175	0.02%	0.01	0.00
	Stationary Bike	23	0.02%	292	0.01%	0.00	0.00
	Whirlpool	3	0.00%	2175	0.01%	0.00	0.00
Kitchen & Breakroom	Common Refrigerator	919	0.83%	761	1.45%	0.10	0.06
	Coffee Maker	1022	0.92%	472	1.00%	0.11	0.06
	Personal Refrigerator	1277	1.16%	308	0.82%	0.14	0.08
	Vending Machine	81	0.07%	2375	0.40%	0.01	0.00
	Microwave	1221	1.10%	115	0.29%	0.14	0.07
	Electric Kettle	427	0.39%	265	0.23%	0.05	0.03
	Toaster	476	0.43%	213	0.21%	0.05	0.03
	Water Cooler/Heater	486	0.44%	203	0.20%	0.05	0.03
	Dishwasher	102	0.09%	650	0.14%	0.01	0.01
	Water Cooler/Filter	79	0.07%	221	0.04%	0.01	0.00
Lab Equipment	Lab Freezer	1520	1.38%	5070	15.98%	0.17	0.09
	Incubator	1600	1.45%	3427	11.37%	0.18	0.10
	Water Bath	986	0.89%	3919	8.02%	0.11	0.06
	Lab Refrigerator	1759	1.59%	1943	7.09%	0.20	0.11
	Autoclave/Sterilizer	167	0.15%	8295	2.87%	0.02	0.01
	Centrifuge	2746	2.48%	211	1.20%	0.31	0.16
	Microscope	1649	1.49%	350	1.20%	0.19	0.10
	Hot Plate	2273	2.06%	243	1.15%	0.26	0.14
	Shake Table	644	0.58%	485	0.65%	0.07	0.04

	Grow Lamps / Plug Lighting	185	0.17%	210	0.08%	0.02	0.01
	Vortex Mixer	1593	1.44%	24	0.08%	0.18	0.10
	Dryer	25	0.02%	858	0.04%	0.00	0.00
	Washing Machine	19	0.02%	391	0.02%	0.00	0.00
Office Occupant Comfort	Desk Lamp	13563	12.27%	67	1.88%	1.52	0.81
	Space Heater	955	0.86%	542	1.07%	0.11	0.06
	Fan	1865	1.69%	84	0.32%	0.21	0.11
	Air Conditioning Unit	151	0.14%	314	0.10%	0.02	0.01
Printers & Scanners	Small Networked Printer	2037	1.84%	287	1.21%	0.23	0.12
	Large Networked Copy/Printer	520	0.47%	799	0.86%	0.06	0.03
	Personal Printer	3582	3.24%	111	0.82%	0.40	0.22
	Scanner	614	0.56%	84	0.11%	0.07	0.04
	Fax Machine	378	0.34%	54	0.04%	0.04	0.02
	Plotter	61	0.06%	163	0.02%	0.01	0.00

Appendix C



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