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Green Labs are Gold: Evaluating and Improving Environmental Impact of USF's Laboratories

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ABSTRACT

The University of South Florida has been taking many steps to becoming a more environmentally conscientious campus, from substantial actions, such LEED-certification on newly constructed buildings and the approval of a tuition fee to fund energy related improvements, to seemingly miniscule improvements including the use of more environmentally friendly restroom supplies and an increase in the number of recycling containers available. Being a research-oriented university, USF has many labs on campus, including the newest facilities in the Interdisciplinary Sciences building. However, in a university environment, some of the largest investments in resources are the laboratories. In an effort to increase the environmental efficiency of the campus labs, a brief guide was created by a group of undergraduates for the labs to follow in the spring semester of 2011.

In order to provide support the proposals in that guide, this project was designed to research the positive environmental effect that any changes would result from adopting the idea put forth in the guide. To reinforce the previous project, additional points were researched that were not in the original. To provide a comparison, the chemistry laboratories at USF were observed, taking the environmental impact of the methods used in the laboratories into consideration where possible. This research will provide a valuable tool for the continued development of USF's research facilities, and will aim to give those with control over the construction and renovation of the new and old labs some insight into ways that USF can continue to simultaneously expand its facilities and promote a green attitude amongst all who participate.

TABLE OF CONTENTS

I. An Introduction to Environmentally Conscious Labs 4
A. The "Green Campus" Movement 4
B. To What Extent Do Laboratories Use Resources? 4
C. Incentives for a Greener Lab 5
D. USF's Own "Green Lab Guide" 6
II. Behavioral Changes 7
A. Energy Saving Techniques 7
a. General Electricity Guidelines 7
b. Proper Fume Hood Use 8
B. Efficient Use of Resources 9
a. Prevention of Waste 9
b. Green Chemistry 11
C. Evaluation of Labs 11
a. Green Lab Surveys 11
b. The Green Representative 12
D. Efforts to Promote Green Habits at USF 12
III. Material and Chemical Changes 14
A. Chemical Inventory Management 14
a. General Management Guidelines 14
b. Inventory Management Software 14
c. The Hazardous Inventory Tracking System 15
B. Chemical/Material Replacements 15
a. General Material Replacements 16
b. The Green Alternatives Wizard 16
C. Chemical Reclamation and Repurposing 17
D. Chemical and Material Policies at USF 18
IV. Changes in Equipment and Facilities 18
A. Maintenance of Facilities 19
a. Optimizing Lab Performance 19
b. Lab Check-Up 20
B. Purchasing New Equipment 20
a. General Equipment 21
b. Fume Hoods 21
c. Air Conditioning 23
d. Water- Using Equipment 23
e. Solvent Stills 24
C. Uses for Old Equipment 25
a. Selling Old Equipment 25
b. Donating Old Equipment 26
c. Disposing of Broken Lab Equipment 27
D. Equipment Policy at USF 28
V. Conclusion & Suggestions 29
Appendix A: Useful Resources 32
Appendix B: Selected Personal Communications 34
A. Questionnaire Concerning EHS Involvement in Environmental Efforts 34
B. Sustainable Information for USF's ISA building 35
C. Energy Use Comparison for NES and CPR (CY 2011) 36
Works Cited 37

I. AN INTRODUCTION TO ENVIRONMENTALLY CONSCIOUS LABS

A. The "Green Campus" Movement

In the past century, the general public has drawn an ever increasing focus to environmentalism. As a result, an increasing number of organizations are "going green" by adopting more environmentally conscious practices. A part of the motivation for such changes may be driven by an opportunity to increase public favor amongst competitors, using a green methodology as a marketing factor (Polonsky, 1994). Despite not being a traditional business model, universities nevertheless are participants in a competition for consumer attention. From new students to distinguished faculty, institutions of higher education are looking for ways to stand out amongst the multitude of other campuses. One trend that prospective attendees may look for in their campus is the attitude of the university towards the environment. This is evident in the fact that some college preparatory companies are now including "green campuses" as a subsection of published materials designed to help students decide on what college to enroll at (Leckstrom, 2008).When considering what facilities are the most resource-intensive, the campus laboratories are one of, if not the biggest target.

B. To What Extent Do Laboratories Use Resources?

In a university setting, laboratories require the largest investment of resources to maintain. Much of the energy resources go into preventing hazardous conditions for those that need to use the facilities. The chemicals used are often volatile (readily form a vapor) and require experiments to be performed under a fume hood to limit exposure to the chemical vapor. Since the ventilated air usually contains traces of such chemicals, it would be a health hazard to recirculate the air through the building, instead opting for single pass ventilation. Lab equipment is also expensive in terms of the energy used. Much of the equipment required by the lab is left on for a large portion of the day, if not overnight. Such extended periods of activation may be out of necessity, such as freezers and rocking agitators containing samples, or for convenience, as in the case of heat-drying ovens and lab computers. Such intensive equipment use is reflected in a university's energy distribution. At Harvard University, labs account for about a quarter of building area, but consume approximately half of the total utilities (Nolan, 76). The distribution is even more skewed in favor of laboratories elsewhere;

the labs in the University of California, Los Angeles account for ten percent of the building space, but accounts for over sixty percent of the total energy use (Borchardt, 2009).

USF is no different from these other universities. The Natural and Environmental Sciences building (NES) is dedicated to both teaching and research laboratories. Cooper Hall (CPR) is one of the most populated buildings on campus, containing lecture halls, classrooms, and even a restaurant. These two buildings on USF's Tampa campus, while similar in size, differ greatly in their energy usage; when determining the annual energy use through electrical means and water heating/cooling for 2011, NES had used over twice as much energy as CPR (*See Appendix B*) (Desai [Personal Communication], 2012).

Labs also create a large amount of waste in the normal course of use; waste products range from simple solvents, such as water, to biologically or chemically hazardous wastes that require special disposal. Some equipment in the laboratory relies on a constant supply of water to provide cooling, and it is often the case that the water is flushed into the drain after passing through. This stresses the labs both ecologically and financially, as wasting water negatively affects the environment and increases the water utility bill (Nolan, 76).

C. Incentives for a Greener Lab

While green facilities do potentially give the campus an appeal to some prospective students and faculty, the major tangible incentive for a greener university is lowering the price of running the facilities. Because labs are energy intensive, the amount of money used to keep them up and running is substantial. By lowering the amount of energy that the facilities use, the costs will predictably decrease, freeing some of the budget for other ventures in the labs, such as new equipment and so on. Such success is not undocumented, as annual projected results for a sample test group of 16 labs at the University of Washington at St. Louis concluded that a savings of 80,000 pounds of carbon dioxide and about $2,000 in energy bills were possible from the sample group alone. If WUStL was able to expand the initiative to half of its facilities, it would see savings of nearly $12,000 and over 2 million pounds of carbon dioxide emissions from the campus annually (Daues, 2012).

Another possible incentive for the implementation of a lab greening initiative is the chance to receive funding through private or public sponsors. Several grants for universities focus on the establishment and promotion of environmentally conscious practices at the campus. Opportunities for grant money have been offered from government programs such as the Environmental Protection Agency, which awards money to fund environmental projects in education, including such ventures as reducing the emissions of buses on campus (Harris-Young, 2007). Many private corporations are also offering grants to expand the environmental attitude of campus laboratories and students in the United States. In February of 2012, the University of California, Berkley received a grant for $3.5 million from the Dow Chemical Company to develop more environmentally conscious chemistry practices by renovating the chemistry labs, incorporating sustainability, and providing modern, efficient equipment (University of California, 2012).

D. USF's Own "Green Lab Guide"

In the spring of 2011, a group of students chose to create a guide for the University of South Florida's laboratories with the goal of lowering the impact of the teaching labs on the environment. Drawing inspiration from the success of similar programs implemented at other universities, work immediately began on building a guide to be presented to USF's Department of Environmental Health and Safety (EHS). The final product of the project was a flyer that was intended to be distributed to the labs on campus that would inform any person who had involvement in the labs of the more environmentally conscious choices that were available. Possible equipment changes were listed, with the intention that those in charge of purchasing new supplies would be aware of the more environmentally efficient choices of equipment and materials, as well as some that would result in saving money in the long run. General behavior guidelines were included in order to maximize the efficiency of the equipment used during each lab. Many of the points were targeted at experimentation intended as learning experience rather than those dedicated to research. As the project drew to its conclusion, the flyer was electronically transferred to USF's Department of EHS for distribution (Abdel-Rahim *et. al*, 2011).

While the finished product was a success, the guide was also designed to be expanded and retooled to meet the circumstances of the labs on any given year. Thus, this thesis was formulated with the intention of expanding and giving a more in-depth guide to labs at USF.

II. BEHAVIORAL CHANGES

The purpose of this section is to present behavior that would require minimal expenditure of resources, yet have an effect on the environmental consciousness of the lab that uses these procedures. Many of the behaviors outlined in this section may apply to both coordinator and student alike, and will require participation from both parties to be effective. However, due to the low monetary investment required to participate, these approaches may be adopted in a fairly quick timeframe.

A. Energy Saving Techniques

Whether powering the fume hoods or to heat a solution, electricity is a mainstay in an teaching laboratory. While some power consuming sources must remain active to avoid a potential safety hazard, there are many adjustments that a lab may take to improve the performance of the energy consuming devices without raising the costs of the department.

a. General Electricity Guidelines

Energy saving methods that can be used in general purpose buildings may generally work in favor of the labs as well. Simple steps such as turning off the lights of unattended labs and offices lowers the energy consumption as expected. Another way to decrease the amount of energy consumed is to forego using the overhead lights when the laboratory is not occupied by a significant number of people. Instead, area lighting may be used to light the occupied workspace, reducing the amount of energy used by the lighting system (Borchardt, 2009). This may be easily accomplished in organic and associated labs using fume hoods, as each fume hood is equipped with a bench light that provides a sufficient amount of light for the work area.

Another distinguishable source of energy consumption is computers and the equipment associated with them, especially when left powered on for extended time periods. Such energy use may be mitigated by shutting down the computers when they are not needed, such as when the lab is finished being used for the day, or when the occupying lab group is not using the machines. In addition, when a lab group that uses the computers dismisses and another lab group will be coming in later needs to use the machines, the computers may be set to a low-power sleep mode to save power while being able to be quickly turned back on (Borchardt, 2009).

Furthermore, other electrical regulations will help in lowering energy use. In an average building, the energy used by power drain from electronics in standby mode accounts for almost 10% of the total energy total. Such energy drain is especially prevalent in power strips and power cords with an integrated transformer. Since many of the instruments in the lab are not being used at one time, unplugging the power cords will prevent this so called "vampire power" being leeched from the unattended machines (Raphael, 2008). When the lab room will not be used for a long period of time (i.e. for Spring or Winter Break), the air conditioning should be adjusted to be closer to the outside temperature (warmer in the spring/summer and cooler in the fall/winter) when it is safe to do so. By lowering the reliance on the conditioning system when the rooms are unoccupied, the amount of electricity wasted is minimized and the expenses for powering the building are lowered as a side effect (Borchardt, 2009).

b. Proper Fume Hood Use

Due to the high level of energy use by fume hoods, they are considered separately from other electrical equipment. Fume hoods are a necessary utility for nearly all higher-level chemistry laboratories. With hazardous chemical fumes being produced by the reactions carried out in the lab, the hoods provide the proper ventilation to protect those experimenting. However, taking such safety measures does not come without a price; fume hoods are perhaps the most energy demanding pieces of equipment in a laboratory setting. It is estimated that a building containing fume hoods increases the energy consumption by four to five times that of a typical commercial building (Mills & Sartor, 2005). Since the fume hoods may not be simply turned off between uses due to safety concerns, the best course of action is to ensure that the hoods are operating at optimum capacity.

Closing the sash of an unused fume hood is a relatively simple action that produces a great effect. A closed sash limits the velocity of airflow through the ventilation for the hoods, significantly reducing the amount of energy consumed in the process (Borchardt, 2009). In addition, regulating the height of the fume hood when it is in use also increases the energy efficiency of the lab in question. The general agreement is on a sash height of about eighteen inches when working in the hood. This not only raises the energy efficiency of the hood, but also increases the factor in which the hood protects the user from vapors released by the contents (Boger, 2008). In addition, when conducting an experiment requiring the use of fume hoods, if the procedure calls for an extended period of inactivity (allowing the solution to boil, distill, cool, etc.), closing the fume hood during this time will increase the effectiveness of the ventilation, as well as protect against any hazards that may occur while not interacting with the instruments (i.e. spills from boiling, breakage from misuse, etc.) Other things to consider when working with the fume hoods are optimizing the flow of air through the positioning of the chemicals that are being worked on. In general, chemicals should be positioned no closer than six inches from the opening of the fume hood, which has the additional effect of preventing vapors from escaping the current in the hood (Boger, 2008).

B. Efficient Use of Resources

a. Prevention of Waste

The first principle of green chemistry is the prevention of excess waste. This may be accomplished through careful planning and procedure, ensuring that trials do not need to be repeated because of careless handling of reagents and equipment and through the elimination of excess waste of chemical reagents. The goals of waste minimization should be to minimize used chemicals, the waste from the experiment, and overall risk associated with the chemicals being used (CPSMA & DELS, 1995).

When possible, any material that is able to be recycled (worksheets, plastic pipette tip boxes, certain types of glassware, etc.) should be recycled or reused. For example, the plastic cover of the box of micropipette tips may be repurposed as a dish when working with gel electrophoresis for storage between lab periods or for soaking in solvent (Pollenz, Kimble & Cannons, 2008). Many companies also offer to take back the packaging for their brand of supplies (pipette tips in particular), usually in exchange for a nominal reduction in the cost of replacement supplies. In addition, many labs rely on the submission of typed lab reports for grades; a paper recycling bins should be provided to accommodate those who elect not to keep the written report after it is returned.

Lab participants should be considerate of the use of a product or reagent and create the least amount of the material that is needed. For example, a starch indicator is used to determine the presence of iodine molecules in a solution. Due to the nature of the starch in the indicator solution, it is only useful if it is freshly prepared, and typically is not used after it is a day old. If an experiment calls for 160mL of the starch over 32 trials for a single lab section, then about 200mL of the solution should be more than enough for the lab per section. However, some labs create the solution fresh at the beginning of each section, in 1000mL (1 L) flasks, which is disposed of afterward, creating a large amount of liquid waste. Many individual lab experiments have some form of sensitive solution that must be prepared fresh to ensure quality (Carson, Sp. 2012). Therefore, by taking the precautions to only prepare what is needed, a lab may cut its experimental waste output significantly.

Water waste is another major problem for labs, as many of the instruments are water-intensive. Obviously, efficient usage of the tap when rinsing or dispensing water is a concern, saving an average of three gallons per minute when the tap is not in use. Turning off the tap when not in use will accumulate savings in water-use fees and wasted water. A lab oriented way to save water and energy is to not use as much distilled water when washing equipment. In order to make distilled water, untreated water must be boiled and then cooled back to liquid, removing contaminants. This process is very intensive in terms of energy and water; using tap water to wash the equipment and rinse the excess detergent will reduce the need to process more water for the distilled water reservoir. A final rinse with distilled water may be used to ensure that contaminants are removed (Buie, 2011).

A pollution prevention assessment may also prove to be useful for labs to reduce waste. According to a collaboration from the Board on Chemical Sciences and Technology (BCST) and Earth and Life Sciences (DELS) organizations, an assessment of one organic chemistry lab revealed that a group of 25 researchers used 1 L of quick-drying solvent (i.e. acetone) to expedite the cleaning of glassware and other items used. The principle reasons that the researchers used acetone to treat their equipment was the lack of cleaning materials and extra glassware to accommodate their research. The lab then purchased new glassware, better cleaning materials, and an ultrasonicator that cleaned with a mild detergent. These purchases saved enough of the solvent (through purchase and disposal costs) to cover the expense of the new equipment within three months (2011).

b. Green Chemistry

Lab managers should be trained in green chemistry processes. Although programs differ based on individual experiments and by department, most training programs conform to the principles of green chemistry established based on the work of Paul Anastas. According to the principles, green chemistry focuses on prevention of waste over the treatment or clean-up after it has been formed. This is logical, as this approach saves more resources than the alternatives mentioned. In this vein, experiments seeking to synthesize compounds should be designed to maximize the usage of reactants in the products, giving high percentage yields, and compounds used in the experiments should be optimized to minimize wastes. The principles also emphasize the use of safe chemicals, from solvents used in experiments, to making non-hazardous products for additional use. Attendance of a green chemistry conference should be encouraged by coordinators when possible. The principles and conferences may be found on the ACS Green Chemistry Institute's website (Anasatas & Warner, 1998).

C. Evaluation of Labs

a. Green Lab Surveys

Most famously established by Yale University, a "Green Lab Survey" is a method of certification in which labs on campus determine what actions and behaviors have been established to improve the sustainability of the facility. The model program at Yale was largely a voluntary effort, with a lab completing the survey at its discretion and submitting the form to Yale's Environmental Health and Safety Department for evaluation. Answers on the survey translated to points on the evaluation, and these points were then divvied up into grades. Grades of merit were awarded in levels based on the letters Y-A-L-E, with E being the most prestigious (any requiring an outstanding amount of effort to attain) ("The Yale Green", n.d.)

A survey of the labs on positive laboratory practices has the potential to benefit the labs on multiple stages. By itemizing the methods that a lab has taken to improve its environmental impact, the participants are given a point of reference to where the lab stands in its sustainability, what areas that have room for improvement, and a general idea of what options are available to the facility to improve the impact that it creates. By offering to grade the performance of the labs based on the answers to the survey, the program serves to bring recognition to a lab that may have otherwise contributed a large but unnoticed effort to improving the environmental impact of the school as a whole ("The Yale Green", n.d.).

b. The Green Representative

In order to streamline the process of certification, appointment of a "Green Representative" should be considered. The representative's duty is largely to increase the awareness of a lab to the possible areas of improvement that it may undertake. This was largely inspired by the certification program at Harvard, which dispatches a "green advocate" to help the labs evaluate their current policy. The procedure begins with a meeting being planned with a representative from the lab to do a walkthrough of the lab and associated offices. The advocate then returns to review the findings from the walkthrough and come up with recommendations to discuss with the lab group in conjunction with the representative. The group then agrees on a set number of recommendations to be adopted by the lab. This improves the ability of the labs to fulfill objectives, as the lab does not need to devote a large number of personnel towards finding ways to improve the lab sustainability. Instead, the advocate designated to the lab takes some of the burden away from the lab group ("FAS Green Lab", n.d.).

D. Efforts to Promote Green Habits at USF

USF's Department of Environmental Health and Safety has done exceptionally well in promoting the "health" and "safety" aspects of the campus, and has recently increased its efforts behind the "environmental" portion. Online, guidelines are available for safe and efficient fume hood use, as well as information regarding the different types of hoods on campus. In the past year, EHS has posted clings on the frames of the hoods, advising students on the optimal height of the sash, which provides the most benefit to energy use and safety while simultaneously allowing the experimenter to access the chemicals and equipment in the hood ("Fume Hoods", n.d.). From observational as well as practical experience, general electricity conservation methods are common practice in USF's labs (including turning off unused equipment, turning off lighting when the room is unoccupied, etc.). However, some of the more advanced methods (using bench lighting over ceiling lighting, unplugging idle equipment, etc.) are not typically used by the experimenters or promoted by the lab managers.

An increased focus on raising awareness of energy saving practices among the lab participants would magnify the current energy savings programs, increasing the savings and improving the environmental impact of the labs on campus.

While no resources on green chemistry training are publicly available on the EHS website, there are links to other sites regarding green chemistry. This is an indication that the department is at least aware that programs exist for training. A suggestion for the EHS is to ramp up its efforts to increase awareness of the chemistry program and offer training, either voluntary or mandatory to further increase the awareness of the environmentally conscious choices that the lab staff may adopt in their operations.

Presentation of a usable lab survey was a prospective goal of the original USF Green Lab Group, but a full-fledged survey was not created. Instead, the points of the survey were integrated into the flyer that was distributed to EHS. The achievement titles were an offshoot of the system at Yale, instead integrating the school colors as levels of merit rather than the letters in the school's name. The first stage, "Green" would be awarded to labs that have made substantial efforts towards a greener lab. While an exact point value was not established, the general consensus was that an appreciable amount of progress and effort towards greening the lab would have earned this award. The higher level, "Gold" would have been reserved for the labs that made substantial progress in greening and were focused on continuing to improve the lab's impact in the future evaluation period. Generally, this would require some type of action plan for the lab to submit to whoever was chosen as the survey administrator for approval. According to a questionnaire filled out by a representative of EHS, the department has confidence that the implementation of such a survey is both realistic and beneficial (Lawrence [Personal Communication], 2012).

The laboratories able to earn these distinctions would not go without honor; similar to Yale's incentive, one planned reward for completion of the survey was an annual banquet, in which all associates of the lab (coordinator and assistants) would be invited. At the banquet, the labs that managed to earn a Green or Gold merit would be awarded a plaque to display in the lab (or equally appropriate place). This method of certification could be carried out on an annual basis, motivating the participating labs to continually strive to improve the environmental sustainability year after year ("The Yale Green", n.d.).

III. MATERIAL AND CHEMICAL CHANGES

A. Chemical Inventory Management

a. General Management Guidelines

When storing chemicals, it is important to ensure that the chemicals are stored properly. Placing stored chemicals on spill tray will prevent any compromised containers from leaking uncontrollably, keeping those mishaps locally confined to the tray. Chemical storage containers should be regularly inspected for any such leaks, and anything found to be a hazard due to such should be appropriately dealt with. By ensuring that the integrity of the chemical container is not compromised through cracking, leakage, or some other mishap, the safety of the lab is preserved, and the environment is not put at risk due to the leaked chemicals. If chemicals are stored properly, then they may be of use to multiple labs on campus (Buie, 2011).

b. Inventory Management Software

Knowing what chemicals are available on campus is a valuable way to lower consumption in the laboratory. Although this may be accomplished manually with several dedicated inventory managers, this is most efficiently accomplished with a searchable computer-based chemical database. If each person supervising each lab records what he/she uses during the course of the lab, the inventory may be monitored in actual time, letting those in charge of ordering chemicals and supplies keep track of when to order what is needed. In addition, if one lab needs a certain chemical, it may use the inventory manager to find labs that have a surplus of such chemical before ordering additional chemicals. Depending on the software chosen, additional information, such as the Chemical Abstracts Service (CAS) number, Material Safety Data Sheet (MSDS) information, and purchasing options may also be included in the inventory results. By consolidating the inventories of all of the labs, the number of redundant chemicals purchased is reduced, saving money and lowering the amount of waste generated from unused chemicals passing the expiration date. Some of the more sophisticated software optimizes this process further by printing adhesive bar codes to stick to the chemical containers that can quickly monitor the location of the chemical and the rate of consumption (BCST & DELS, 2011).

c. The Hazardous Inventory Tracking System

In terms of an inventory management program, USF has developed the Hazardous Inventory Tracking System (HITS), a comprehensive control system. It serves the purpose of giving the campus a way to share the inventory of each individual lab, while simultaneously increasing safety by providing information to emergency responders. The materials to be tracked by the first phase of the system include flammable liquids and solids, corrosives, toxic liquids and solids, among other things. The HITS is an ongoing project, and the subsequent phases of the project seek to include biological agents and other currently unapproved materials on the approved chemical listing ("Inventory Scope", n.d.). Unopened chemicals suitable for redistribution are listed under the HITS Surplus, which allows labs to request chemicals listed by calling the office with the bottle number after confirming that the chemical is available. The chemical will then be delivered to the lab that requests it by EHS staff. MSDS information is also available online, accessed through a specialized search ("HITS Tutorial", n.d.).

The utility also acts as the hub for chemical removal and disposal from USF's labs. After completing the information on the HITS tag (which entails materials and percentages in the waste container) and complete the necessary forms online. If the container is determined to at least partially hold highly toxic materials by the HITS program, then the wastes are designated as "P-Listed," and must be specially disposed of by EHS staff. After all necessary steps have been followed, the EHS will send specialists to pick up the container from the designated Satellite Accumulation Area. The HITS also allows the labs to request disposal materials if needed, including waste containers, buckets, tags and labels ("HITS Tutorial", n.d.).

B. Chemical/Material Replacements

Chemistry laboratories handle a large array of compounds, ranging from harmless solvents to incredibly reactive acids and bases. Naturally, some of these chemicals can provide devastating results if introduced into the atmosphere or water supply. However, in an teaching laboratory setting, an understanding of the type of reaction taking place is often the intended goal of the experiment, rather than the result of mixing specific chemicals. With such information in mind, many environmentally hazardous chemicals can be replaced with chemicals that are less hazardous or that can be effectively neutralized in the lab.

a. General Material Replacements

For general materials, sustainability efforts may follow those taken in non-lab environments, including as standard materials used in the lab being replaced with recyclable ones. For example, many laboratories on campus require the use of protective gloves that are contained in paperboard boxes. These boxes may be purchased from companies that use post-consumer recycled materials in the packaging, and may in turn be recycled again. Other materials that may be replaced with recycled materials in labs are batteries, corrugated cardboard and other paper products in general, and certain plastic packaging materials. The purchase of such recycled products contributes to an ecological trend amongst vendors by providing incentive to use more recycled materials in their products (Buie, 2011). In addition, some labs offer a manual, typically through Pro-Copy or the USF Bookstore, which are printed at the respective establishment. Insisting that the manuals be printed on chlorine-free or recycled paper would be a more sustainable approach to distribute the material over the alternative bleached white paper, encouraging the use of sustainable products.

b. The Green Alternatives Wizard

To aid in the selection of safer chemicals for the environment as well as the scientists, MIT has created a program that provides alternative chemicals and processes for existing procedures (*see Appendix A*). The wizard is a simple tool to use, listing all chemicals or processes on a dropdown menu. After selecting the chemical, the wizard lists all other chemicals that can be used in place of the one in question; for each chemical, summary with a list of pros and cons help the user decide on whether or not a certain chemical replacement would be appropriate for the experiment they are performing. From the results screen, the user may also access sites to purchase the chemical and access journal articles that support the claims of the summary page. An example of one such chemical that may be replaced is ethidium bromide; the chemical is a common compound used in biology labs to stain DNA, allowing it to appear under ultraviolet light. However, care must be taken when working with the chemical, as it is a known carcinogen and the waste requires handling by a hazardous materials disposal service (Pollenz, Kimble & Cannons, 2008). Inputting ethylene bromide into the Green Alternatives Wizard, a safer and more effective alternative to the stain is a brand-name compound called SybrSafe™, which boasts stronger fluorescence and lower disposal costs than ethylene bromide, even being approved for sewage disposal in certain states. However, the tradeoff is a higher up-front cost than ethidium bromide.

C. Chemical Reclamation and Repurposing

In some cases, it is possible to reclaim or reuse chemicals that are used in previous experiments. Such practices are green in that the materials that would normally be used for a single experiment may be used for additional experiments, saving time and chemicals that the lab must account for. Ideally, a chemical must be kept as pure as possible in order for that chemical to be recycled. For example, many titrations require the use of a 50mL burette to transfer solvent into an analyte. Oftentimes, the burette contains an excess of solvent due to a low volume requirement to reach the endpoint. This excess is almost always collected in a communal waste container for the experiment, mixing the chemicals of the titrant, titrand, and other miscellaneous chemicals used in the experiment. According to a study on behalf of a joint project between the Commission on Physical Sciences, Mathematics, and Applications (CPSMA) and the Engineering and Physical Sciences (DEPS), if the solvent used in the burette were to be purified using a distiller, the resulting recycled material would be of a consistently lower quality than if it had been collected in a separate container free of the other chemicals (1995).

(More information on types of solvent distillers may be found in Section IV-B-e)

In several cases of basic lab experimentation, the chemical products of one lab may be used as the basis for a following lab. Granted that single element solutions may be collected separately, solutions may be precipitated into solids, ready for use in a future lab. These samples should provide a quality that is acceptable for most experimentation done for the purpose of learning. In the case of a mixed element sample, it may be used as a reactant in a decomposition experiment, allowing the same materials to be used again. This reduces overall waste, as what would have been disposed of at the end of one particular experiment would be repurposed as a reactant in the next experiment. Good examples lie in the use of toxic metal elements in the qualitative analysis of inorganic lab experiments, such as cadmium and lead. Despite the relatively small mass of toxic metal elements normally used in experiments requiring such toxic compounds, the recycling and reuse of the same toxic species for multiple experiments will greatly reduce the stress on the environment and avoid some of the typically expensive disposal costs associated with the compounds (CPSMA & DELS, 1995).

D. Chemical and Material Policies at USF

According to a questionnaire submitted to Aisha Lawrence, Lab Safety and Hazardous Waste Manager for USF's Department of Environmental Health and Safety (*See Appendix B*), the university has a procedure to minimize lab-generated waste. In addition, all labs on campus are required to comply with HITS standards with no special exceptions granted to any laboratory's waste. The HITS is a project in development, and further phases of the HITS seek to include elements from the now-separate Radiation Safety and Biosafety programs on campus. In addition, EHS requires that all chemicals purchased must be accompanied by a Material Safety Data Sheet (MDMS) for approval, and hazardous chemical handlers must be trained in how to manage the material. However, in many cases, labs do not actively seek the help of EHS to decide on less hazardous chemicals, and training for lab managers does not incorporate environmental concerns beyond the subject of safety.

In terms of waste, minimization is not emphasized in a lab's curriculum, with little attention devoted to the subject. However, many lab manuals actively advise the participants on any hazards to the water supply if a chemical is disposed of via the drain. In addition, labs make waste collection bins available for each experiment, isolating all of the chemicals for one experiment into its own waste container. No instances of specific chemical collection were observed for the purpose of reuse or recycling. It is presumed that most, if not all, chemicals used in teaching labs are disposed of through the HITS instead of being distilled for reuse where possible.

IV. CHANGES IN EQUIPMENT AND FACILITIES

Equipment for science laboratories is continually improving. As such, there comes a time when newly developed equipment must be bought and old equipment needs to be replaced. This section seeks to guide those in charge of stocking and maintenance of the labs in making informed choices in their purchase and removal of equipment. Since scientific devices require a sizable amount of money to purchase, suggestions for buying new equipment should be taken to heart when the budget permits or when new equipment is absolutely necessary.

The lab facility itself is also subject to improvement as technology and research expands the understanding of a lab's consumption. As time marches forward, newer and more improved methods of building new facilities and maintaining older ones will allow the lab staff to improve the sustainability of lab operations without compromising the quality that is expected of the experiments.

A. Maintenance of Facilities

a. Optimizing Lab Performance

The environmental objective of optimizing the lab's performance is to streamline the process of using the laboratory, allowing the experiments to be conducted in a timely manner. This lowers the chances that trials will need to be repeated, thus lowering the chance of overusing resources. If a lab requires the use of specific classes of equipment (balances, water baths, etc.) the instruments should be zoned so that a large group of people will be able to use all available units without causing a bottleneck. Proper zoning will also serve to enhance the safety and increase the flexibility of the lab (Hackman, 2009). In addition, freezers and refrigerators can be oriented according to certain parameters that maximize their efficiency. These units may be indexed to minimize the amount of time that they are open, thus conserving the energy required to maintain the cool environment within. In addition, the orientation of the coolers has a bearing on the efficiency of the machines. Since refrigeration devices depend on the displacement of heat through the coil on the back, units in close proximity to other objects cannot disperse the generated heat. An open space of at least one foot around the cooling units will minimize the insulating effect of surrounding items (Borchardt. 2009).

When commissioning facilities, it is important to consider the size of the facility and choose a size that is optimal for the lab's purpose. This idea, termed "rightsizing," is a design choice that seeks to prevent an overestimation of the needed space within a lab. Over-sizing the building area leads to a cascade of other wasteful provisions, including oversized cooling and electrical systems. Failure to right-size results in a higher initial costs and increased operation expenses compared to an ideal facility (Goudarzi, 2012).

b. Lab Check-Up

It may be in the institution's interest to take on a retro-commissioning, or "lab check-up," campaign to conform to a higher standard of sustainability. While the finer details should be considered on a case-by-case basis, there are some general steps to take in the process of retro-commissioning. The first phase of the campaign involves developing a plan between the staff of the facility, EHS, design engineers, and the participants. The current specifications of the lab facility, current function statements, and any alterations should be gathered to supplement the discussion. The investigation should gather data on energy/utility use, determine any trends in the use of the lab, and test all of the equipment in terms of overall functionality, accuracy, and resource requirements. Of particular testing importance are the fume hoods in the labs, as they are significant in terms of safety and energy usage. After the investigation is complete, selected improvements should be prioritized and implemented. Each change should be followed by performance verifications for future reference. To finalize the changes made, any relevant information should be documented and any training deemed necessary should be given to the participants of the lab (BCST & DELS, 2011).

Much like the other efforts mentioned in other sections, a well executed sustainability drive holds additional financial incentives for the campus. A study by the EPA that observed the results of several retro-commissioning campaigns revealed a minimum energy use reduction of 30%, with the savings paying for the renovations within three years. Post-campaign, personnel should continue to monitor the efficiency of the labs; by ensuring that the systems are being used properly, the processes will continue to remain efficient. As technology and research improves the sustainability of labs, later committees may perform additional retro-commissioning efforts to bring the efficiency to the newly established ideal levels (BCST & DELS, 2011).

B. Purchasing New Equipment

Whether through age, failing function, or even having spare money in the budget, old lab machinery will need to be replaced at some point in time. When the inevitable time for replacement arises, those with the responsibility to purchase the new equipment should consider several factors before settling on a new device to take the old one's place.

a. General Equipment

When choosing electrical equipment, the energy efficiency should be one of the top priorities in selection. Noting the amount of energy required to run the machine as well as any conservation enhancements included in the equipment will give an idea of how much it will cost the lab in both dollars and the amount of greenhouse gases kept out of the atmosphere. With this in mind, many of the pieces of equipment used in a lab may be rated by the ENERGY STAR® organization according to energy use (Schmeltz & Duff, 2008). The decision on a rating is based on a number of variables; for example, refrigerators are rated on factors ranging from door openings to automatic defrosting settings. Choosing equipment that is rated by the organization is a simplified way to browse models and manufacturers without investing a substantial amount of time separating the efficient models from the wasteful ones ("ENERGY STAR® Laboratory", 2009).

b. Fume Hoods

Fume hoods should be considered one of the more permanent fixtures of the laboratory. Replacing the existing fume hoods entirely would be an expensive project to undertake and would put the labs out of commission for a period of time while the new hoods are installed. Therefore, brand-new fume hoods should only be considered for existing labs when there is absolutely no viable choice other than replacement. Aside from that fact, new hoods must also be considered when constructing new buildings intended to house laboratory work. Most standard fume hoods are classified as "constant volume" types, expelling the same amount of air, regardless of the sash position. These types of hoods are not as ecologically sound as their counterparts, as the amount of energy dedicated to keeping the machines at this output is the same, regardless of whether such utilization is safe or efficient (Reindorf & Goldman, 2011).

Due to the energy intensive nature of fume hoods, many newer models have options to increase efficiency. A "high performance hood" is designed to operate safely at less than the standard of 100 feet per second required of constant-volume hoods. This permits the hood to serve its safety obligations while using a lower amount of electrical energy. A hood with a variable air volume control adjusts airflow based on the position of the sash, optimizing the power needed to ensure that the proper amount of air is being pulled from the hood area for safety. This option limits the amount of air exhausted from the fume hoods, lowering the total cost of energy of the lab (Reindorf & Goldman, 2011). Another option for new fume hoods is the "Berkeley" style of fume hood. This type of hood relies on supplying the front of the operator with air, while only drawing in about 20-40% of the air from the operator. This method of operation creates a layer of fresh air that is contaminant free in front of the operator, resulting in a lower volume of exhaust required to remove errant chemical vapor and other contaminants. A side effect of the layer of air is that the efficiency is nearly similar at all sash positions (Mills & Sartor, 2005). One of the newest models of fume hoods is the recently developed "ductless model." This type of hood uses an activated carbon filter to purify the air and return the cleaned air to the lab. This prevents several thousand cubic feet from being expelled into the external environment, saving money. A hood such as this requires no ductwork, playing into a modular lab design scheme that gives labs the flexibility to fill a variety of roles. Manufacturers also extensively seek to prove the ability of the hoods, with safeguards such as a metal oxide detector, an "acid array" that monitors gas saturation levels, and more (DePalma, 2011). Because fume hoods are such an integral part of a scientific environment as well as a large investment of energy, the design is continually being researched and developed to improve their environmental impact.

Even with the multitude of new models, older models of fume hoods are by no means limited in their options; many different methods of retrofitting exist to increase the efficiency of the hoods. Such adjustments can reduce air flow, introduce variable flow controls, and other means of reducing energy consumption. Such means should be considered before completely replacing fume hoods, as retrofitting may cost from 10-25% of the price of a new hood, resulting in a return of investments after only one or two years (Reindorf & Goldman, 2011). The departments should also adopt the practice of having adjustable fume hoods inspected for misuse or improper airflow and recalibrating them to suit the need of the lab on a given semester. This has the potential to produce significant energy savings for the department, a victory for both the environment and the budget.

c. Air Conditioning

When installing an central air conditioning system in a laboratory building, safety requirements dictate that the system must take in a high percentage of fresh air from the outside of the building. This eliminates the option of installing the more energy efficient option of recirculating the air in the building. Instead, heat recovery systems allow the labs to maintain a safe air quality while reducing the amount of energy spent on conditioning the air. One such option is the rotary enthalpy wheel, which relies on the fresh air supply and the exhaust being in close proximity to lower heating needs for the building. Such methods involve a minor risk with contamination from the fume hood exhaust, with recirculated contamination levels below 0.1% when the purge system is working properly (Reindorf & Goldman, 2011). Of particular note is that different types of wheels conserve different extremes, needing two wheels reserved for heating and cooling respectively. However, the heat-conservation wheel may not be entirely necessary, as use of the heating system in the warm climate of Florida would be limited to a brief period in the winter.

Other options for labs requiring the safe degree of air quality instead may implement a "run-around-loop" system, which circulates fluid between two streams of air to heat or cool the air before venting it into the lab area. This has the additional benefit of being able to be retrofitted onto existing systems to increase the efficiency, rather than needing to replace the ventilation entirely (Reindorf & Goldman, 2011). By installing a "wrap-around-loop" alongside the run-around, the cooling capacity increases even more, saving energy in the more common hot months of Florida by pre-cooling the incoming air before being further conditioned by the powered cooling coil. This allows the conditioning system to run at a lower output to produce the same temperature ("Energy Recovery", 2003).

d. Water-Using Equipment

A common practice in the lab is the use of tap water to cool equipment or condense a solution, such as in distillation experiments typical of an organic chemistry lab. This produces a lot of water waste, as the tap water is cycled through an apparatus once before pouring into a waste drain. To address this concern, the use of a refrigerated recirculator is advised, which circulates a water solution from a self-contained reservoir to cool the equipment, effectively using the same water for multiple experiments. However, such an instrument is rather expensive at about $4,500 per unit; therefore, these should be seriously considered for the labs or pieces of equipment that use water-cooling intensively (BCST & DELS, 2011). A more economical approach to preventing water waste is to ensure that the flow of water to the equipment is being delivered at an appropriate rate. For example, a minimal amount of water is needed to pass through a condenser apparatus in order for it to work, with a small volume of water being expelled from the outward flowing tube. If conducted properly, the water being drained has little or no contaminants, and may be collected to be used as "gray water" to wash glassware with before a final rinse with distilled water (Buie, 2011).

A specific piece of water-using equipment to avoid is the water aspirator, which is used primarily in filtration and solvent-removal experiments in an organic chemistry lab. Water aspirators are hazardous in that they may contaminate the water cycled into the device with chemicals, which may in turn contaminate the waste water and sewer systems. Because of this, the water drained from an aspirator must be disposed of into a dedicated hazardous material receptacle, generating waste that will cost the university a good sum of money to dispose of. As an alternative, a vacuum or air aspirator should be given priority when purchasing equipment. This type of apparatus uses no water and only produces a minimal amount of waste; only the removed solvent requires dedicated disposal techniques (BCST & DELS, 2011).

e. Solvent Stills

In a number of experiments, the solvent used is required to be of a high purity, with contaminants such as oxygen, water, peroxides, etc. reduced to negligible amounts. To produce such solvents, a distillation apparatus is required, and either a thermal or column still is commonly chosen for the task. However, in terms of environmental impact, the column still should be considered superior to the thermal still, beating it in virtually all aspects. In terms of safety, a thermal still must be carefully handled, requiring a dedicated chemical hood to remove vapors. Reactive metal samples and high temperatures are needed to run the distillation, both of which pose a fire hazard. Due to such a risk to the safety of the lab and staff, thermal stills require at least partial attention when being run and may not be left unattended for safety reasons. They also is requires a substantial investment of water, using an average of 70,000 gallons of water annually. When considering a column still, most of the disadvantages of the thermal still are eliminated without sacrificing the yield. The apparatus is intrinsically safe, not requiring a dedicated hood to capture loose vapors, freeing up workspace for the participants to use for experimentation. The distillation process does not require heating elements or reactive metals to distill the chemicals, significantly reducing the fire hazard. In addition, a column still uses no water in the distillation process, reducing the department's water waste by 70,000 gallons per unit (BCST & DELS, 2011). Therefore, in terms of environmental impact, lab safety, and cost to the department, column stills should be the preferred piece of equipment when considering a distillation system.

C. Uses for Old Equipment

In some circumstances, a piece of equipment that is still functional may require replacement for some reason or another. In a case such as this, the machine itself may not be of use to the campus, but may still be useful in other settings. While redistribution within the campus is a logical choice, many lesser-known options are open to functional machines that are significantly better for both the environment and the scientific community when compared to disposing of them outright.

a. Selling Old Equipment

The market for used equipment is on the rise in the scientific community. In addition to participating as a buyer, the laboratories may also choose to sell old equipment to bolster the budget. However, a timeframe of about five years for analytical equipment (spectrophotometers, balances, microscopes, etc.) is suggested for significant returns on lab equipment, since increasing market standards for such instruments make older models obsolete. Other non-analytical equipment, such as agitators, freezers, and low-cost equipment may retain value after the five year period (Bird, 2010).

The process of selling the equipment is largely dependent on the vendor chosen as the middleman in the transaction. In some cases, the vendor acts as a salesman, refurbishing the equipment before listing it for sale on its choice of sales medium (typically web-based.) An advantage of selling the used equipment through such a handler is that returns are immediate on relevant instruments, as the secondhand company maintains an inventory rather than purchasing only the equipment it desires. However, because the company is trying to turn a profit, the money offered for old equipment is less than that of other options (Bird, 2010). Some types of vendors act as a means for buyer and seller to meet, similar to that of public auction websites. These mediators make money off of the sale by charging the seller a nominal fee in order to list the equipment. This tends to result in higher returns, as there is no official middleman to sell through, but returns tend to be more delayed than that of the sales handler. The seller is also responsible for the safe transport of the instruments to the buyer's facility (Bird, 2010.) The choice of seller to choose is largely dependent on the type of machinery needing to be sold, as the price for a certain type of machine fluctuates in a manner based upon demand.

b. Donating Old Equipment

While universities often have the financial means to purchase what equipment it needs, other places may view the cost of purchasing instruments as a major barrier to the science program. In such cases, the donation of surplus or replaced equipment is a viable option for a campus looking to reduce waste and lower the impact on the environment. Donating equipment is often tax deductable, and the lab does not need to pay the costs normally associated with outright disposal.

Public high school laboratories are one category of recipient to consider. Often needing to meticulously balance a budget, labs in high schools typically are required to go without a sufficient selection of equipment in the science courses. Universities may loosen the burden by donating unused lab equipment in a manner similar to the University of Notre Dame, which established its ND LIGHTS (Laboratory Instrumentation Giving Hope To Students) program in 2010, seeking to provide underserved high school labs with its old equipment. Their program has been a success so far, donating lab equipment worth a total of over $275,000. Such instruments donated were not limited to simple instruments and glassware; a DNA sequencer, microinjectors, and spectrophotometers were also donated. While the main focus of donating the used equipment was to provide the schools with the necessary resources, the opportunity to include student participation also presented itself to the university. A course was included in

Notre Dame's curriculum that designed experiments for the recipient schools using the donated instruments ("Donated Lab", 2012).

Donated equipment may also be sent overseas to sciences laboratories in developing nations. Much like high schools, the financial barrier to scientific development is often an insurmountable obstacle to these laboratories, with commonplace supplies in often in short supply. Even simple pieces of equipment such as plastic test tubes are used for upwards of three months out of necessity. In order to support the developing labs, universities such as Harvard have consolidated excess and unused supplies and equipment to send overseas. These donations are facilitated through the Seeding Labs organization, which distributes donated supplies to the labs in question by shipping a 20-foot container of lab equipment to various countries on a quarterly basis (*See Appendix A*). This program is also undertakes training the foreign lab technicians on proper use of the equipment donated in order for the beneficiaries to get the optimal benefit from the provisions (Shapiro, 2011).

c. Disposing of Broken Lab Equipment

In some cases, the reuse or repurposing of lab equipment is not viable due to some detracting factor of the instrument, and disposal is necessary. Since the equipment often comes into contact with hazardous chemicals or organisms, care must be taken to ensure the safe removal of the equipment. In order to prevent any ill effects on the environment or those who may come into contact with the broken machine, some general guidelines should be followed before final disposal.

Any portion of the equipment being disposed of that contains hazardous materials should be removed or drained of the hazard in question. After removal, the substance should be properly disposed of according to the appropriate methods. This precaution prevents the hazard from being introduced into the environment when finally disposed or from transport beforehand. Similarly, the equipment must be decontaminated for chemical, biological, and radiological traces where applicable. Examples of such specimens that need decontamination are mercury, bacterial culture, and asbestos, each of which must be individually addressed as needed. A standard form entailing the procedures should be readily available by the

Department of EHS for general lab use, as seen in campuses such as Washington University (Eriksen, 1996).

When decommissioning equipment, the department should also consider if the old equipment could be repurposed for some perverse use. The equipment found in labs used to make methamphetamine could easily be interchanged with common chemical laboratory equipment. Since it is possible for some of the equipment in a meth lab to be of a high enough quality to be repurposed as university lab equipment, it is not unfeasible to think that the reverse situation is possible (Drewes, 2007). With that possibility in mind, those responsible for the disposal of lab equipment should ensure that the removed equipment will not be able to be reused for such purposes.

D. Equipment Policy at USF

The call for environmentally acceptable lab conditions has not gone unheard by USF as a whole. The newly built Interdisciplinary Sciences (ISA) building had integrated many of the proposed integral changes to labs as it was being constructed. It targets energy, water and material efficiency in its design, ranging from high efficiency air conditioning systems to the surrounding plants that do not require a permanent form of irrigation. The prizes for this effort are a reduction of energy use by 31% and a water use reduction of 40% when compared to an equivalent lab building, and the building as a whole being awarded the LEED Gold certification for its environmental design (Williams, S. [Forwarded Personal Communication], 2012).

According to the questionnaire in Appendix B, EHS at USF has little to no role in the process of equipment purchase and disposal. The addition or removal of equipment is largely regulated by the department that manages the lab. Based on personal observation of chemistry labs, the responsibility for the upkeep of equipment is even further divided into those who use the labs. Each lab seems to have its own method of equipment distribution and maintenance (Lawrence [Personal Communication], 2012). The quality of the oversight varies to a certain degree, but the level of the quality seems to vary based on the way the equipment is distributed to the participants of the lab. In general and organic chemistry labs, equipment is typically functional and kept tidy, largely due to a "check out" system, in which the responsible party fills out a slip of paper to indicate what equipment has been taken. In order for the slip to be returned at the end of the session, all used equipment must be cleaned and turned in to the equipment room. In virtually all of these examples, the room is tidy and mistakes seldom happen.

In the observed analytical/inorganic chemistry lab, glassware was not organized, congregating mostly around the sinks and sometimes contained precipitates from previous lab groups. While mistakes happened as infrequently as the general and organic chemistry labs, bottlenecks did occur around certain pieces of equipment. In an experiment that required extensive use of an analytical balance, large groups of students accumulated while waiting for one of the two functional balances to become free. In this lab, there were two other, non-functioning balances that remained out of commission for the entirety of the semester. If all balances were functioning, the experiment would have progressed in a more timely manner. This session functioned on a "drawer assignment" basis, with one person assigned to a numbered drawer of glassware and other supplies. However, virtually all drawers did not contain the equipment listed on the responsibility agreement that was signed on the first day of class which was reserved as an orientation/attendance day.

V. CONCLUSION & SUGGESTIONS

The development of green science is an ever-developing field, with new technology and discoveries being put forth to improve the effect that scientific experimentation and research has on the environment. Even as the end of the timeline for this thesis draws near, new research is being presented and becoming more prominent in the collective minds of the scientific community. If USF wishes to establish itself as a green campus, it will need to be able to recognize new developments in environmentalism and be able to adapt to the challenges set forth.

The Environmental Health and Safety Department is very thorough in its policy towards health and safety regarding the labs on USF's Tampa campus, and has begun to step up its efforts to improve the environmentalism of the labs. However, virtually all efforts made by the campus also have safety connotations as well. In addition, a questionnaire sent to EHS has indicated that its focus is more safety and health oriented, largely remaining outside of environmental affairs. If EHS were to expand its regulations to include environmental choices as well as those that are safety and/or health oriented, the resulting changes would benefit virtually all departments in terms of monetary and environmental savings over time. Such improvements are already manifesting in the further development of the HITS and other policy changes.

However, EHS tends to remain outside of the realm of purely environmental regulation. Because of this, the responsibility of maintaining an environmentally conscious lab program falls on the individual labs. Some have taken some form of initiative to reduce consumption and production of waste, such as container and glassware recycling; however, room always exists for improvement. In order to make the transition to increased environmental participation, individual departments should hold a conference to determine what purchases or changes will provide the most advantageous returns (whether it be quickness of breaking even, amount that returns provide, or some other factor should be carefully considered.) With careful self-regulation, implementation of any green investments will be easily sustained by the department's budget, and will provide returns to expand on other green efforts or create a larger portion of the budget for the department to work with.

In addition, monitoring the labs separately from the rest of the campus for water, energy, and other resource use should be considered in order to gain a better understanding of the challenges that will be faced in terms of cutting consumption and waste. With tangible statistics on hand, the individual departments will have some idea on prioritizing what aspects should be improved. To supplement these monitoring initiatives, the establishment of a Green Labs Blog would serve to bridge the gap between the departments. The open forum that a weblog provides would allow them to communicate on strategies developed, provide feedback on organizations playing a part in the greening, and other relevant information. Such a blog may be organized through one of the many blog hosting sites, or may be built through the USF organizations application in Blackboard.

As for the creation of a Green Chemistry course, a traditional lecture-lab science course may be implemented into the available courses. There are many resources to aid in the development of a green chemistry course, many of which may be found in USF's own library (investigated print resources were located in section TP 155 of the Tampa campus library) as well as many online resources to accommodate or support the development of such a course. A possible course for USF's Honors College to implement might be themed on creating a class curriculum regarding green chemistry. A professor might design a course through Seminar in Applied Ethics (IDH 3600) or Major Works and Issues (IDH 4000). The schedule could be managed in halves in the course, with the first half being dedicated to learning about green chemistry and the various developments in creating more environmentally friendly lab facilities. Using the information gathered from the first half of the course, the class could then develop a possible syllabus and schedule during the second half of the semester for a chemistry class to follow. If the final project turned in is of an appropriate quality, the theoretical syllabus and schedule could then be submitted through the necessary avenues to become a full-fledged science course at USF.

USF has taken the initiative in many aspects to integrate a green attitude into the campus lifestyle, but that still leaves room for improvement, especially in the laboratories on campus. The implementation of the principles of environmentalism is not only relevant in terms of money and environmental impact, but such an attitude is also important in promoting an environmentally conscious outlook in the student body, many of which will become outstanding role models in society. While the creation and maintenance of green science is by no means an easy task, the potential rewards to be reaped from the effort are far too valuable for the university to cast the challenge to the wayside.

APPENDIX A: USEFUL RESOURCES

Department of Environmental Health and Safety (University of South Florida)

http://usfweb2.usf.edu/EHS/

The Department of EHS for USF accounts for all of the current safety standards at USF, offering updates to policies, lab management documents, and training forms for occupational health. While the site is a valuable resource for lab and campus safety, there are few resources that address environmental training and issue that the university's labs face. Information on the USF-developed Hazardous Inventory Tracking System (HITS) is also available on the EHS website. Although use of the HITS is limited to authorized personnel at USF, a user tutorial for the HITS may be viewed at: *http://usfweb2.usf.edu/EHS/hits/HITS%20Tutorial.pdf*

"Green" Alternatives Wizard (Michigan Institute of Technology)

http://ehs.mit.edu/greenchem/

This program streamlines the process of determining safe alternatives to chemicals used in the laboratory. The only information that is needed is the name of a chemical that is being used in the experiment. After determining the chemical, the program provides a list of alternative chemicals, as well as suppliers and journals relevant to the chemical.

Green Chemistry Network

http://www.greenchemistrynetwork.org/index.htm

The GCN provides education materials as well as a multitude of other resources related to green chemistry. It covers topics related to both academic and outside settings, and is designed to make resources easily accessible to the general public, as well as those with stakes in business, education, and so on. Some sample experiments are available on the site that are designed to be a greener alternative to some traditional chemistry experiments.

Green Chemistry Educational Resources (American Chemistry Society)

http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=1444&use_sec=false&sec_url_var=region1&__uuid=491de240-6b8c-4398-9e71-d9251a8492fb

The American Chemistry Society has compiled a list of resources for green chemistry education. Material ranges from cases in green chemistry to how to integrate green chemistry into course curriculum. The page includes both print and online resources and provides a few sample experiments sorted by level of education.

Greener Education Materials (GEMs) for Chemists (University of Oregon)

http://greenchem.uoregon.edu/gems.html

This site offers resources to educate chemists on exercises, lecture topics, multimedia that outlines concepts relevant to green chemistry. Search results incorporate a variety of materials, both published and unpublished, and may be interlinked by various parameters, not requiring a specific aspect or concept to obtain a result.

Green Lab Certification (Yale University)

http://www.yale.edu/ehs/sustainability/greenlabs.htm

Yale's lab certification website may serve as a model for the development of a lab survey. The site goes into how it awards ranks and directions for participation.

ND LIGHTS (University of Notre Dame)

http://www.science.nd.edu/ndlights/

This is the program implemented at the University of Notre Dame that donates unused lab equipment to resource-limited schools across the United States. It offers forms and acts as a hub for potential recipients of donated equipment to apply for donations. While lab donations are limited to the Notre Dame campus, this site may serve as a model for other universities to implement their own similar program.

The Online Lab Optimizer (Washington University in St. Louis)

http://greenlabs.wustl.edu/optimizer/

Washington University's Optimizer program is an online tool that helps labs in reducing their energy usage by calculating the amount of energy that is currently used against the "optimum" percentage of energy that can be used by the labs. The application compares the annual impact in kilowatts per hour, pounds of CO_2, pounds of coal and the dollar value of running the lab at both the current and the optimized values, and calculates the savings in the aforementioned resources under the optimized use. This tool would be a valuable resource to a representative tasked with auditing the energy use of the labs.

Seeding Labs

http://seedinglabs.org/home/

This organization offers labs the opportunity to donate reliable, functional lab equipment to labs in developing nations. It outlines the donation procedure and even offers to make shipping arrangements if the donating lab cannot ship it to the distribution center of their own expense. However, it should be noted that the organization discourages donating significantly out-of-date equipment, as it is not useful to the receiving facilities.

APPENDIX B: SELECTED PERSONAL COMMUNICATIONS

A. Questionnaire Concerning EHS Involvement in Environmental Efforts

(Questionnaire answers provided as a courtesy of Aisha Lawrence, Lab Safety and Hazardous Waste Manager for EHS, and returned on April 18, 2012. Redirected questions have been omitted for clarity.)

In what ways has the EHS promoted "greening" the labs? (May also coincide with safety promotions, i.e. fume hood stickers)

- EH&S has established a chemical surplus which allows laboratories to share chemicals that haven't been used.
- Fume hood stickers identifying 17 or 18 inch mark to keep sashes lowered.
- The University also has a waste minimization procedure.

Are any labs exempt from using the Hazardous Inventory Tracking System for disposing chemicals that fit the criteria posted on the EHS website? If so, what circumstances excuses a lab's waste from being included in the HITS?

There are no exemptions for any USF System research and teaching lab to use the HITS system to maintain and track its chemical inventory.

The EHS website lists the HITS as being developed in "phases." What phase is the HITS currently in, and what does the EHS hope to include in future phases?

Great question. HITS is currently in Phase 1. The Project Team at the time identified a Phase 2 which included the inclusion of radioactive and biological materials. However that has not occurred as yet. Currently both the Radiation Safety and Biosafety programs have mechanisms to track these materials currently at the University.

Does USF use some form of evaluation for the environmental impact of the labs on campus? If not, could the establishment of such an evaluation be realistic and/or beneficial?

Another good question. I am not aware of such an evaluation form, however, the establishment of an evaluation is realistic and can be very beneficial.

Is there anything that the equipment or chemicals bought for a lab absolutely must comply with from EHS's standpoint in regards to environmental impact?

- Must have an MSDS sheet for chemical
- Individuals handling chemicals must be trained on hazardous waste management.

Does EHS play any role in equipment disposal, as it does in chemical disposal? What about functional but decommissioned equipment?

EH&S does not play a significant role in equipment disposal. This is done through the department or Colleges themselves. You might want to check with the Facilities Manager of your College about their processes.

Do you encourage the lab managers (TAs, etc.) to promote ways for students to save energy while using the lab? If so, please name a few ways that this is promoted.

We have not promoted energy efficiency within our trainings. Our primary focus is mainly on the safety and compliance.

Do labs actively seek out replacements for hazardous chemicals that may be in use? What criteria would a new chemical need to fulfill if it were to replace a currently use hazardous one?

Generally speaking, we are not approached frequently by labs inquiring about replacements to hazardous chemicals that are being used with less hazardous ones.

B. Sustainable Information for USF's ISA building

(Information provided as a courtesy of Sean Williams, Designer, Sustainable Design Leader of the LEED program and was originally received by Dr. Christian Wells on September 23, 2011. Communication was forwarded by Dr. Wells on April 23, 2012. Minor corrections and formatting were introduced for clarity.)

[ISA] is the first lab [at] USF to seek LEED certification:

Energy efficiency:

1. This project is designed to be at least 31% more efficient than a similar lab designed by code.
2. The combination of Sunshades and High efficiency glazing aid in reducing the energy load
3. The use of Heat entropy [Daniels, Suchi] enthalpy wheels to capture lost energy in the exhaust air and use it to pre heat / dehumidify the incoming are alleviates the requirement for energy to do the same task

Water efficiency:

1. This building consumes 40% less water than a similar lab designed by code
2. Separate piping for future condensate collection has been installed to alleviate the for potable water on the landscaping.
3. All of the plants are native species that do not require permanent irrigation.

Material efficiency:

1. Care was taken to include as much recycled, and regional material as possible.
2. At least 10% of the material cost was from regional materials
3. Low VOC paints, sealants and finishes were selected
4. 75% of all of the construction waste was diverted from landfills.

USF interdisciplinary Science building is seeking LEED Gold certification sometime at the beginning of 2012 completing the 3rd party review of the sustainable attributes it has achieved.

C. Energy Use Comparison for NES and CPR (CY 2011)

(Information provided as a courtesy of Nainan Desai, Assistant Director of USF's Physical Plant Department and was received on April 24, 2012. Minor formatting was introduced to fit within the page borders.)

Energy Use Comparison for NES and CPR (CY 2011)

CY 2011	January	February	March	April	May	June	July
NES							
Electric (kWh)	231,225	211,727	238,066	232,340	234,472	227,005	230,377
Chilled Water (kWh)	194,268	407,965	440,202	720,189	845,148	1,061,718	1,288,486
Hot Water (kWh)	128,301	162,676	132,403	86,540	96,269	47,974	66,700
Total Energy (kWh)	553,793	782,369	810,671	1,039,069	1,175,890	1,336,696	1,585,563
CPR							
Electric (kWh)	120,600	114,200	125,600	123,400	114,200	113,200	115,200
Chilled Water (kWh)	93,075	87,800	91,405	132,374	148,844	170,442	180,582
Hot Water (kWh)	305,219	230,255	222,343	194,151	205,111	177,476	184,011
Total Energy (kWh)	518,894	432,255	439,347	449,925	468,155	461,118	479,793

CY 2011	August	September	October	November	December	Annual
NES						
Electric (kWh)	230,056	187,869	208,846	221,301	216,188	2,669,472
Chilled Water (kWh)	1,285,819	948,627	602,731	486,856	369,663	8,651,672
Hot Water (kWh)	54,274	71,213	110,659	143,393	140,316	1,240,717
Total Energy (kWh)	1,570,149	1,207,709	922,236	851,550	726,167	12,561,861
CPR						
Electric (kWh)	122,600	102,600	113,467	104,960	116,200	1,386,227
Chilled Water (kWh)	207,690	166,339	184,870	153,738	90,819	1,707,978
Hot Water (kWh)	191,601	160,215	17,861	271,401	341,002	2,500,644
Total Energy (kWh)	521,891	429,154	316,198	530,098	548,020	5,594,848

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