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The Mueller Report:

Moving Beyond Sustainability Indicators to Sustainability Action at Penn State

Penn State Green Destiny Council

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This report is available at The Green Destiny Council Website (www.bio.psu.edu/greendestiny/).

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Executive Summary

Scientists are an eccentric lot. One thing they share in common is curiosity and this curiosity sometimes leads them to some very peculiar places. This study is a case in point. We were curious to learn what impact a Penn State science building (and its 123 occupants) had on the natural world. To some this might seem like an unusual question. What discipline does it fit into? Is it Biology? Environmental Science? Ecology? Political Science? Sociology? Economics? In fact, each of these fields makes contributions to our investigation.

But why, really, would a researcher want to spend his/her time studying something as mundane as the impacts that a building and its occupants have on the environment? The short answer is, because it is important. After all, what if in the practice of their science--in addition to making discoveries--scientists unwittingly bring unnecessary suffering into the world? What if, for example, the buildings they inhabit, their purchasing decisions, and their personal habits are all wasteful on a colossal scale? What if they develop sophisticated climate change models, document the deleterious effects of endocrine disrupters, trace the toxic plumes of pollutants in ground water, and map soil erosion processes worldwide, all the while contributing to some of these very things because of the way they work and live?

Unfortunately, for the scientists who work in the Mueller Biology building this has been the case. Because of its poor design and inefficient operation, Mueller has a significant negative impact on the environment. On an annual basis, the building (and occupants) consumes, 2,872,210 kWh of electricity and an additional 2,564,019 kWh equivalent in heating energy. This energy consumption is linked to the burning of 2,223 tons of coal, the burning of which releases over 5,750 tons of carbon dioxide (CO_2 -- a greenhouse gas). On an annual per capita basis the numbers are sobering: 18 tons of coal, 46 ¾ tons of CO_2.

The purchasing decisions employed by Mueller (and PSU as a whole) are a second contributing factor to colossal waste and environmental harm. Little effort is made to address the life-cycle environmental impacts of products or to purchase products containing recycled materials or to ensure that the purchased products are highly efficient and are produced using clean technologies. For example, carpet covers almost 12,000 square feet of floor space in Mueller. Mueller's carpet comes from 100% virgin synthetic fiber (i.e., from petroleum); the backings and adhesives associated with Mueller's carpeting off-gas volatile organic compounds (VOCs), some of which are known and suspected carcinogens.

The assignment that we gave ourselves was: *Cut the ecological impact of Mueller Building in half while creating healthier working conditions for all building occupants.* The analysis on the following pages reveals that it is, indeed, possible to reduce significantly Mueller's aggregate impacts in many areas. For example, there are "off-the-shelf" solutions that can significantly reduce Mueller's impact on the environment connected with carpeting, furniture, paints, cleaners, toner, paper, food, lighting, heating, ...in short everything associated with the building.

The majority of environmental improvements that Mueller could make would actually save money! For example, by following the suggestions outlined in the energy portions of this study Mueller building could reap more than $45,000 per year in energy savings alone (as detailed in Table 1). The environmental improvements sum to approximately a half million dollars a year, if extrapolated to the building stock in the College of Science.

Table 1. Potential Energy, Coal, and CO_2 Reductions and Money Savings for Mueller Building

System	Energy Savings (kW-hrs)	Coal Consumption Reduction (tons)	CO_2 Emission Reduction (tons)	Money Savings ($)
Lighting	143,292	58.5	151	4,421
HVAC	1,662,372	679	1,757	38,734
Computers	30,790	13	33	1,850
Printers	8,530	3.5	9	425
Elevators	3,627	1.5	3.8	85
Total	**1,848,611**	**755.5**	**1,953**	**$45,515**

Details of the calculations for this table can be found in the energy and communication sections of this study.

In addition to energy savings, this study details how Mueller building could enhance the working environment of its occupants while it:

- Reduces water use by 100,000 gallons/year
- Reduces paper consumption by two thirds and paper expenditure by $3,000/year
- Reduces computer waste, energy use, and expenditures by $173/computer while allowing occupants the mobility and performance of state-of-the-art laptops
- Dramatically reduce waste associated with he disposal of transparencies, diskettes, carpeting, furniture, and printer cartridges.

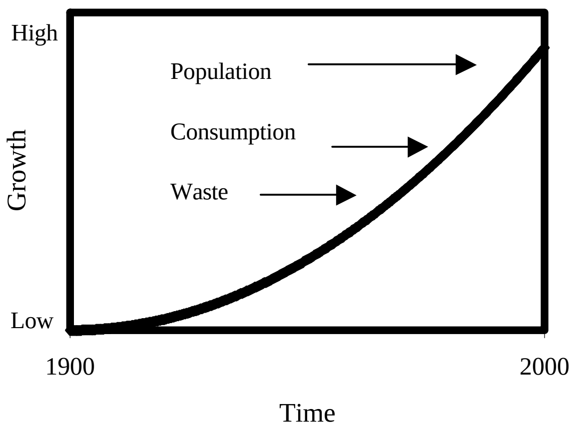
The bottom line is that smart design improvements will save money while contributing to environmental stewardship. The broader message of this study is that Mueller Building suffers from an aggregate of systemic design failures, poor engineering, and inefficient technologies that waste energy and squander money.

Yes, this study has quantified methods to curtail Mueller's waste but more importantly it has demonstrated the need for the College of Science and Penn State University as a whole, to vow that that such "environmental embarrassments" (and there are many "Muellers" on campus) never be built again. For the College of Science this means doing everything possible to ensure that the new Life Sciences Building requires, at a maximum, only one-fifth the energy per square foot of Mueller. This is both a reasonable and responsible goal.

I. Introduction

A Challenge for the 21st Century

Future historians wishing to summarize the environmental history of the 20th Century will almost surely use the graph (below) showing exponential growth of population, consumption, and waste on planet Earth.



It was not only human population that increased exponentially during the 20th Century, but also consumption of food, cars, jet plane fuel, washing machines, computers, VCRs, land mines, Barbie dolls--you name it. In addition, waste generation became so great in the 20th Century that human civilization began to significantly change the character of the very atmosphere enveloping Earth--the ozone layer thinned over the poles, the rain turned acidic in many regions, and the climate warmed (due primarily to the exponential growth in fossil fuel combustion).

As we enter the 21st Century, many exponential "growth" trends continue unabated. Meanwhile, the environmental consequences of continuing on this path are increasingly evident. In January, 2001, the UN Intergovernmental Panel on Climate Change released a 1,000-page report assembled by 700 scientists (including PSU faculty) which concluded that global temperatures could rise by as much as 10.4 F over this century. Even their most conservative estimate of a ~3-5 degree temperature increase would lead to a rise in global sea levels threatening to flood many parts of Florida, Louisiana, Boston, and New York City as well as low lying countries such as Bangladesh and the Netherlands. “Climate change” is perhaps too benign a characterization for what humanity now faces; “climate destabilization” might be a more accurate description.

Of course, none of this is inevitable but to avoid the grim consequences of “climate destabilization” those of us in the industrialized world will have to dramatically reduce our "ecological footprint." As the institutions harboring a virtual monopoly on environmental expertise, universities have both an opportunity and responsibility to act. Fortunately, universities are beginning to respond. For example, more than 265 university presidents and chancellors have signaled their commitment to sustainable practices by signing the Talloires Declaration which reads in part: "We, the presidents, rectors, and vice chancellors of universities from all regions of the world, are deeply concerned about the unprecedented scale and speed of environmental pollution and degradation and the depletion of natural resources. Pollution, toxic wastes, and depletion of the ozone layer threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations." In signing this document universities registered a willingness to:

* Engage in education, research, policy formation, and information exchange on population, environment, and development to move toward a sustainable future.
* Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and responsible citizens.
* Set an example of environmental responsibility by establishing programs of resource conservation, recycling, and waste reduction at the universities (Text from Talloires Declaration).

The purpose of this ecological report is to illustrate, step-by-step, how Penn State's footprint could be significantly reduced. Our unit of study is one building, Mueller Lab, home of Penn State’s Biology Department. Buildings are the locus of consumption; it is here that we use and eventually dispose of computers, paper, equipment, furniture, energy, and so on. Insofar as the consumption patterns in Mueller Lab are typical of Penn State as a whole, as well as most other universities, (and we believe that they are) the solutions proposed herein should have broad relevance.

The Footprint Concept

We have found it useful to express the environmental impact of Mueller using the "ecological footprint" concept developed by Wackernagel and Rees (1994).[1] A building's aggregate ecological footprint is a measure of the productive land area needed to sustainably support all the material input and disposal needs of that building. Everything that the building consumes (energy, paper, cleaning agents, etc.) has a footprint that can be expressed in terms of land area.

Here is an example: In the year 1999, approximately 2,872,000 kWh of electricity were consumed in Mueller Lab. Coal (approximately 1,175 tons) was burned to produce this electricity. This coal--highly compacted plant biomass--is the result of past photosynthesis. If Mueller relied not on fossil biomass--an ephemeral resource--but, instead, on renewable biomass (i.e., present-day photosynthesis), the building would require an “energy plantation” the size of the entire main campus (~500 acres) to supply just its electricity needs.

Wackernagel and Rees found that each American citizen would need approximately 25 acres of land in production year in and year out to sustainably supply all his/her needs (i.e., food, fiber, energy, raw materials, etc.). If everyone on Earth lived as we do, three Earth's would be required to support the planet's current population of six billion people. The challenge, clearly, is to dramatically reduce our footprint.

Project History

This project began as a question posed to a Penn State Ph.D. candidate during a comprehensive exam. Professor C. Uhl asked: "In what ways is this university (Penn State) like an ecosystem?" Uhl had some embryonic ideas of his own on this topic and asked the question in hopes of having his own thinking further stimulated. The exchange that day was fruitful.

A few years later (Fall, 2000) Uhl posed a related question to his Biology 450 class--namely: "In what ways is Mueller Building like an ecosystem?" After some initial hesitation, students began to respond. One mentioned that everything in Mueller had its origins in the natural world. Another observed that energy and materials were constantly coming into Mueller and this was also true for natural ecosystems. Uhl asked about "outputs" and a student observed that Mueller appears to have a large waste stream whereas in natural ecosystems "waste" is essentially non-existent.

As the discussion developed, Uhl introduced the concept of "ecological footprinting" and asked the class to consider the possibility of reducing the environmental impact of Mueller Building by half. Slowly a class project began to take shape. Each student took one "input" category (e.g., paper, cleaning products, carpeting, etc.) and determined: i) Mueller's annual consumption of that input; ii) the environmental impacts of that consumption; iii) low-impact alternatives; and iv) footprint reductions if alternatives were adopted.

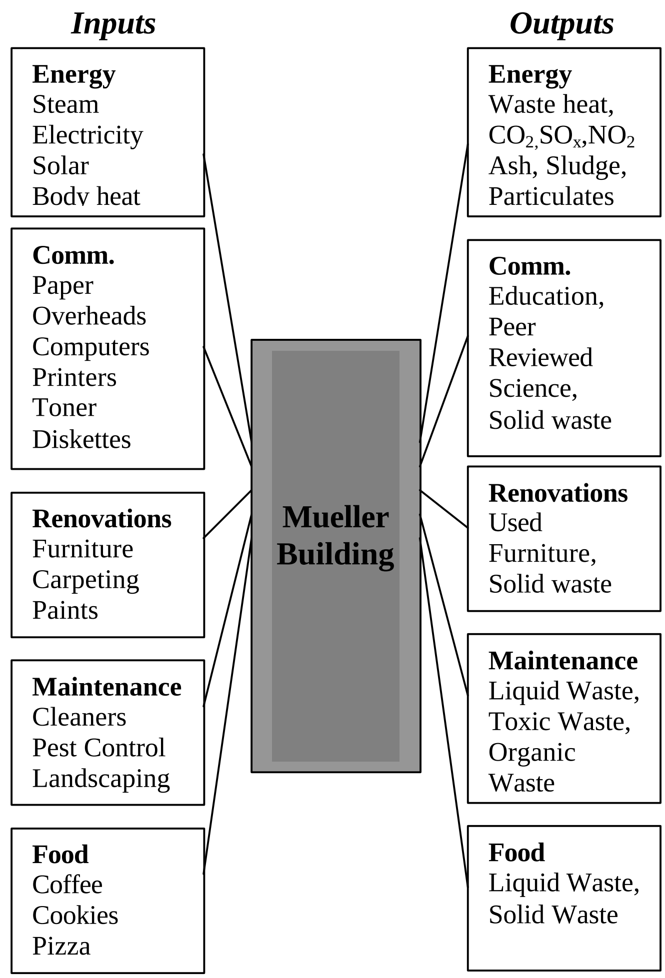
Although these Bio 450 students had only five weeks to work on this project, they did a remarkable job of "blocking out" the problem, gathering data, and presenting preliminary results. Overall, their findings suggested that it might be possible to reduce Mueller's footprint, but much data collection and analysis still lay ahead.

During January-May 2001, Austin Mandryk, Dennis Matalavage, Christie Vischer, Loren Byrne, Sara Eisenfeld, and Joshua Pearce took up the work initiated by the Bio 450 class and, under C. Uhl's guidance, developed it into this report. Mandryk played a pivotal role in the data collection phase while Pearce took the lead in the synthesis phase of the work.

Reducing Mueller's Ecological Footprint

Materials are constantly moving into Mueller Building. All these materials -- paper, computers, toners, coal (via electricity), carpeting, etc. -- originate in the natural world and, in one form or another, return to the natural world (Figure 1). Both choice of materials and the manner in which materials are used affect building "footprint" size. Here we consider concrete ways of reducing Mueller's ecological footprint in the realms of: i) energy use, ii) communications and computing, iii) furnishings and renovation, iv) maintenance, and v) food.

Figure 1. Inputs to and outputs from the Mueller Building.



Who is the Audience for this Report?

The messages of this report have great relevance for people who care about buildings -- students, building designers, operations and purchasing personnel, and decision makers. Here is what you can expect to learn from this report:

i. Students: The buildings we inhabit have lessons to teach. Penn State undergraduates did the initial work for this Report. These students learned how to gauge the ecological impact of a building. The report offers a template for how to reduce the ecological footprint of university buildings and by extension schools, churches, offices and private homes.

ii. Purchasing Department Personnel: This report tells exactly where to go (i.e., phone numbers/websites) to purchase products (e.g., paper, computers, toners, paints, cleaners, furniture, carpets, food) that minimize the environmental impacts of offices and buildings.

iii. Building Designers: This report emphasizes that much of the building stock on university campuses and throughout the country is poorly designed. This results in much unnecessary waste. The report makes it clear that it is now possible to construct cost-competitive buildings that are at least five-times more efficient than Mueller.

iv. Physical Plant Personnel: University physical plant personnel will nod knowingly as they read this report (especially the energy section). These professionals know that our buildings are tremendously inefficient. Given the mandate and the funds, physical plant personnel are ready to transform existing buildings from energy guzzlers to energy misers.

v. University Decision Makers: University administrators are charged with carefully watching the "bottom line". This means eliminating waste and seeking greater efficiency whenever possible. This report is a tale of waste--wasted money, wasted energy, and wasted opportunity. At the same time, the report offers a blueprint for ensuring that there will be no more "Muellers" in Penn State's future.

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1. Wackernagel, M. and W. Rees. 1994. *Our Ecological Footprint*. New Society Publishers.

II. Reducing the Ecological Footprint of Mueller Building

A. Reducing Mueller's Energy Footprint

1. Energy--An Ecological Profile

The past hundred years has been characterized by growing fossil fuel dependency worldwide. At Penn State, the expansion of building space, the increased use of electronic devices, and a growing university population have led to a significant increase in the use of fossil fuels over the last three decades.

At present rates of consumption, global supplies of fossil fuel energy will be exhausted, for all practical purposes, within the next few centuries (much sooner for some sources, like petroleum). However, before dwindling supplies limit our use of fossil fuels, the negative health and environmental impacts of our current unsustainable patterns of energy use may provoke a reduction in our use of fossil fuels. The adverse effects of fossil fuel combustion such as air pollution, acid precipitation, and global warming are avoidable. As a research institution, especially one with strong colleges of Engineering, Earth and Mineral Science, and Science, Penn State has an opportunity to be a leader in the design and implementation of highly efficient and environmentally benign energy systems.

2. The Mueller Connection – Overview

Mueller Laboratory is an academic center for the teaching and research of biology. The Mueller building uses energy in the form of steam (for heating) produced on campus and electricity purchased from Allegheny Power. Virtually all of the energy consumed at Mueller is derived from fossil fuels, principally coal. Electricity, whether for lighting, computers, research equipment, chilling units, autoclaves, air conditioning, ventilation fans, centrifuges, or incubators, is a necessity for Mueller's daily operations. However, there are many strategies that can be utilized to reduce the electricity consumption of Mueller Laboratory while improving the work environment of its occupants.

Mueller's annual electrical consumption has risen substantially over the last decade (Figure 1). The total amount of electricity used in 1999 was more than twice that used in 1990 (2,872,210 kWh vs. 1,393,840 kWh).[1] Thus, on average, a Mueller resident[2] consumed 23,350 kWh of electricity in 1999. To provide this energy for each resident, 9.6 tons of coal were burned, emitting nearly 25 tons of CO_2 (a greenhouse gas), 134 pounds of SO_x (main cause of acid rain), and 136 pounds of NO_2 (major cause of smog). In the process, approximately 14,688 gallons of water were used.[3] Although it is difficult to determine exactly why such a large increase in demand has occurred, suspected factors include: 1) a total air-conditioning (AC) retrofit completed during the years 1993-1995; and 2) the purchase of energy demanding research equipment.[4] The possibility that climatic conditions contributed to the dramatic rise in electricity use was ruled out by the lack of correlation between energy consumption and average temperatures during the months commonly associated with AC use.[5]

Figure 2 illustrates the breakdown of Mueller's electricity use. The heating, ventilation, and air conditioning system (HVAC) is the primary consumer of electricity at an estimated 64% (1,838,214 kWh)[1], followed by the lighting system (10%). The amount of electricity drawn by the 15 walk-in coolers inside the building comprises approximately 3% of total energy usage.[6] Plug in devices (including research equipment) use roughly 20% of Mueller's electricity, with computers and printers accounting for another 3% of Mueller's total electrical demand. The two elevators found in Mueller consume less than 1% of the building's electricity.

Figure 1. Electricity Consumption in Mueller Building (1990-1999).

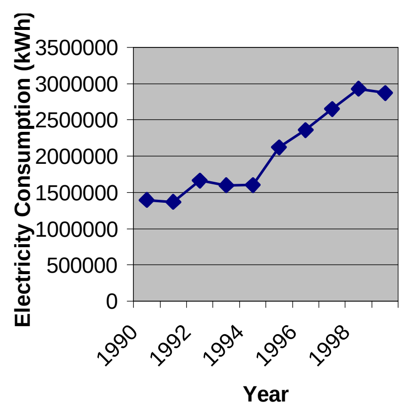
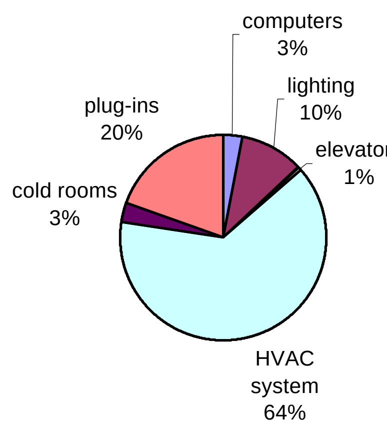


Figure 2. Estimated Breakdown of Mueller Electricity Consumption.



Reducing Mueller's energy consumption by half may seem like a daunting task but we will show how this could be accomplished.

3. Mueller Lighting – A Case Study

Artificial lighting often constitutes a significant portion of a building's total energy usage. In fact, the United States currently spends more than $37 billion annually, or approximately 25% of the nation's total electricity budget, on lighting. Retrofitting of antiquated lighting with highly efficient lighting devices and fixtures can help cut lighting costs 30% to 60%, while simultaneously enhancing lighting quality and reducing environmental impacts. [7]

The Mueller Lighting Connection

The lighting system within Mueller consists of 701 T-12 fixtures,[8] 197 T-8 fixtures, 22 compact fluorescent, and 19 incandescent fixtures. These lights consume approximately 290,887 kWh of electricity per year,[9] or approximately 10% of the building's total energy input (based on 1999 total energy consumption data).[1] Annually, the electricity needed for the lighting system in Mueller requires the combustion of 119 tons of coal which, in turn, results in the release of over 308 tons of CO_2 (a greenhouse gas) into the atmosphere.[3] Per each building resident, this amounts to ~1 ton of coal and 2.5 tons of CO_2 gas.

The Mueller Lighting Solution

A 50% decrease in the energy consumed by Mueller's lighting system can be achieved without compromising the research, teaching, or administrative activities of building residents. To achieve such a reduction in lighting-related electricity use, the following steps would need to be taken: 1) use artificial lighting only when necessary, which can be accomplished through either: *Option A*, increased mindfulness of personal habits pertaining to light use, or *Option B*, the use of occupancy sensors; and, 2) upgrade existing light fixtures with more energy-efficient models.

Step 1: Avoid using lights unnecessarily.

All rooms in Mueller were sampled at four different times of the day (morning, noon, afternoon, and evening) over the course of a week to determine room occupancy and levels of illumination. These surveys revealed that lights were on in unoccupied offices and labs approximately 14% of the time and in unoccupied bathrooms 60% of the time (Table 1).

Option A: If a strategy of manually turning-off lights in unoccupied rooms is followed by Mueller residents, ~$819,[10] 35,153 kWh of electricity[11], ~14 tons of coal, and greater than 37 tons of CO_2 emissions could be saved per year[3]. The habit of turning off lights when leaving a room, even if only for a short time, can have additive effects saving significant amounts of energy over time. Any decrease in energy consumption prevents the combustion of fossil fuels and extends the longevity of fixtures and bulbs, resulting in a decrease in both the number of bulbs and fixtures that need to be produced as well as light fixture waste sent to landfills.

Option B: The installation of occupancy sensors could also decrease levels of unneeded lighting (note: a zero level is virtually impossible for practical reasons due to delays in the amount of time the lights stay on after no motion is detected (adjustable within each individual sensor)). Based on information provided by the Office of the Physical Plant (OPP), ceiling-mounted InfraRed/UltraSonic sensors placed in all the bathrooms in Mueller at a total cost of $1,240 would pay for themselves in approximately 19 years (based on 60% unoccupied rate and associated 2,692kWh per year savings).[12] As with Option A, Option B (installation of sensors) in Mueller bathrooms would prevent the combustion of ~1 ton of coal per year, and reduce CO_2 emissions by ~3 tons[3]. Though the concept of sensors may be attractive, the environment can be negatively impacted by the manufacture, installation, and disposal associated with these devices. It is apparent in Table 1 that the savings from personal habits are both larger and pay for themselves faster than technical fixes.

Summary

It is clear from Table 1, that either behavioral change - Option A) or technical innovations - Option B would have a significant effect on Mueller's energy use. If Option A or B where implemented in bathrooms as well as in offices and labs, electricity consumption used for illumination could be reduced by approximately 35,000 kWh or ~12% and save approximately $800/year.

Table 1. Savings and Payback Associated with Eliminating Unnecessary Illumination in Mueller Bathrooms, Offices and Laboratories[11]

Building Area	*Status Quo*	*Only Use When Needed (Option A)*	*Occupancy sensors (Option B)*
Bathrooms: Unnecessary Illumination	60%	0%	5%
Potential Savings	0	$66/year	$63/year
Payback	NA	Instantaneous	19 years
Offices/Labs: Unnecessary Illumination	14%	0%	5%
Potential Savings	0	$753/year	$715/year
Payback	NA	Instantaneous	20-40 years*
Potential Savings for Bathrooms and Labs		$819/year	$778

*Payback varies depending on the number of fixtures per occupancy sensor.[12] Calculations assume that the lights are currently turned off at night, when this is not the case, the payback period decreases significantly.

Step 2: Upgrade existing light fixtures with more efficient models.

Initiative I: Replace all incandescent bulbs with compact fluorescent bulbs. The incandescent light bulbs invented by Thomas Edison are now completely antiquated – the majority of electrical energy that they use is lost as waste heat (which results in additional draw on AC systems). A much more efficient illumination device is the compact fluorescent light (CFL) bulb, which uses ¼ of the energy of a standard incandescent while providing an equal amount of illumination. Please note: the quality of illumination is also comparable when 'soft white' CFL bulbs are utilized. Mueller building contains 19 incandescent light bulbs, which could be replaced with CFLs. This retrofit would save 5,130 kW-hrs of electricity every year,[13] enough to prevent 5.4 tons of CO_2 from entering the atmosphere.[3] These upgrades would save electricity, as well as decrease electrical demand.[10] In addition to energy savings, using CFL bulbs will prevent the land-filling of 84 incandescent bulbs every year, because CFL bulbs last 13.3 times longer than incandescent bulbs.

There is a tendency to avoid CFL bulbs because of the greater initial purchase price, \$9.74 compared to \$0.24 for an incandescent bulb. Even though the CFL lasts longer than the incandescent, it is still more expensive than 13 standard bulbs needed for 10,000 hours of illumination. However, once energy savings are taken into account the CFLs are significantly more economical. The retrofit of CFLs in Mueller will save \$752 and the initial investment of \$185 will be recouped in 0.68 years, with the next 2.1 years representing free money (Table 2). Please note this is a conservative estimate because the cost of labor to continually change the incandescent light bulbs was not taken into account.

Table 2: Results of Replacing Incandescent Bulbs with Compact Fluorescent Light Bulbs[13]

Retrofit savings (kWh/yr)	5,130
Cost of retrofit	\$185
Savings (\$/ year) of retrofit	\$271
Estimated payback time (years)	0.68

Initiative II: Mueller's T-12 fluorescent lighting fixtures could be retrofitted with T-8 fixtures with no compromise in light quality. On average, a 2-bulb T-12 fixture with a magnetic ballast draws 82W of power, while a 2-bulb T-8 fixture with electronic ballast requires only 60W of power.[14] The retrofit cost is \$39.79 per 2-bulb fixture, including labor and disposal.[15] To retrofit 3-bulb and 1-bulb fixtures the costs are \$50.77 and \$33.97, respectively. Electronic ballasts are superior to magnetic ballasts because they: eliminate flickering and noise, are more energy-efficient, and reduce fixture temperatures and the rate of ballast failures. [16]

The economic and environmental benefits of retrofitting old T-12 fixtures with T-8 fixtures within the Mueller Building would be considerable (Table 3). If all T-12 fixtures in the building were replaced with T-8 fixtures a savings of over \$2,900 would be realized per year. These retrofits would pay for themselves in 6 years in the hallways and 9.6 years if the entire building were retrofitted.[17]

Table 3. Results of Replacing T-12 with T-8 Light Fixtures in Mueller Building.

	Hallways Stairwells	Remainder Building	Total
Current %T-12 fixtures[18]	100%	76%	78%
Retrofit Savings kWh/yr[19]	14,840	49,421	64,261
Retrofit Savings \$/yr [20]	\$500	\$2,400	\$2,900
Cost of Retrofit[17]	\$3,064	\$24,829	\$27,892
Estimated Payback Time	6.1 years	10.35 years	9.6 years

T-8 Fixtures, however, are not the state-of-the-art. Mueller's T-8 fixtures could be retrofitted with direct/indirect T-5 fixtures with an <u>increase</u> in illumination quality. Direct/indirect fixtures use 70% up-light and 30% down-light in order to provide uniform illumination in the work plane and reduce glare on computer monitors and shadowing.[21] A well-designed lighting system using T-5 fixtures uses fewer fixtures per area than a direct T-8 system. A system design using 15 T-5 fixtures replacing 20 T-8 fixtures would reduce the W/ft^2 from 3.36 to 1.97 (or 41%).[21] However, replacing T-8 with T-5 lighting systems would not be a simple 1 to 1 retrofit and thus would require redesign of a rooms lighting layout and for optimization involve the expense of highly reflective ceiling tiles.

Initiative III: Many rooms in Mueller are flooded with sunlight at various times of the day, depending on the season. Thus, substantial savings on lighting electricity usage can also be realized in Mueller through half-lighting. Fractional lighting allows occupants to control the amount of light in an individual room by manipulating light-switches to obtain desired illumination levels. With this option, a 2-bulb lighting fixture can illuminate either 1 or 2 bulbs, or a 3-bulb fixture can utilize 1, 2, or 3 bulbs for light. Half-lighting can reduce electrical consumption by up to 50%, depending on the situation.[22] If used in Mueller 50% of the time, half-lighting would save 56,831 kW-hrs of electricity annually (2% of 1999 total electricity usage and \$1,324/yr)[22] and would result in an overall reduction in light-related electricity use of approximately 20%. Some rooms in Mueller already have ½ lighting installed and it is of course important that occupants use this function in order to reap energy savings. Occupant exertion could be eliminated with daylight controls that detect natural illumination levels and adjust artificial lighting appropriately at greater expense.

Lighting Summary

If behavioral changes and technical upgrades were adopted in Mueller, lighting-related electricity consumption could be reduced by over 140,000 kWh per year (i.e. a 50% reduction as seen in Table 4 [23]). This translates to a yearly savings of over $4,421 and prevents the combustion of 59 tons of coal, in turn, preventing the release of approximately 151 tons of CO_2 into the Earth's atmosphere.

Table 4. Economic and Environmental Benefits of Improvements to the Mueller Lighting System[23]

Behavioral Changes Only				
Savings	***A. Lights off restrooms only***	***B Lights off lab/offices only***	***C. ½lighting only***	***Total Behavioral changes: A + B + C (1-0.14%)***
Energy Saved (kW-hrs per year)	2,834	32,319	56,831	84,028 kW-hrs/yr
Pounds of coal saved per year[3]	2,316	26,409	46,439	68,663
Pounds of CO_2 gas emissions avoided per year[3]	5,992	68,332	120,160	177,659
Dollars saved per year	66	753	1324	$1,958

Technical Upgrades Only						
Savings	***CFL only***	***Motion Sensors Restroom only***	***Motion Sensors Lab/Office only***	***T-8 Retrofit Hallways only***	***T-8 Retrofit remainder only***	***½ Lighting only***
Energy Saved kW-hrs/year	5,130	2,692	30,703	14,840	49,421	56,831
Pounds of coal per year[3]	4,192	2,199	25,089	12,126	40,389	46,439
Pounds of CO_2 gas per year[3]	10,846	5,621	64,915	13,376	104,490	120,157
Dollars saved per year	271	63	715	500	2,400	1,324
Total Savings from Behavioral and Technical improvements to lighting system: 143,292 kW-hrs/year or $4,421 /year						

4. Mueller's HVAC System

The Mueller HVAC system consumes about two-thirds of the building's energy. Mueller's HVAC system contains many different components including: air conditioning fan coil units (120 total in building), compressors and condensers, multiple exhaust fans, chilled water pumps, heat exchangers, and hot water pumps.[24] All of these devices require the use of electricity in order to operate. In addition, Mueller's heat is derived from steam generated primarily through the burning of coal.[25] The steam is piped underneath the campus and into the ground floor of Mueller where it is converted to hot water through heat exchangers and then distributed to the rest of the building. In 1999, Mueller required 7,721,000 lbs. of steam (approximately 8,751 Mbtu[26]) to fulfill its heating requirement, translating to the combustion of roughly 336 tons of bituminous coal.[27]

The electricity (1,838,214 kWh[1]) used by Mueller's HVAC system in 1999 required the combustion of 751 tons of coal, resulting in the release of nearly 2,000 tons of CO_2 gas into the atmosphere.[3]

The Mueller HVAC Solution

Step 1. Energy Star Tune-up. Mueller should undergo an Energy Star building "tune up". Penn State has joined the EPA Energy Star program. Buildings that undergo tune-ups often achieve a 30% reduction in energy use. A tune-up consists of installing or upgrading an "energy management system". This means, among other things, evaluating and sizing of fan systems and upgrading them, if necessary, with more efficient motors and variable speed drives. Among other possible improvements the Energy Star program may include: ventilation air heat recovery, lab hood heat recovery, eliminate lighting above IES standards to reduce cooling load, operable windows for cooling feasibility, running fan coil units at lowest effective fan speed, and chiller retrofits.

Finally, the Energy Start Tune-up will eliminate simultaneous heating and cooling. Currently, the heating and AC systems in some of the rooms in Mueller actually work against one another because some of the air conditioning and baseboard heaters are run from two separate controllers. These controls were not integrated and existing piping systems were not modified during past renovations of the building.

The overall goal is to reduce the building heating and cooling load enabling a shift to smaller, less expensive replacement HVAC system components. If the Energy Star program is able to reach its 30% goal for Mueller, 551,464 kW-hrs/ year in electricity alone would be saved.[28]

Step 2. Temperature Adjustments. Raising air conditioning settings by one degree Fahrenheit can cut roughly 5% off cooling energy use.[29] Similarly, during winter a thermostat lowered 1 degree Fahrenheit will reduce normal heating energy use by approximately 3%.[29]

Temperature surveys taken in Mueller during March 2001, showed the average daytime and nighttime temperatures of the building to be 71.2 and 70.7 degrees Fahrenheit, respectively.[30] From these data it appears that nighttime temperature set backs are not being utilized.[31] Table 5a and 5b show the benefits of lowering (during winter) or increasing (during summer) the nighttime temperatures in Mueller.[32] It can be noted that even a modest one-degree decrease in temperature during the winter can produce significant benefits. A larger setback (4 degrees) could save over 55,148 kWh of electricity,[33] 22.5 tons of coal, 58 tons of CO_2 gas emissions,[3] and $1,200 over the course of a year[10] (as seen in Table 5a). On the other hand, even larger savings are possible during the summer by reducing AC loads (as seen in Table 5b). A one degree increase in temperature can save $535 and 22,977 kW-hrs of electricity a year while a 4 degree shift can save over $2,000/yr. If Mueller optimized its temperature settings to follow the maximum/minimum OPP recommended standards (78 degrees during the cooling season and 72 degrees during the heating season) sizeable economic and environmental benefits would incur. These benefits could also be multiplied substantially by utilizing nighttime temperature setbacks or increases depending on the season. If Mueller occupants dressed appropriately for the seasons – the temperature settings would be comfortable year round while making enormous savings in energy.

Table 5a.
Benefits of Temperature Setbacks during Winter.

Savings Per Year	*With One Degree Change*	*With Four Degree Change*
Electricity (kWh)[33]	13,787	55,148
Tons of coal[3]	5.6	22.5
Tons of CO_2 gas[3]	14.6	58.3
Dollars[10,33]	$321	$1,284

Table 5b.
Benefits of Temperature Increases during Summer.

Savings Per Year	*With One Degree Change*	*With Four Degree Change*
Electricity (kWh)[34]	22,977	91,908
Tons of coal[3]	9.4	37.6
Tons of CO_2 gas[3]	24	97
Dollars[10,34]	$535	$2,140

Step 3. Ceiling Fans. Ceiling fans could be environmentally friendly alternatives, or supplements, to Mueller's air-conditioning system. Properly installed ceiling fans (those placed no more than 8 to 9 feet above the floor) can save up to 40% of summer cooling costs by creating a wind chill effect within a room. Because evaporative cooling is enhanced when a ceiling fan is in operation; a room with an ambient temperature of 75 degrees F will feel like 71 degrees F. This, in turn, will save air-conditioning costs by allowing thermostats to be raised.[35]

Ceiling fans are more efficient than air-conditioning systems. On average, a ceiling fan run on high speed will consume less than 100W of electricity. If only used during the 12 hours of occupancy they would draw 64,625kW-hrs/yr to reduce temperatures by 4 degrees and reducing the AC electrical load by 91,908 kW-hrs.[36] Ceiling fans would thus save 27,283 kW-hrs/yr if used as a supplement to the current AC system and save $636/yr in Mueller's electrical rate. However, the added electrical demand would cost $2,728. It is therefore inadvisable to add ceiling fans to Mueller building on economic grounds alone unless Mueller residents were willing to do without all AC.

If they were and 300 ceiling fans were installed in Mueller and operated constantly on high speed for 6 months during the "cooling seasons", they would only draw 129,600 kWh of electricity.[36] In comparison, the air-conditioning system of Mueller consumed an estimated 1,148,884 kWh of electricity in 1999.[37] Therefore, if Mueller was cooled entirely by ceiling fans over 1,019,000 kWh of electricity (or $23,757)[38] could be saved per year, equaling approximately 35% of Mueller's total 1999 electricity use.[39] At first, completely replacing Mueller's air conditioning with ceiling fans appears unviable. However, two points should be made: i) 15 years ago Mueller occupants functioned well without AC, and ii) AC is really only necessary 20-30 days a year, in which case desk fans could be supplemented for AC.

An added benefit of ceiling fans with operable windows might be increased air-quality because greater amounts of fresh air would be allowed to enter the building. Additionally, ceiling fans can be used during winter to decrease heating costs by up to 10%. By reversing the rotation of fan blades so they operate in a clockwise direction warm air will be pushed-up against the ceiling and down the walls, effectively circulating warm air without creating a wind chill effect[40]. In new buildings it is advisable to add ceiling fans in the beginning so that AC units can be down-sized. In this way the new building would realize demand savings rather than demand costs.

The combination of these three steps (namely: Energy Star Tune-up, temperature adjustments, and ceiling fans) could halve Mueller's HVAC use.

5. Mueller Elevators

Although the electric motors powering the two elevators in Mueller building are relatively large (10hp), they represent only a small portion of Mueller's total electrical usage because they are only in use intermittently. Nevertheless, the operation of the two elevators consumes ~3,600 kWh per year[41]. This largely represents an unnecessary waste of energy (and another 3.8 tons of CO_2 in the atmosphere and 1.5 tons of coal) because the majority of the elevator use is due to non-physically handicapped individuals.

The elevator is a relatively inefficient device. A single trip to the 6th floor of Mueller building on the elevator requires 0.093 kWh or 80 Calories (the number of Calories in a medium apple). For a single trip the elevator generates 49 liters of CO_2 and consumes 35 grams of coal. On the other hand, your body could get itself to the 6th floor using only 5 Calories[41] – a factor of sixteen times less energy used than the elevator.

The Mueller Elevator Solution

By avoiding elevators and using stairs Mueller residents can conserve energy while improving their own health. When walking up stairs, both the most important of the 22 muscles connected to the pelvic girdle (gluteus maximus and the anterior of the leg (quadriceps) are sequentially flexed and relaxed.[42] This results in increased cardiovascular activity. Benefits of increased cardiovascular fitness include[43]:

- Lower risk of heart disease
- Lower risk of cancer
- Lower incidence of depression
- Greater capacity for physical activity (endurance)
- Lower blood pressure
- Beneficial changes in blood lipids (specifically a lowering of triglycerides and an increase in HDL cholesterol ("good" cholesterol)
- Enhanced circulation and cardiac output
- Enhanced utilization of body fat stores for energy needs
- Enhanced digestion and bowel regularity

By avoiding elevators and using stairs Mueller residents can conserve energy while improving their own health.

The experience of climbing stairs could be further enhanced through art installations commissioned from Penn State students. Conversely, the elevators would continue to receive no amenities

6. Other Energy Reduction Opportunities

Whenever an energy-consuming device is misused or left on while not in use, or an inefficient or poorly engineered device is used, energy and money are being wasted and unnecessary pollution is created. If Mueller residents made an effort to be mindful in their energy use and to adopt the most efficient technologies available, they could easily cut the energy use of Mueller Building by more than 50%. Although technical improvements can greatly enhance the energy efficiency of Mueller building, optimum performance can only be realized with the cooperation of Mueller's occupants.

7. Ecological Footprint Reduction

Whether in the past or during the present, the importance of energy to Mueller Building should not be understated. Almost forty years ago (1963), massive amounts of energy were needed to create and transport the materials used during the construction of Mueller. Additionally, human energy was expended to accomplish such tasks as laying bricks. In 2000 Mueller broke the 3 million kWh mark and in 2001-02, immense quantities of energy continue to be used within the confines of Mueller. Computers, elevators, lights, air conditioners, heating, and many different types of research equipment all contribute to the electricity budget of the Mueller Building.

This section has shown how the amount of electricity used by the HVAC, lighting, and other Mueller systems could be significantly reduced. Simple, "common sense" upgrades or behavioral changes can conserve substantial amounts of electricity as well as prevent fossil fuels combustion. Overall, the suggestions presented in this section (and the potential energy savings from computer and printer use in Section IIC) could prevent 1,954 tons of CO_2 emissions every year.[44] This represents a reduction of 64% from current emissions of over 3,000 tons of CO_2. In addition Mueller building's ecological footprint could be reduced by 164 acres.[45,46]

8. Model Energy Policy for Mueller

Mueller Laboratory, through its commitment to environmental stewardship, seeks to reduce the environmental impacts of its energy use. In order to accomplish this goal, the following steps will be taken:

- Artificial lighting will only be used when necessary. This can be accomplished either through individual actions or the installation of occupancy sensors.
- All incandescent light bulbs will be replaced with compact fluorescent bulbs.
- All T-12 fixtures will be replaced with more energy-efficient T-8 and in cases where it is warranted T-8 or T-12 fixtures will be replaced with T-5 fixtures.
- ½ lighting controls will be installed for all fixtures and may be further enhanced with daylight controls.
- Mueller will undergo an Energy Star tune-up.
- HVAC system will be programmed to decrease temperatures during the night in the winter and to raise them at night during the summer.
- Thermostats will be manually adjusted to environmentally friendly levels (78 in the cooling season and 72 in the heating season).
- Ceiling fans will be installed and used in place of the current AC systems to the extent possible.
- Mueller residents will utilize the stairs as much as possible.
- Unnecessary lighting and other heat generation equipment, including computers, will be turned off when not in use.
- Computer upgrades will be followed according to section IIB of this document.

9. Energy Conclusion

Of course, the electricity conserved through upgrades and retrofits will cost money to accomplish. All too often this is the primary reason improvements are not made to buildings. However, it should not be overlooked that the improvements will pay for themselves by reducing the amounts that are spent on purchasing electrical power. **In fact, the total energy savings that can be realized in Mueller through both behavioral and physical changes is over $45,000 per year.**

There has been a tendency at Penn State in the past to greet this kind of revelation with a sense of resignation (e.g., "We are stuck with an antiquated steam system and old leaky buildings."), but in this time of climate destabilization this response is no longer acceptable. Underlining the need for Penn State to take action 40 Penn State Professors that research the causes and effects of global climate change (including seven from Biology) recently signed the following statement:

"We are Penn State scientists who are familiar with the causes and effects of climatic change as summarized recently (January, 2001), by the United Nations Intergovernmental Panel on Climate Change. We endorse this report and observe that the further accumulation of greenhouse gases commits the Earth irreversibly to further global climatic change and consequent ecological, economic and social disruption. The risks associated with such changes justify preventive action through reductions in emissions of greenhouse gases. Our familiarity with the scale, severity, and costs to human welfare of the disruptions that the climatic changes threaten leads us to introduce this note of urgency and to call for Penn State to take a leadership role in early actions to reduce its greenhouse gas emissions via the most cost-effective means."

The energy solutions presented in this section offer a concrete plan for greenhouse gas reduction while increasing the quality of the Mueller environment. These actions are not just for Mueller. They could be adopted throughout Penn State and in the Commonwealth, as a whole.

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1. FASER Report, University Park, PA, *Mueller Building Electricity Usage*, 2000.
2. 123 persons, including: faculty, instructors, staff, and graduate students based on the 2000/2001 Dept. of Biology Directory.
3. Union of Concerned Scientists, "How Coal Works", http://www.ucsusa.org/energy/brief.coal.html

Calculations based on 500MW coal plant producing 3.5 billion kWh/year.

number of kW-hr/year	1	
	tons	pounds
coal burned	4.09E-04	8.17E-1
carbon dioxide	1.06E-03	2.11E+00
sulfur dioxide	2.86E-06	5.71E-03
nitrogen oxide	2.91E-06	5.83E-03
particulates	1.43E-07	2.86E-04
hydrocarbons	6.29E-08	1.26E-04
carbon monoxide	2.06E-07	4.11E-04
ash	3.57E-05	7.14E-02
sludge (from scrubber)	5.51E-05	1.10E-01
pounds of arsenic	X	6.43E-08
pounds of lead	X	3.26E-08
pounds of cadmium and other heavy metals	X	1.14E-09
gallons of water	6.29E-01	X

Other useful conversions:
1BTU = 0.000293 kW-hrs, 1kW-hr = 3112.142 BTU
1 kW-hr = 859845 cal, 1 cal= 1.163E-6 kW-hrs
1 cal = 0.003968 BTU, 1BTU = 251.9958 cal
1000cal = 1kcal or 1Cal (the Calories used on food labels)

4. R. Kessinger, Personal Communication (University Park, PA, February, 2001).
5. Annual avg. temperatures for Pittsburgh, PA http://www.nws.noaa.gov/er/pit/histemp.htm
6. The cold rooms contain R-12 refrigerants, which are harmful to the Earth's ozone layer. The coldrooms consume approximately 86,000 kWh of electricity each year, requiring the consumption of 35 tons of coal.
7. U.S. Dept. of Energy, *Energy Efficiency and Renewable Energy Network (EREN): EREN Fact Sheets* http://www.eren.doe.gov/erec/factsheets/eelight.html
8. The number after the T indicates the total width in 8^{ths} of an inch, so T-12 equals 1.5 inches.
9. Based on assumption that all lights, excluding hallways, stairwells, and lobbies (which are illuminated 24 hrs/day all year), are 'on' 12 hrs/day, 25 days/month, or 3600 hours annually.

Total energy use for lighting =T-12 lights in Hallways [77 fixtures x 82W/fixture x 8760hrs/yr x 1kW/1000W = 5.5310E4 kW-hrs/yr] +
T-12 lights in remainder [624 fixtures x 82W/fixture x 3600 hrs/yr x 1kW/1000W = 1.8420E 5kW-hrs/yr]+
T-8 lights [197 lights x 60W/fixture x 3600 hrs/yr x 1kW/1000W = 4.2552E4 kW-hrs/yr] +
CFL lights [22 fixtures x 25W/fixture x 3600 hrs/yr x 1kW/1000W = 1.980E3 kW-hrs/yr] +
incandescent lights [19 fixtures x 100W/fixture x 3600 hrs/yr x 1kW/1000W = 6.84E3 kW-hrs/yr] = 2.90887E5 kW-hrs/year

Percent of Mueller total electrical usage = 2.90887E5 kW-hrs/year / 2872210 kW-hrs/yr = 10%

10. Mr. Doug Donovan, Personal communication, (University Park, PA, April 2001). Price for electricity avoidance is $0.0233 per kWh saved; electrical demand savings = $7.58 kVA (note: electrical demand savings apply only when retrofits to more efficient devices are completed).
11. Unoccupied room calculations:

Hallways must be illuminated 24 hrs/day.
Restrooms electrical savings from eliminating unnecessary illumination:
8 rooms x 2 fixtures/ room x 3600 hrs/year x 82W/fixture x 1kW/1000W x 0.60 unoccupied = 2834kW-hrs/yr
Monetary savings: 2834kW-hrs/yr x $0.0233/kW-hr = $66
Lab/offices electrical savings:
The energy used by T-12 for lighting excluding restrooms and hallways:
(624 fixtures - 16 in restrooms) x 82W/fixture x 1kW/1000W x 3600hrs/yr = 1.795E5 kW-hrs/yr
Thus the potential energy savings from lab and offices by eliminating unnecessary illumination is:
(T-12 [1.795E5] + T8 [4.255E4] + CFL [1.98E3] + incan. [6.84E3]) x 0.14 = 32319 kW-hrs/year

Lab/offices monetary savings: 32319 kW-hrs/year x $0.0233/kW-hr = $753
Total energy conserved by eliminating unnecessary illumination:
lab/offices[32319]+ restroom[2834]=35153kWhrs/ yr
Total monetary savings = restroom [66] + lab/office [753] = $819/yr
Percent of Mueller total electrical usage for lighting = 35153 kW-hrs/ yr / 2.90887E5 kW-hrs/year = 12%
With occupancy sensor savings would be approximately 5% less:
Restrooms: 2834 x 0.95 = 26921kW-hr/yr
$66 x 0.95 = $63/yr
Lab/office:
32319 x 0.95 = 30,703 kW-hrs/yr
$753 x 0.95 = $715/yr
Total:
35153 x 0.95 = 33395 kW-hrs/yr
$819 x 0.95 = $778/yr

12. Cost for materials and labor per ceiling-mounted IR/UltraSonic occupancy sensor is $155.00. Calculation for sensor payback time: $155.00 * 8 bathrooms = $1,240 total for sensors for Mueller bathrooms. Payback time for sensor in restrooms: Cost of sensor [1240]/ savings [66] = 19 years. Payback time in labs and offices will depend on the number of fixtures per sensor. For details see: (http://energy.opp.psu.edu/engy/ECOs/Lighting/LtgAnal2.htm).
13. Calculations of incandescent and CFL bulbs were based on manufacture performance ratings and prices of bulbs at State College Wal Mart: Incandescent - $0.24 per bulb, lifetime=750 hours, 100W; CFL - $9.74 per bulb, lifetime=10,000 hours, 25W.
CFL bulbs will last 2.78 yrs assuming they are used for 3600 hrs/yr (10,000hrs/ 3600hrs/yr). A CFL bulb lasts 13.3 times as long as an incandescent bulb. Replacing all the incandescent bulbs with CFL bulbs in Mueller will result in a savings of bulbs to landfills of:
19 fixtures x 13.3 - 19 bulbs = 234 bulbs every 10,000 hours or 234/2.78 = 84 less bulbs/yr
Total Savings over 10,000 hours = cost of bulbs + energy rate savings + energy demand savings:
Cost of bulbs: incandescent [19 fixtures x 13.3 changes x $0.24=$60.65
Savings for energy rate: 10,000hrs x 75W x 1kW/1000W x $0.0233 x 19 fixtures = $332
Savings for demand: 2.78yrs x 12 x $7.58 x 19 fixtures x 75 W x 1kW/1000W = $360
Total savings: $60 + $332 + $360 = $752
Total Savings per year: $752/2.78yrs =$271/yr
Electrical savings per year: ($360 + $332) / 2.78 yrs = $249/yr or in kW-hrs: [19 fixtures x 75W x 1kW/1000W x 3600 hrs/yr] = 5,130kW-hrs/year
Payback: (retrofit cost [19 fixtures x $9.74/fixture= $185]) / (rate [3600hrs x 75W x 1kW/1000W x 19 x $0.0233/kWhr = $120] + demand [12 x $7.58 x 19 x 75W x 1kW/1000W = $130] + incan [19 x 5 changes/yr x $0.24 = $23] = 0.68 yrs
Free money = 2.78 - 0.68 = 2.1 yrs
14. Ballasts control the electricity used by the lighting unit, and are required for starting the lights and circuit protection
15. PSU OPP Energy Webserver, Lighting Energy Conservation Opportunities, (http://energy.opp.psu.edu/engy/ECOs/Lighting/LtgAna12.htm).
16. D. Donovan, Personal communication, (University Park PA, Feb., 2001).
17. At present, Penn State requires a payback on investment of less than five years before adopting energy saving measures (D. Donovan, personal communication).
18. T-12 to T-8 retrofit calculations: 701 T-12 fixtures (77 in hallways on 24hrs/day x 365 days/yr = 8,760 hrs/yr per fixture and 624 in the rest of the building are on 12 hrs/day, 25 days/month, or 3600 hrs/yr per fixture. Costs were determined from footnote 10. The fixtures were assumed to have 2 bulbs.
19. 77 Hall light fixtures x 22W x 8760 hrs/yr / 1000 kW/W=14,839kWh/yr; 624 Remaining light fixtures x 22 W x 3600hrs/yr / 1000 kW/W = 49,421kWh/yr
20. Hall: 77 x 22W/1000 x $7.58 x12 + 14,839kWh x $0.0233/kWh = $499.84 savings; Remaining = 624 x 22W/1000 x $7.58 x 12+ 49,421kWh/yr x $0.0233/kWh = $2,400.21savings
21. Cacka, John, *Direct/Indirect Laboratory Illumination, An Analysis of Lighting Quality and Energy Consumption*.
22. To calculate the energy saved for ½ lighting, lights in the hallways and restrooms were excluded leaving:
total [290,887] - hall [5.53E4] - restroom [14 x 2 x 3600 x kW/1000W x 82W = 8265] = 227,322kW-hrs/yr
227,322kW-hrs/yr x savings during [0.5] = 1.1366E5 kW-hrs/yr
Approximating ½ lighting would be used 50% of the time (more on south and East sides less on the north and west sides of the building) the total savings is:
1.1366E5 kW-hrs/yr x 0.5 = 5.6831E4 kW-hrs/yr
Savings: 5.6831E4 kW-hrs/yr x $0.0233/kW-hr = $1,324
Percent of total electricity: 56831/2872210 = 2%
Percent of electricity used for lighting: 56831/2.9E5 = 20%
23. To calculate total energy savings from lighting the savings from each initiative cannot be simply added together linearly. For the total calculation the behavior savings were accounted for first and then the savings for retrofitting were calculated for the decreased usage (86% of CFL retrofit, 40% restroom T-8 retrofit, finally for the T-8 retrofit in the labs/offices the values for the restroom was subtracted from the total and multiplied by 86% and 75% to account for both ½ lighting and unoccupied savings).
Total energy savings for lighting (units: kW-hrs):

½ lighting [56,831] + unoccupied restroom [2834] + unoccupied lab/office [32319] + CFL [0.86 x 5,130= 4,412] + T8 restroom [0.4 x 22W/1000 x 3600hrs/yr x 8 x 2= 507] + T-8 lab/office [0.86 x 0.75 x (49,421 - 507) = 31550] + T8 hall [14,840] = 143,293 kW-hrs/yr

Percent savings: 143,293 kW-hrs/yr / 2.90887E5 kW-hrs/year = 0.4926 ~50%

Monetary savings (units: dollars):
½ lighting [1,324] + unoccupied restroom [66] + unoccupied lab/office [753] + CFL [0.86 x 249= 214] + T8 restroom [0.4 x 22W/1000 x 3600hrs/yr x 8 x 2 x $0.0233 + 12 x 7.58 x 8 x 2 x 22W/1000= 44] + T-8 lab/office [0.86 x 0.75 x (2400-44) = 1520] + T8 hall [500] = $4,421/yr

24. Penn State Univ. Office of the Physical Plant Records, *PM Inventory for Mueller Building*.
25. PSU OPP Energy Webserver**,** *West Campus Steam Plant*, http://www.opp.psu.edu/divisions/ops/us/steam/wcsp.htm
26. 18,554 Mbtu =est. total energy (electricity and steam) used by Mueller in 1999 derived from 1997-98 data (http://energy.opp.psu.edu/engy/Consumpt)18,554 Mbtu – [(2,872,210 kWh * 3,413 btu/kWh)/10^6] = 8,751 Mbtu.
27. [(8,751 Mbtu * 10^6) / 13,033 btu per lb. bit. coal] / 2000 = 336 tons bit. coal.
28. To calculate the Energy Star tune-up 30% reduction only the HVAC electrical use was taken into account of: 1,838,214 kW-hrs/yr x 0.3 = 551,464 kW-hrs/yr
To calculate monetary savings it is assumed that only generation charges are saved in the calculations (although there would surely be both electrical demand savings and savings from reduced steam which would be quite substantial). If it assumed that only the generation charges can be saved Mueller would save: 1,838,214kW-hrs x 0.3 x 0.0233$/kW-hr= $12,849/year.
29. D. Hayes, *The Official Earth Day Guide to Planet Repair*, (Washington D.C.: Island Press, 2000).
30. Temperatures were recorded at 20 different locations on all floors and faces of the building during both afternoon and early-morning hours.
31. Nighttime refers to 12 hours (half of a day).
32. Year arbitrarily divided into 6 months of summer (AC used) and 6 months of winter (heat used).
33. Savings determined by the following calculations:
[(total kWh used for HVAC = 1,838,214)/(2)] = 919,107
919,107 kWh/(2)] = 459,554 kWh = the total nighttime kWh for summer or winter
459,554 kWh x 0.03 = 13,787 kWh saved per degree in one winter (0.5 year)
Monetary savings: 13,787kW-hrs x $0.0233 = $321/yr
55,148kW-hrs x $0.0233= $1,284/yr
Temperatures were recorded at 20 different locations on all floors and faces of the building during both afternoon and early-morning hours.
34. Savings determined by the following calculations:
459,554 kW-hrs x 0.05 = 22,977 kW-hrs/yr
4 degree: 4 x 22,977 = 91,908 kW-hrs/yr
Monetary savings:
22,977kW-hrs/yr x $0.0233 =$535/yr
91,908kW-hrs/yr x $0.0233 = $2140/yr
If both winter and summer night time temperature alterations are made by 4 degrees [91,098 + 55,148 = 147,056kW/hrs] will be saved a year or [147,056 x 0.0233 = $3,426].
35. Hunter Fan Company, *Ceiling Fans*, (http://www.hunterfan.com/showroom/fans.html). Also, newer fans are more reliable than older models, and some require no oiling or other maintenance (models like the Hunter Original utilize an oil-bath lubrication system that keeps the primary motor bearings lubricated at all times).
36. Calculations for ceiling fans:
(300 fans x 100W/fan x 24 hours/day = 720 kWh) x 180 days (6 months) = 129,250 kWh. (A very large overestimate of realistic use.)
If only used during the 12 hours of occupancy: 129,250/2 = 64,625kW-hrs / yr to reduce temperatures by 4 degrees and reduce the AC electrical load by 91,908 kW-hrs.
Savings: 91908-64625 = 27283 kW-hrs/yr
Rate savings: 27283kW-hr x $0.0233 = $636/yr
Demand costs: 100W/fan x 1kW/1000W x 300 fans x 12 x $7.58 = $2,728
37. Assuming air conditioning is 40% of electrical budget: 2,872,210 kWh (1999 usage, see endnote 1) * 0.4 = 1,148,884 kWh.
38. 1,148,884 kWh – 129,250 kWh (annual elec. draw of ceiling fans) = 1,019,000 kWh saved per year.
1,019,000 x 0.0233 $/kW-hr = $23,743/yr
39. 1,019,000 kWh / 2,872,210 (1999 usage) = 0.35, or 35%
40. Hunter Fan Company, *Ceiling Fans*, www.hunterfan.com/support/fans_faq.html
41. a)For a single 45 second trip (ground to 6th floor): 7.5 kW (= 10 HP, the power of motor) x 0.0125 hr. (time of trip) = 0.093 kWh = 80kCal; Conversions from footnote 3 give: 0.075 lbs = 35g and 0.197 pounds of CO_2 which is 49L at STP.
b)It takes 60 seconds for a person to climb the stairs to the 6th floor, assuming 32m climb, and 70kg body: Energy consumed= 70kg x 9.8m/s/s x 32 m / 1000W/kW / 3600 sec/hr= 0.006kW-h = 5Cal
c) Yearly totals: 750 full trips per week (assumption) * 0.075 lbs. of coal per full trip * 52 weeks per year =~2925 lbs. of coal per year.
0.093kW-hrs x 750trips x 52weeks/year = 3,627kW-hrs/yr
42. E. Darden, *The Nautilus Body Building Book*, *Contemporary Books Inc*., Chicago, 1982.
43. www.bcbs-ga.com/services/quizzes/fitness/wellsource_fitness/aerobic.htm
44. Total Energy Conserved [kWh/yr]= Lights (143,292) +

Building tune-up (551,464) + Temperature setbacks (91,908) + Computers (30,790) + Printers (8,530) + Ceiling Fans (1,019,000) + Elevator (3,627) = 1,848,611 kWh/year

Please note: the calculations for the ceiling fans, EPA Energy Star building tune-up and temperature setbacks are rough estimates. A portion of the energy savings from the temperature setbacks would not be electrical (winter – heat from steam plants) and were excluded here. The building tune-up would also have considerable heat savings. However, the calculations indicated that a large quantity of energy/money could be conserved through optimization of the HVAC system.

Converting kW-hr to CO_2 prevented from footnote 3 = 1,954 tons; Percent reduction = 1954/3036 = 64%

45. Land area calculated for ecological footprint follows from: M. Wackernagel and W. Rees, *Our Ecological Footprint: reducing Human Impact on Earth,* (Philadelphia, PA: New Society Publishers, 1996). Gives conversion factor from energy to land area as 11,241 kWh/ acre: 1,848,611 kW-hrs/11,241 = 164 acres

46. Total Fiscal savings per year for suggestions: Lights 4,421) + Building tune-up (12,849) + Temp. setback (2,142) + Computers (1,850) + Printers (425) + Elevators (85) + ceiling fans (23,743) = $45,515

B. Reducing Mueller's Water Footprint

1. Water - An Ecological Profile

All life processes take place in an aqueous medium. It is the nature of water's hydrogen bond that gives it many of its properties (e.g., good solvent, ability to withstand temperature change). Humans like most other organisms are composed mostly of water (e.g., approximately 65% of body weight in case of humans).[1]

Although the United States is endowed with abundant surface and ground water, our clean water supply is far from unlimited; careless water use and neglectful stewardship can lead to water contamination or even exhaustion.

The Spring Creek Watershed received enormous rainfall (4th greatest out of 106 years on record) in 2001 yet because of increased water use in the area the water table levels were at a record five-year low at that time.[2] The necessity for efficient use of our water supplies is apparent.

In addition, buildings and the pavement surrounding them combine to create a rather impervious surface, with the result being a dysfunctional hydrological regime. Water quality and water quantity are compromised, and aquatic and riparian habitats are diminished.

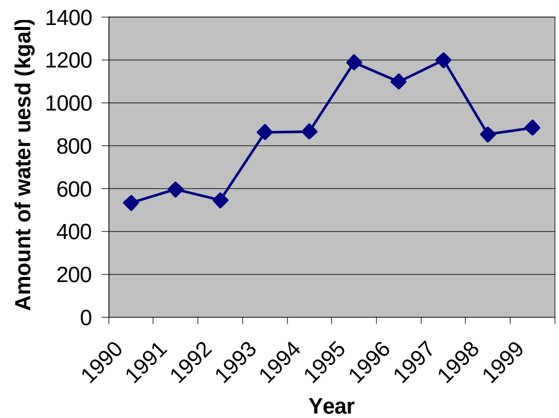
2. The Mueller Connection

Mueller Laboratory contains 103 sinks (including bathrooms and lab rooms), 14 toilets, 7 urinals, and 14 water fountains[3]. Mueller's water comes from the Big Hollow and Houserville well fields.[4] The water is treated before it enters the Mueller Building. After leaving the building the water undergoes biological and chemical (chlorine) treatment at the University Wastewater Plant located on University Drive. This water is then sprayed onto fields and woods just north of campus. The trees and crops in the spray area are, in effect, fertilized with the treated effluent. When functioning properly, this innovative system strips the nutrients from the effluent for the betterment of the trees and crops above ground while maintaining water quality below ground.

Mueller water consumption showed a rising trend during the 1990s (Figure 1).[5] In 1999 total water consumption was 883,000 gallons, approximately 50% greater than consumption at the beginning of the decade. Of this total, approximately 171,886 gallons (19.5% of total water used in 1999) were used by the sinks, toilets, and urinals found within the building's bathrooms. The remainder was used in Mueller's laboratories. (see calculations for Table 1)

The Mueller Building is sits in the center of a complex web of paving. Paving, simply by its lack of porosity, causes ecological harm. Typical sidewalks have a high surface runoff potential and also lose water by evaporation. This adds to the depletion of ground water and aquifer stores. At first the loss of water from paved surfaces seems like a small problem, until one starts calculating the actual area of the surfaces covered. For instance, at University Park there are 31 miles of streets and 23 miles of walkways[6]. The walkways single-handedly account for more than 607,000 square feet of impervious surfacing[7]. This is over 13 acres!

Figure 1. Water Use in Mueller Laboratory (1990-1999)



3. The Mueller Solution

The bathrooms of Mueller consume approximately 168,850 gallons of water a year. This equates to nearly 1,373 gallons per year for each building resident.[8] The toilets and urinals found in Mueller consume approximately 2.0 and 1.5 gallons per flush, respectively.[9] These devices are pressurized systems and consume much less water per flush than do the gravity-fed systems that are commonly located in most homes.[10] However, remarkable water savings can still be accomplished using waterless urinals and toilets. In addition a 40% decrease in the amount of water used by the 103 sinks within Mueller can be achieved with water saving faucets.

Reducing water use in the laboratories without compromising research quality can be accomplished by personal awareness of water use habits of the research personnel. Additional water savings can be accomplished by eliminating all single-pass water-cooling systems for laboratory equipment and by replacing high-pressure water vacuum systems with electrical pumps.

Mueller can increase its water-use efficiency without compromising the research, teaching, or administrative activities of building residents. To achieve this goal the following steps would need to be taken: 1) Upgrade water use equipment by replacing bathroom faucets with high-efficiency models; 2) install waterless urinals; 3) install waterless toilets; 4) increase personal awareness regarding water-use habits; and 5) install porous paving.

Step 1: The installation of high-efficiency faucets in bathrooms and labs. Most of the faucets currently found in Mueller's bathrooms have a flow rate of 2.5 gallons per minute (gpm),[11] and have either standard control knobs or ones that produce water for 2-3 seconds when pressed.

There are several ways to reduce flow rates of faucets; the fixtures themselves can be replaced with more efficient models, or flow control devices can be added to the ends of the faucets.[12] Flow control devices that add air to the water are called faucet aerators. These devices add air to the water, therefore producing smaller water droplets which tend to wet objects more thoroughly.[12] Another type of flow control utilizes laminar flow technology. These devices are more efficient than faucet aerators because they create many parallel streams of water without mixing the water with air. In other words, the parallel streams created by a laminar flow system wet objects more thoroughly than do normal faucet aerator systems.[12]

If Mueller bathroom sink fixtures were replaced or upgraded with high-efficiency models (e.g., having a flow rate of < 1.5 gpm) sink water could be reduced by 40%. The ability to wet objects more efficiently would also be a benefit in some laboratories (decrease wash time), however, the decreased flow rate could be detrimental (increased fill time) so upgrades to laboratory sinks must be made on a lab-by-lab basis. Faucet aerators are remarkably economical and are even designed to be tamper resistant. [13]

Step 2. The installation of waterless urinals. Utilizing state-of-the-art urinals will dramatically reduce water use in urinals (100%).[14] Waterless (or No-flush) urinals resemble conventional fixtures, and easily replace them. They install to the regular waste lines, but eliminate the flush water supply lines, flush valves, and handles. The urinal bowl surfaces are urine repellent; urine is 99% liquid and its drainage is effected without flush water. The daily cleaning procedures are the same as for flushed urinals. The conventional water-filled urinal's trap drain is replaced by a disposable EcoTrap[15] inserted in the urinal outlet. It holds a layer of the immiscible liquid floating on top of a urine layer that block out sewer gases and urine odors from the room.

Step 3. The installation of waterless toilets. Self-contained toilets will also dramatically reduce water use in toilets (100%).[16] Waterless self-contained (or composting) toilets unites the natural process of composting with modern technology to accelerate and optimize biological decomposition, evaporate excess liquid and exhaust odors and water vapor without wasting water.

Nature does its own composting. In warm weather, natural aerobic soil microorganisms digest and transform leaves, grass and other organic debris into a hygienic natural fertilizer called ‘compost". Compost provides the nutrients for new plant growth and holds moisture in the soil. Gardeners around the world utilize this process when they compost yard and garden wastes and use the compost as fertilizer (as is done with Penn State’s successful dining hall composting program). The compost generated in Mueller building could be used to increase the growth and health of the plants in the landscaping around Mueller without the use of chemical fertilizers.

Waterless toilets look very similar to conventional toilets – except they contain a receptacle underneath for collection of the compost. They are ruggedly constructed, reliable and highly efficient. To use a waterless toilet one simply opens and closes a bowl trap rather than flushing. The operation is sanitary, odor-free and environment friendly. The maintenance/cleaning is similar to a normal toilet except that the bowl is removable. The systems are designed for easy cleaning and collection of the compost. Composting toilets could be installed throughout Mueller demonstrating advanced environmentally responsible technology even in the restrooms.[17]

Step 4: Increase awareness of personal water use habits. It is obvious from Table 1 that the majority of water use for Mueller building occurs in the laboratories. Small increases in water-use efficiency can be accomplished by installing water saving devices on faucets in laboratories. However, the optimal method of increasing water use efficiency is for individuals to only allow water to run when it is actively being used to complete a task (e.g. filling beakers, washing hands, or cleaning equipment). A faucet having a flow rate of 2.5 gpm will expel one gallon of water every 24 seconds. Also, leaking faucets can waste significant amounts of water. A slowly dripping faucet can waste up to 15 gallons of water each day.[18] When leaking faucets are identified maintenance personnel should quickly be alerted to repair them. It is impossible to ascertain the possible savings from personal awareness, but the fact that water use increased in Mueller by 50% in the past 10 years indicates there is some room for improved water-use efficiency.

Step 5. The installation of pervious pavements. Utilizing pervious paving in sidewalks, bike lanes, and roads surrounding the Mueller Building will have numerous benefits. Porous pavement provides hydrological storage, reduces peak runoff rate, and enhances soil infiltration because it allows rainfall to percolate through it.[19] Porous pavement has already been tested at PSU at the Centre County/Penn State Visitor Center.[20] In addition recycled materials, such as crumb-rubber from waste automobile tires can be utilized to fabricate permeable sidewalk surfacing (as demonstrated at the 8th Annual PSU Green Design Conference).

Table 1. Water Consumption in Mueller Before and After Proposed Upgrades.

Total Water Use (gallons/ year)[21]	***Status Quo (1999)***	***After Upgrades (Step 1)***	***Savings by % After Upgrades (Step 1)***
Bathroom Faucets Alone	3,036	1,882	38%
Waterless Urinals Alone	32,472	0	100%
Composting Toilets Alone	75,680	0	100%
Bathrooms Total	171,886	60,698	65%
Entire Building	883,000	771,812	12.5%

4. Ecological Footprint Reduction

By implementing these five steps -- retrofitting faucets, urinals, and toilets with more efficient water-conserving devices, increasing personal water use awareness, and replacing paving with permeable surfaces -- Mueller could reduce water use by over 50% and begin assisting the recharge of local ground water.

5. Model Water Usage Policy

Mueller Laboratory, through its commitment to environmental stewardship, seeks to reduce the environmental impacts associated with water usage. In order to accomplish this goal, the following steps will be taken regarding water relating to the building:

- Bathroom and laboratory faucets will be retrofitted with high-efficiency flow-control devices.
- Flush urinals will be replaced with waterless urinals.
- Flush toilets will be replaced by composting toilets.
- Increase our awareness of personal water use habits.
- All once-through water-cooling systems on laboratory equipment will be replaced.
- Any leaking or damaged plumbing fixtures will be promptly repaired or will be replaced.
- Paving surrounding Mueller Building will be replaced with permeable paving.

For more information:
High Efficiency faucets:
http://www.nrgsavers.com/aerator.htm
Waterless urinals:
http://www.waterless.com/
Waterless/composting toilets:
www.compostingtoilet.org
http://www.envirolet.com/enwatsel.html
http://www.vipimage.com/bio/index.htm
Pervious paving:
http://www.petrusutr.com/paving_paper.htm

6. Water Conclusion

Mueller's current high water consumption can be markedly reduced by retrofitting existing sinks with more efficient faucets in bathrooms and laboratories, installing waterless urinals and toilets, and by improving personal awareness of water use habits.

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1. KanCRN Collaborative Research Network, Water Conservation (http://www.kancrn.org).
2. T. Giddings, *The Invisible Drought Continues..., Springs and Sinks*, July 2001 pg. 2.
3. S. Jenkins, Lacko, M., McInerney, J., and Richey, M.; *Biology 450W Ecology in Action Project: Air and Water Use in Mueller Lab, and Their Impacts on the Environment* (Dec. 2000).
4. Penn State Consumer Confidence Report, Water Quality Report, 1999.
5. FASER Report, University Park, PA, Mueller Building Water Usage, 2000.
6. OPP (Office of Physical The Plant), *Summary of Selected Data for the Pennsylvania State University*, 1997-1998, http://www.opp.psu.edu/fact/facttbl.htm
7. 23 miles = 121,440 feet, 121,440 ft long x 5ft wide = 607,200 ft^2 = 13.9 acres
8. 123 persons, including faculty, instructors, staff, and graduate students based on the 2000/2001 Dept. of Biology Directory. 168,850/123 = 1373 gallons/person/year
9. R.W. Harris, Personal Communication (University Park, PA, March 2001).
10. Flushmate Toilet Manufacturing (http://www.flushmate.com/framemfg.html).
11. Average value taken from flow surveys of Mueller bathroom faucets (March 2001).
12. A. Jones, Rocky Mountain Institute, High-Efficiency Showerheads and Faucets (Snowmass, CO: RMI, 1993).
13. Tamper proof faucet aerators come with locking keys and are Brass/chrome plated with a high quality finish. Comes in flow rates of 0.5gpm, 1.5gpm, 2.2gpm with male or female threads. P/N NS3205 Retail Price: $3.10 http://www.nrgsavers.com/prodwater.htm
14. http://www.waterless.com/
15. http://www.waterless.com/Ecotrap.htm
16. http://www.waterless.com/
17. A waterless toilet that could handle 6 people for continuous use would cost $1,275. Assuming occupants only expel half of their average waste at Mueller- 14 composting toilets could handle 168 people or a 36% over capacity. http://www.envirolet.com/enwatsel.html
18. KanCRN Collaborative Research Network, Water Conservation (http://www.kancrn.org).
19. Novotny, V. and Olem, H., *Water Quality*, VNR pub., New York, 1994.
20. http://www.psu.edu/ur/archives/intercom_2000/Nov2/visitorcenter.html
21. For water use calculations the following assumptions were made: 1) Undergraduate student use of facilities was NOT included in calculations; 2) Building population (123 persons) was 60% women and 40% men; 3) Women use toilets two times per day, men use urinals two times per day and 50% of men use toilet once per day; 4) Faucets used 75% of the time after toilet or urinal use; 5) Average washing time of 15 seconds = 0.625 gallons used per wash; 6) Bathrooms in use 5 days a week x 34 weeks in complete school year, and 5 days a week x 15 weeks in summer x (2/3 population during summer).

Calculations:
Female use= (123 people) x (0.6 female) x (2 turns) x (2 gal/ toilet flush) = 295 gal/day

Male use= (123 people) x (0.4 male) x [(2 turns) x (1.5 gal/flush in urinal) + (1/2 turn) x (2 gal/toilet flush)] = 197 gal/day (49 for toilets)
Total = 492 gal/day for toilets and urinals
Total for toilets = 295 gal/day female + 49 gal/day male = 344 gal/day (or 75,680 gal/year)
Total visits = (123 people) x (0.6 female) x (2 visits) + (123 people) x (0.4 male) x (3 visits) = 295 visits/day
Sink use = (295 visits) x (0.75 wash rate) x (0.0625 gal/wash) = 13.8 gal/day or 3,036 gal/year
Total water use in bathrooms = 13.8 gal/day + 492 gal/ day = 506 gal/day
Total water use in bathrooms/year = (5 days/week) x (34 weeks in school year) x (506 gal/day in toilets and urinals) + (5 days/week) x (15 weeks in summer) x (2/3 occupancy) x (506 gal/day) = 111,320 gal/year
Waterless urinals save = (123 people) x (0.4 men) x (2 visits) x (1.5 gal/urinal flush) = 147.6 gal/day, 32,472 gal/ year

C. Reducing Mueller's Communications/ Computing Footprint

1. Paper

An Ecological Profile

The thirty-year-old vision of the paperless office has yet to see widespread reality. In fact, paper use in the United States increased two-fold between the mid-1970s, when such predictions first appeared, and today, when the use of computers, digital storage, and electronic mail in business is at an all-time high.

Paper is the end-product of an industry which moves trees from forests to chip, pulp, and paper mills, then to distributors, and finally to end-users. Not only is the pulp and paper industry the third largest consumer of chlorine and the second largest consumer of energy in the United States, but it is unrivaled in its use of water per ton of product. Furthermore, paper production contributes to air and water pollution: to the air it adds greenhouse gases and pollutants, such as nitrous and sulfur oxides, acetone, methanol, and carbon monoxide; and to the water it adds many noxious chemicals, including deadly but avoidable dioxins, furans, and chloroform.[1]

The Mueller Connection

Mueller Building occupants consume, collectively, approximately 5.3 tons of paper (i.e., over one million sheets) per year.[2] Approximately 8.4 acres[3] of temperate forest land (or 2 acres of southern pine plantation) are necessary to supply the pulp for Mueller's annual paper consumption. The "Penn State Copier Bond" that Mueller uses in its copying machines comes from Willamette Industry's paper plant in Johnsonburg, PA.[4] In 1998, that plant released 27 tons of pollutants into surface water and 311 tons into the air, including 61 tons of sulfuric acid and 148 tons of hydrochloric acid.[5]

The Mueller Solution

The environmental impacts of Mueller paper use are striking but a significant decrease in the impact of Mueller paper use is possible without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller: 1) purchase recycled, environmentally friendly paper; 2) fully utilize paper, and 3) correctly channel waste paper.

Step 1: Purchase recycled, environmentally friendly paper. In the 1999/2000 fiscal year Mueller purchased approximately $5,540 of "Penn State Copier Bond,"[2] 0% post-consumer content, chlorine-bleached paper at $2.74 per ream (500 sheets/ream).[4] Mueller could purchase Badger Envirographic 100 (the paper that this document is printed on), which has 100% post-consumer recycled content, is "process chlorine free,"[6] and costs $4.30 per ream.[7] Other universities (e.g., University of Buffalo) have already taken this step.[8]

Step 2: Fully utilize paper. In our universities, documents are often printed without considering how font size, column width, and line spacing decisions affect paper needs, but paying attention to these "details" can dramatically reduce paper consumption. For example, a hundred-page "standard" print job (i.e., 12-point font, 1.25" left-right and 1" top-bottom margins, double spaced, one-sided) can easily be reduced to less than 20 pages by paying attention to all these measures and even applying one or two of them can often reduce paper use by as much as half (Table 1).

Table 1. Four measures that can dramatically reduce paper use.

Paper Reduction Measure	Standard Printing	Reduced-Impact Printing	% Reduction in Document Length	Resulting Page Length*
Font Size	12-pt	10-pt	25%	75
Margins	1.25" l,r 1" t,b	0.75" l,r,t,b	19%	81
Spacing	double	single	50%	50
Printing	1-side	2-sides	50%	50
All Measures			85%	15

* For a 100 page document at the start; ideal case.

At present Mueller personnel do occasionally employ these paper-saving strategies. For example, a survey of Mueller personnel and an audit of various recycling bins and copy jobs indicates that reduced font size is used for 25% of printed pages,[9] reduced margins for 25% of printed pages,[10] and single-spacing for 70% of printed pages. Performing these font, margin, and line-space reductions decreases Mueller paper requirements by approximately 30% (Table 2). Mueller also "duplex" prints 40% of its document pages and gives 10% a "second life"; this combined with the foregoing measures results in an overall Mueller paper savings of 46%.[11]

Table 2. Percent of Mueller Pages Receiving Paper Conservation Methods*

Impact Reduction Method	*Status Quo*	*Mueller Potential*
Input: % Recycled Paper Procured	0%	70%[12]
Use:		
% Small Font, Narrow Margin, or Single Line Space	40%[13]	100%
% Duplex Printing	40%	75%
% Given a "Second Life"	10%**	25%
Output: % Recycled	90%	100%

* Data from surveys and pre- and post- use audits
**Rough estimate.

Step 3: Channel waste paper in an environmentally responsible fashion. Mueller already performs this function well by recycling, but could further decrease its environmental impact by channeling paper having one clean side into a "Second Life" bin. On a building-wide scale, the sum of re-usable paper per year (i.e., paper with a blank side) that could be collected is approximately 250 reams, or 125,000 pages. This quantity could produce 1250 one-hundred sheet notebooks for faculty, staff, and student use. For example, the University of Michigan's "Homemade 100% Recycled Notebooks" are composed of re-used paper bound between re-used cereal boxes from the dining commons.[14]

Ecological Footprint Reduction

By buying 100% post-consumer recycled paper, fully using that paper, and then recycling it, Mueller could reduce its annual paper use from just over 1 million to approximately 310,000 sheets of paper. This, in turn, would result in a dramatic decrease in the environmental impacts of Mueller's paper consumption (Table 3).

Table 3. Potential Reduction in Environmental Impact Associated with Annual Paper Use in Mueller Using Best Practices.

	Status Quo	*Mueller Potential*	*% Reduction*
Paper (reams required/yr)	2022	664	67%
Landfill (tons/yr) [15]	6.3	1.26	80%
Water (1000gallons/yr) [16]	87	19	79%
Energy (million BTUs/yr) [17]	199	46	77%
CO_2 emissions (tons/yr) [18]	73	17	77%
Forest (acres/yr) [19]	4	0.82	90%
Price (dollars/yr) [20]	5532	2544	54%

Expressed on a per capita basis, a Mueller occupant (n=123) adopting these "best practices" (Table 3) would decrease his/her paper consumption from over 8000 to approximately 2700 sheets and in so doing save over 555 gallons of water, about 1.25 million BTUs of electricity, approximately 2650 square feet of forest land, nearly 85 pounds of landfill waste, and almost 800 pounds of CO_2 emissions. Moreover, although recycled paper costs more per sheet, the potential reduction in paper use could reduce per capita costs by almost $25 per year.[21]

Model Paper Policy:

Mueller Building, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its paper use. In order to accomplish this objective, the following steps will be taken during the procurement, use, and disposal of paper products:

- When possible, purchase i) paper having 100% post-consumer recycled content, ii) paper manufactured by a "totally chlorine free" (TCF) or "process chlorine free" (PCF) process, iii) paper containing wood fiber from sustainably managed forests, and iv) paper originating from within the Mid-Atlantic region.
- Print documents using small fonts, narrow margins, and reduced line spacing to the extent that the quality and end-use of the document remains uncompromised.
- Set all printer defaults to "duplex" and print as such while the quality and end-use of the document remains uncompromised.
- Collect and re-use all paper (i.e., give paper a "second-life") on a building-wide scale to the extent that security, privacy, or other concerns permit.
- Collect and recycle all paper on a building-wide scale when its uses have been exhausted.

For More Information

- Rainforest Action Network: Old Growth Campus Organizing Manual, http://www.ran.org/ran_campaigns/old_growth/campus/index.html
- ReThink Paper, http://www.rethinkpaper.org/
- Environmental Defense, *Paper Task Force Report*, http://www.environmentaldefense.org/pubs/Reports/ptf/

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2. Transparencies

An Ecological Profile

Americans dump fifteen million pounds of transparencies into landfills each year. A stack of transparencies of that weight would reach nearly 135 miles into the air. Although transparencies are Type-1 polyester, the same as soda bottles, their film covering makes the recycling process too difficult for standard recycling centers.[22]

The Mueller Connection

Mueller Building occupants collectively used 8000 sheets (134 pounds) of transparencies in 2000 at a cost of $1,250.[23]

The Mueller Solution

The measures necessary to reduce the environmental impact of transparency use in Mueller would be relatively easy to implement without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller channel its waste transparency sheets to the 3M Company recycling plant in Exeter, Pennsylvania.[24,25] The only cost would be shipping, which would be approximately $11 more than the cost of dumping per year.[26]

Ecological Footprint Reduction

Mueller could ship its used transparencies to the Exeter, PA, recycling plant and reduce the building's ecological footprint in two ways. First, Mueller could reduce the amount of waste it discards to landfills each year by 134 pounds. Second, Mueller could contribute to the stream of post-consumer "raw" material and reduce the requirement for virgin raw material.

Model Transparency Policy

Mueller Building, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its transparencies use. In order to accomplish this objective, the following step will be taken during the disposal of transparencies:

Channel all used transparencies into building-wide collection bins to be located in 208 Mueller and ship to the 3M recycling plant in Exeter, PA.

For More Information

- http://www.recycle.umich.edu/grounds/recycle/materials/transparencies.html
- http://www.3m.com/front/transfilm

3. Computers

An Ecological Profile

Producing a new desktop computer system generates approximately 140 pounds of waste and consumes 3000 cubic feet of natural gas, 7300 gallons of water, and 2300 kilowatt-hours of energy.[27] The 50 million new U.S. computers manufactured in 2000[28] used almost 120 billion kilowatt-hours of energy during their production, one quarter the amount that they will use in a four-year lifetime.[27] Meanwhile, energy use for personal computers is projected to increase by 4.5 percent per year in the foreseeable future.[29] Fifty percent of all heavy metals found in U.S. landfills, including cadmium and lead, originate from discarded consumer electronics. Projections indicate that tens of millions of presently in-use or warehoused computers will contribute hundreds of millions of cubic feet of trash and the brunt of incoming heavy metals to landfills by 2005.[30]

The Mueller Connection

Mueller Building occupants utilize approximately 300 computers and seek new units every 2 to 4 years, which is similar to the national average.[31] Mueller computers annually consume over 35 thousand kilowatt-hours of electricity,[32] which results in the release of approximately 37 tons of carbon dioxide[33] into the atmosphere. They also might contribute approximately 3 tons to the landfill every 4 years if not directed elsewhere at the time of their disposal.[34]

The Mueller Solution

The environmental impact of Mueller Building's computer usage could be reduced by more than half without compromising the research, teaching, and administrative activities of building occupants. This improvement requires that Mueller: 1) purchase environmentally-friendly computers, 2) extend the life of computers by upgrading, 3) keep computers off when not in use, and 4) channel obsolete computers in an environmentally responsible fashion.

Step 1: Purchase environmentally friendly computers. Mueller occupants report that 75% of the computers that they buy are brand-new, less than 10% are laptop models, and 92% have built-in energy saving features. Mueller could reduce its environmental impact if building occupants purchase: 1) laptop models, which, in general, require 1/3 the energy and are 1/10th the weight of desktop models;[27] 2) EPA "Energy Star" compliant computers, which "power down" after periods of inactivity to use 70% less energy than conventional models (Table 4);[29] 3) monitors only as large as necessary when desktop models are required (a 17-inch monitor uses 30% more energy than 15-inch monitor);[35] and 4) flat panel TFT screens which use less energy than conventional cathode ray tube screens.

Step 2: Upgrade computers before buying new systems. One way to more fully utilize a computer is to upgrade its CPU, storage capacity, and memory rather than to purchase a new system. While approximately 20% of computers in Mueller Building are upgrades, the figure could be increased to as high as 100%.[36] This would reduce both the solid waste flow from Mueller as well as the monetary cost of computing.

Step 3: Keep computers off when not in use. Contrary to popular belief, turning computers on and off a few times per day will not significantly affect the computer’s lifespan. Even if a computer meets "Energy Star" certification, keeping the computer off between uses can reduce energy needs significantly. An "Energy Star" desktop computer still draws approximately 30 watts in standby mode.[37] If Mueller computers were all "Energy Star" compliant, they would still draw up to 28,000-kilowatt hours each year if left on between 5pm and 8am during weekday nights.[37] Additionally, it should be noted that “screen savers” do not save energy, but save the phosphors in the monitor. By turning a monitor off, both energy and phosphors are conserved.

Table 4. Status Quo (Actual) and Mueller Potential (Ideal) for Computer-related energy consumption*

Computer Status	*Status Quo (%)*	*Mueller Potential (%)*
% Laptop	7%	100%
% EPA "Energy Star" feature activated	92%**	100%
% Upgrade	20%	100%
% Off when not in use during day	<10%**	100%

* Data obtained from faculty/staff survey
** Rough estimate

Step 4: Channel obsolete computers in an environmentally responsible fashion when an upgrade no longer suffices. In the last two years, Mueller occupants collectively channeled nearly 40 "obsolete" computers to Penn State Salvage.[38] Salvage finds a new user for 25% of all computers that it receives.[39] The remaining seventy-five percent are sold to be stripped and recycled. Mueller has the potential to channel its obsolete computer systems (many of which presently sit unused in labs) to salvage and further reduce its computer-related landfill impact. In addition, both Hewlett-Packard[40] and IBM[41] offer refurbishing and recycling programs, as does Environmental Solutions Recyclers, Inc., a Pennsylvania-based recycler.[42] Alternatively, Mueller could donate acceptable systems to the Computer Hardware Initiative Project (CHIP), a student-run Penn State program which donates discarded computers to needy schools, non-profit organizations, and individuals.

Ecological Footprint Reduction

Following these four steps Mueller occupants could significantly reduce computer-related energy consumption. Specifically, using more laptop computers, the Energy Star "power down" feature, and keeping computers off while not in use could reduce computer-related electricity use by over 30,000 kilowatt-hours, or 87%, annually.[43] This would translate to a 32-ton reduction in carbon dioxide.[44] The cost for implementing these steps rises in accord with the higher price of laptops, but decreases with the savings achieved through energy use reductions and upgrading. Over an eight-year life cycle of computer use, Mueller would spend approximately 11% less money on computers if it followed the four steps (above)[45] saving $63,054. Were a single Mueller occupant to perform these four steps -- switching from a desktop to a laptop computer, upgrading the computer, keeping the computer off when not in use, and using energy saving modes --s/he could reduce energy use by 109 kilowatt-hours/year, CO_2 emissions by 232 pounds/year, and cost by $35/year. The costs over each eight-year computer cycle are shown in Table 5.[45]

Table 5. ***Reduction in Energy Use and Cost Due to Switch from a Status Quo Desktop Computer to "Mueller Potential" Laptop & Upgrade over Eight Year Cycle.***[45]

Type of Savings /8 years	*Status Quo (Desktop)*	*Mueller Potential (Laptop)*	*Quantity of Savings*
Electrical Demand	60W	15W	45W
Electricity (kWh) /8 years	998	125	873
Cost of Electricity Demand /8 years	$43.66	$10.91	$32.75
Cost of Electricity Rate	$23.25	$2.91	$20.34
Cost of Computer	$2,039	$1,866	$173
Total Cost	$2,106	$1,880	**$226**

Model Computer Policy: Procurement, Use, and Disposal

Mueller Laboratory, through its strong commitment to environmental protection, seeks to reduce the environmental impact of computer use. In order to accomplish this objective, the following steps will be taken during the procurement, use, and disposal of computers:

- Consider purchasing laptop models (as opposed to desktop models) provided that functionality and quality remains uncompromised.
- Purchase EPA Energy Star certified computers and computer accessories.
- Upgrade the CPU, storage capacity, and memory of existing computer systems before purchasing a new system.
- Keep computers in an "off" state while they are not in use, especially over extended time periods, such as during nights, weekends, and vacations.
- Channel all obsolete computers to Penn State Salvage, Penn State CHIP, or other computer re-use/recycling center.

For More Information

- EPA WasteWise, http://www.epa.gov/wastewise/
- Penn State Computer Hardware Initiative Project (CHIP), http://www.shc.psu.edu/chip/
- The Green PC, http://www.thegreenpc.com/

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4. Printers

An Ecological Profile

As is the case with computers (previous section), significant amounts of materials and energy resources are involved in the manufacture, transport, and use of printers. Ultimately these electronic goods find their way to landfills. Americans dispose of 300,000 tons of printers, monitors, and computers to landfills each year.[46] These printers, as well as other consumer electronics, contribute over fifty percent of all heavy metals to our landfills.[47]

The Mueller Connection

Mueller Building occupants currently use approximately 71 printers, including 40 personal laser printers, 10 heavy-duty laser printers (i.e., Hewlett Packard 5si), 20 ink-jet printers, and 1 poster ink-jet printer.[48] Assuming a lifespan of five years, these printers could contribute over one ton of waste and related heavy metals to landfills twice each decade.[49]

The Mueller Solution

It is possible to reduce the environmental impact of Mueller Building printer use without compromising the research, teaching, and administrative activities of Mueller occupants. To achieve this goal requires that Mueller: 1) purchase environmentally-friendly printers; 2) use the energy that powers printers more efficiently; and 3) channel obsolete printers in an environmentally responsible fashion.

Step 1: Purchase environmentally-friendly printers. The Environmental Protection Agency (EPA) certifies "Energy Star" printers which draw 50% less energy than conventional printers through their standby energy saving mode.[50] Furthermore, ink-jet printers consume 13 times less energy per printed page than laser printers.[51] Recent introductions into the printer market, such as the HP DeskjetR850, have shells composed of post-consumer recycled plastic, which further reduces the burden on landfills.[52] Mueller could reduce landfill and energy requirements by purchasing ink-jet, Energy-Star certified printers composed of post-consumer recycled materials when their performance meets Mueller's needs.

Step 2: More fully utilize the energy that powers printers. Even should a printer meet "Energy Star" certification, keeping the printer off between printing episodes reduces energy needs significantly. An "Energy Star" printer still draws between 5 and 40 watts in standby mode.[53] Mueller printers stay on for most of the day, even when not in use. Keeping a laser printer that draws 25 watts in standby mode on for 1 hour, instead of 8 hours, each day reduces the electricity draw by 175 watt-hours (88%), from 200 watt-hours to 25 watt-hours. Applying this energy-conserving ethic through the year, an individual could cut his/her coal use and accompanying CO_2 emissions by 37 and 96 pounds, respectively.[54]

Step 3: Dispose of printers in an environmentally responsible fashion. Mueller Laboratory already performs this step well. Penn State Salvage attempts to utilize Mueller's old printers, either by resale or component re-use.

Table 6. Status Quo (Actual) and Mueller Potential (Ideal) for Reducing Energy Consumption Associated With Printers*

Printer Status	***Status Quo***	***Mueller Potential***
Ink-jet vs. Laser Printer	30% vs. 70%	75% vs. 25%
EPA "Energy Star" Certified Printer	70%**	100%
Printer remains off while not in use	<5%**	100%
Energy consumed/yr[10]	9,009 kWh	479kWh/yr

* Data come from surveyed faculty/staff
** Based on informal survey.

Ecological Footprint Reduction

By implementing these three steps -- purchasing environmentally-friendly printers, fully utilizing the energy which powers printers, and disposing of printers in an environmentally responsible fashion -- Mueller could reduce energy requirements by over 8,500 kWh/year, save $425/year, and prevent the emission of 9 tons of CO_2 into the atmosphere from coal burning (Table 6).[55]

Model Printer Policy

Mueller Laboratory, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its printer use. In order to accomplish this objective, the following steps will be taken during the procurement, use, and disposal of printers:

- Purchase EPA Energy Star certified printers.
- Purchase ink-jet printers to the extent that the printer quality remains uncompromised.
- Keep printers in an "off" state while they are not in use.
- Provide Penn State Salvage with all printers that would otherwise be placed with refuse.

For More Information

- EPA Energy Star, http://www.energystar.gov/

5. Toner and Ink Cartridges

An Ecological Profile

American businesses dispose of 15 million toner cartridges every year, annually adding 40,000 tons of plastic to landfills.[56] These toner cartridges contain volatile organic compounds that contribute to air and water pollution during production, possible air-quality problems in the office during use, and water pollution from landfill leachate after disposal.[57]

There are two frequently used printer types, ink-jet and laser. Ink-jet cartridges contain hydrocarbon solvents, which are skin and eye irritants (under conditions of frequent and/or prolonged contact) and can act as central nervous system toxins. Laser toners contain carbon black, a fine carbon powder that is hazardous if breathed and is possibly carcinogenic.[58] All printer inks and toners also contain heavy metals and rely on an unsustainable, petroleum base.

The Mueller Connection

Mueller Laboratory purchases copy paper, transparency film, and fax paper at an annual cost of approximately $6800.[59] Use of this paper accounts for over 1 million pages printed by Mueller photocopiers, and laser and ink-jet printers each year. Printing that many pages requires that Mueller purchase over 30 laser and 30 ink-jet cartridges each year at a total cost of approximately $3,000,[60] in addition to another 35 copier cartridges (cost built into maintenance agreement for copy machines).[61]

The Mueller Solution

It is possible to reduce the environmental impact of printing without compromising the research, teaching, and administrative activities of Mueller occupants. To achieve this goal requires that Mueller: 1) purchase environmentally-friendly ink-jet cartridges and laser toners; 2) get the most possible use from ink and toner cartridges; and 3) channel spent ink-jet cartridges and laser toners in an environmentally responsible fashion (Table 7).

Step 1: Purchase environmentally-friendly ink-jet and laser cartridges. Mueller Laboratory already performs part of this important step by obtaining the majority of its laser toners from Laserforce, a local company that refills old cartridges for resale. This extends the useful life of the cartridge and reduces landfill waste, as well as the environmental cost of cartridge production. Mueller could also purchase refillable ink-jet cartridges, which reduce waste by increasing a cartridge's useful lifetime. Hewlett Packard sells a refill "service station" for $17.70.[62] Refilling ink-jet cartridges also yields significant cost savings.[63] If Mueller does not refill ink-jet cartridges on the premises, the cartridges could be sent to a remanufacturing facility for professional cleaning and refilling at a cost of $17.[64]

Step 2: Get the most possible use from ink and toner cartridges. Many printers offer a "draft" mode feature, which produces lower quality output, but conserves printer ink or toner by approximately one half. Mueller occupants indicate that they generally do not utilize this mode. Mueller could employ this ink-saving strategy for the draft stage of all documents and reduce ink use by approximately 50% for each draft printing.[65] If 75% of all Mueller documents were printed in 'draft' mode, ink consumption would be reduced by 33%.[66]

Table 7. Status Quo (Actual) and Mueller Potential (Ideal) for Cartridge Type and Print Use*

Ink Cartridge Status	***Status Quo***	***Mueller Potential***
Ink-jet Printer: Refillable or Refilled Ink Cartridges	0%	100%
Laser Printer: Refilled Toner Cartridge	> 90%	100%
Draft Documents Printed in Draft Mode	~10%	100%
Spent Cartridges (Ink-jet and Laser) sent to Recycling Center	0%	100%
* Data obtained from survey of Mueller faculty/staff.		

Step 3: Dispose of ink-jet and laser cartridges in an environmentally responsible fashion. Mueller Laboratory already performs this step well. Laserforce accepts Mueller's spent laser toner cartridges for refilling. Ink-jet cartridge re-use should be discontinued after one or two refills in order to maintain printing quality. At that time Mueller could send its used cartridges to Hewlett Packard which recycles up to 65% of the cartridge (by weight) into its constituent raw materials.[67]

Mueller's current maintenance agreement for copy machines is with IKON. At this time IKON does not refill or recycle toner cartridges.

Ecological Footprint Reduction

Mueller has the potential to reduce the footprint associated with ink and toner use. Refilling cartridges reduces the cost for ink, and printing in draft mode compounds the price reduction by reducing the requirement for ink. Following these "best practices," Mueller could reduce its cost for printer ink use by nearly 50% or over $1,400[68] and reduce ink use by ~33% (assumes that the number and ratio of ink-jet and laser printers that Mueller uses remains the same and that 75% of printed pages are printed in draft mode). The printer ink costs could be reduced further if the "best practices" printer policies were followed from section B4 and Mueller refilled its own inkjet cartridges. Following optimal printer and toner policies Mueller could yield savings of over $2,500/year.[69]

Model Printer and Copier Ink and Toner Policy

Mueller Laboratory, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its printer and copier use. In order to accomplish this objective, the following steps will be taken during the procurement, use, and disposal of printer and copier products:

- Print and copy documents in "draft" mode whenever possible.
- Send spent toner cartridges to remanufacturing facility.
- Refill spent ink-jet cartridges on the premises or send to refilling facility.
- Send all ink-jet cartridges to HP recycling center at end of useful life.

For More Information

- Laserforce. 2597 Clyde Ave., State College. 234-4100; http://www.laserforce.com/
- Pennsylvania Ink-jet Cartridge Remanufacturers, http://www.eco-office.com/states2.cfm?state=Pennsylvania

6. Computer Disks

An Ecological Profile

Every day approximately 3 to 4 million defective or unneeded 3.5" computer diskettes make their way into U.S. landfills or incinerators. That sums to over one billion disks each year,[70] a stack that could reach over 2000 miles high.[71] A disk may take over 450 years to decompose in a landfill, a process which sometimes leaches synthetic chemicals into nearby water sources.[72]

The Mueller Connection

Larger storage media are quickly replacing the standard 3.5" computer diskettes that Mueller personnel once used almost exclusively. Today's 100MB disks have a storage capacity that is almost 70 times greater than that of traditional 3.5" disks. Many Mueller occupants acknowledge that they have scores (sometimes hundreds) of diskettes awaiting disposal.

The Mueller Solution

The measures necessary to reduce the environmental impact of Mueller computer disk disposal would be relatively easy to implement without compromising the research, teaching, and administrative activities of building occupants.

Option A: Mueller residents could attempt direct recycling of used floppy disks on University Park Campus. The disks could be collected at a central location in Mueller and then donated to an undergraduate CAC lab with a sign "***FREE DISKS!***"

Option B: Mueller occupants could channel their waste disks to a disk recycling center. The cost of shipping plus a recycling fee of 10 cents per pound would be about four times the cost of sending these diskettes to a landfill, but will prevent the contamination of contamination of ground water supplies in the vicinity of landfills.

Ecological Footprint Reduction

Mueller could reduce the environmental impact of its computer disk disposal practices by sending disks to a recycling center rather than to a landfill. This is one step (among many) that Mueller could take to begin to close the waste loop and keep its refuse from landfills and incinerators.

Model Computer Disk Disposal Policy

Mueller Building, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its computer disk use. In order to accomplish this objective, the following step will be taken during the disposal of all 3.5" computer disks:

1. Channel all 3.5" and CD computer disks to a building collection bin and then to CAC lab or appropriate disk recycling center.

For More Information

- GreenDisk Services, Manufacturer of High Quality Recycled Disks, http://www.greendisk.com/

7. Communications/Computing Conclusion

All the communicating and computing occurring in Mueller has a hidden biophysical side. Indeed, propping up the reams of paper, the scores of copiers and printers, and the piles of transparencies and diskettes are tons of coal, tens of thousands of gallons of water, acres and acres of forest land, and cavernous landfills. This is the ecological support network for Mueller communications.

Recall that the overall goal of this analysis is to reduce the ecological impact ("footprint") of Mueller Building by half or more. In the realm of communications and computing, this goal is easily achievable:

- **Paper:** The forested land necessary to supply Mueller's paper needs could be reduced from 8 acres to less than 1 acre while reducing paper expenditures by almost 60%.
- **Computers/Printers:** The energy consumed by Mueller's computers and printers could be reduced by almost 40,000 kWh (a > 90% reduction).
- **Toners:** The ink used in Mueller's printers could be reduced by 33% and with a corresponding shift in type of printers a toner cost reduction of 83% could be realized.

Moreover, the Mueller waste associated with paper, transparency, computer, printer and diskette disposal could be dramatically reduced.

These improvements could be made without compromising the research, teaching and administrative functions of Mueller Lab and while realizing approximately $15,625 in annual savings ($3,000 in paper savings; $9,700 in computer-related savings; $425 in printer savings; and $2,500 in toner savings).

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1. J. Abramovitz and A. Mattoon, *Paper Cuts: Recovering the Paper Landscape* (Washington, DC: Worldwatch Institute, 1999).
2. S. Derber, Personal Communication (University Park, PA, January 2001).
3. In other words, the new wood produced in one year on an 8.4 acre tract of temperate forest would supply enough pulp to supply Mueller's paper needs for one year. This calculation derives from the following relationships: 5.3 tons paper x [(70.6 ft^3 wood/paper ton)/(44 ft^3 wood produced/acre/year)] = 8.4 acres. M. Wackernagel, *Biological Footprint and Appropriated Carrying Capacity: A Tool for Planning Toward Sustainability* (Ann Arbor, MI: UMI Dissertation Services, 1994).
4. Customer Service Representative, Penn State General Stores, Personal Communication (University Park, PA, January 2001).
5. Environmental Protection Agency (EPA), *Toxic Release Inventory*, (http://www.epa.gov/, 2001).
6. Unbleached or bleached without addition of chlorine or chlorine derivatives (http://www.rethinkpaper.org).
7. The Copy Centre, 436 E. College Ave, 234-3099, cpyctr@statecollege.com.
8. University of Buffalo, *Buy Recycled Paper*, (http://wings.buffalo.edu/services/recycling/buy.html, Accessed January 2001)
9. A "reduced font" is any font smaller than 12 point Times Roman or equivalent.
10. "Reduced margins" are those smaller than 1.25" left-right or 1" top-bottom.
11. Duplex printing results in a 50% savings in paper use if performed on 100% of printed documents. Mueller only performs this printing technique on 40% of its documents, resulting in a 20% reduction. Mueller already performs formatting techniques on 40% of its documents, resulting in a 28% reduction. The combined effect is a 42% reduction.
12. In a sustainable system, Mueller would have to get a portion of its paper fiber from virgin sources because paper cannot be recycled indefinitely. Mueller could either purchase 100% of its paper as 70% post-consumer recycled content paper, or 70% of its paper as 100% post-consumer recycled content paper.
13. Determined from survey results, which showed that approximately 40% of printed documents exhibit at least one of the three document formatting techniques.
14. EnAct, University of Michigan, *Recycled Notebooks*, (http://www.umich.edu/~enact/notebooks.html, Accessed February 2001).

15. The sum of 1) paper sent to the trash and 2) amount of waste produced during paper production: 1.12 tons of waste/ton of paper for standard production; 0.58 tons of waste/ton of paper for recycled paper production (Environmental Defense, *Paper Task Force Report*, http://www.environmentaldefense.org/pubs/Reports/ptf/)
16. Determined by amount of water used to produce one ton of paper: 16775 gallons/ton for standard paper (J. Abramovitz and A. Mattoon, *Paper Cuts: Recovering the Paper Landscape* (Washington, DC: Worldwatch Institute, 1999)) and 50% of this for recycled paper (National Recycling Forum, *Buy Recycled | Case Study | Recycled Paper*, http://www.nrf.org.uk/buy-recycled/buyrecycled/case-studies/case-study-recycled-paper.htm).
17. Determined by the amount of energy required for paper production per ton: 38.5 million BTUs/ton for standard paper and 21.7 million BTUs/ton for recycled paper (Environmental Defense, *Paper Task Force Report*, http://www.environmentaldefense.org/pubs/Reports/ptf /)
18. Determined by the amount of CO_2 emitted from coal burning for electricity production: 2.11 pounds/1kWh x 1kWh/3412BTUs
19. Refer to footnote no. 3 above for status quo. Mueller potential: (664 reams x 5.125 pounds / ream) x (1 ton/ 2000 pounds) x 30% virgin fiber x [(70.6 ft^3 wood / paper ton) / (44 ft^3 wood produced/acre/year)] = 0.82 acres.
20. Determined by adding the cost of standard and recycled paper: Status quo: (2022 reams x $2.736/ream non-recycled x 30% non-recycled) + (664 reams x $4.30 / ream recycled x 70% recycled) = $2544
21. Divide all annual reduction figures by 123, the number of Mueller occupants. For example, the 54% reduction in price from $5532 to $2544 represents an annual savings of $2989. Divided by 123 occupants, the resulting figure indicates a per capita savings of $24.30.

Further Details on Paper Calculations

- **Calculations relevant to Table 1:**

Paper use reduction was determined by comparing the standard document (1.25" left & right margins, 1" top & bottom margins, 12 point Times New Roman font, doubled-spaced, and single-sided) against a "best practices" document (0.75" margins, 10 point Times New Roman font, single-spaced, and double-sided). First, a maximum percent of paper use based on margin settings was determined by calculating the percent area of the page that the lines of text in a standard document utilize (28.9%). Next, a similar "percent of page use" was determined for the "Mueller Potential" test case (35.6%). A ratio between the former and the latter percentages was determined (81.2%) and was then subtracted from 100% to yield the percent reduction due to altering the margins (18.8%). Second, the factor reduction due to spacing was determined by the ratio between the line-spacing of the standard (double-spaced) and the "Mueller Potential" (single-spaced) documents, and indicated a 2:1 reduction. In other words, a 50% reduction in paper use is realized. Third, the reduction due to changing the font from 12 point to 10 point, a 25% reduction as empirically observed with an ideal document, was applied. Fourth, the reduction due to printing on two sides was applied: a 50% reduction from the standard to the "Mueller Potential."

The total application of these percent reductions – 18.8%, 50%, 25%, and 50%, as respectively presented – indicates a cumulative reduction of approximately 85%. This means that a document which is 100 pages long with standard formatting would reduce to 15 pages after a comprehensive application of these techniques.

- **Calculations relevant to Table 3**

The significant reduction in Mueller's annual paper use from 2022 reams to 664 reams is calculated by determining: 1) the reduction techniques that Mueller already uses; 2) the amount of paper that Mueller would use were it not to perform these techniques; and 3) the reduction from this "worst case scenario" that would occur if Mueller performed these techniques up to its potential (the "Mueller Potential").

1) Mueller prints approximately 40% of its pages on two sides which indicates that it reduces its paper use by 20% (39% of a potential 50% reduction = 19.5%). It also performs document-formatting techniques on 40% of its documents, reducing paper use by 28% (40% of a potential 70% reduction = 28%). The cumulative application of these techniques yields a reduction in paper use from the "worst case scenario" of 42%. This indicates that the "worst case scenario" would use approximately 3489 reams of paper each year (2022 / (100% - 42%) = 3489 reams).

2) Utilizing the paper reduction techniques, detailed in Table 1, this "worst case scenario" could be reduced by approximately 25% when reducing the font size (to approximately 2617 reams), by another 19% when reducing margins (to approximately 2125 reams), by another 50% when single spacing (to approximately 1062 reams), and by another 37.5% (75% of a potential 50% reduction) when printing on both sides or giving one-sided paper a "second life" (to approximately 664 reams).

22. 3M, A Clear Solution for Transparency Film Waste (http://www.3m.com/front/transfilm/ , 1996).
23. S. Derber, Personal Communication, (University Park, PA, January 2001).
24. The transparencies are recycled into new transparencies, as well as downcycled into automotive products, insulating products, carpet, and fiberfill for furniture
25. 3M Transparency Film Recycling Program, C/O Gemark 99 Stevens Lane, Exeter, PA 18643; 1-800-328-1371
26. ($1,248 cost of transparencies in 1999-2000) x (1 box/$15.60) x (100 sheets/box) x (0.0168 lbs/sheet) = 134 lbs.
    Cost of dumping = ($48/ton) x (1 ton/2000 lbs) x 134.1 lbs = $3.22.
    Cost of transport to Exeter, PA = $14.70 (as determined by UPS Ground).
    Cost difference = $14.70 - $3.22 = $11.48.
27. J. Ryan and A.T. Durning, *Stuff: The Secret Lives of Everyday Things*, (Seattle, WA: Northwest Environment Watch, 1997).
28. Stanford Resources, Inc., *Forecast of U.S. PC CPU Shipments, Obsolescence, and Recycling, 1997-2005*, (http://www.thegreenpc.com , 1999).
29. Energy Information Administration, *Annual Energy Outlook*, (http://www.eia.doe.gov/oiaf/aeo.html , 2000).
30. Environmental Protection Agency (EPA), *WasteWise Update: Electronic Reuse and Recycling* (http://www.epa.gov/wastewise/ , 2000).
31. R. Horner, Mueller Network Administrator, Personal Communication, (University Park, PA, January 2001).
32. (60 watt-hours/desktop x 279 desktops + 15 watt-hours/laptop x 21 laptops) x 40 hours/week x 52 weeks/year =35,474 kWh. Rosen and Meier, *Energy Use of U.S. Consumer Electronics at the End of the 20th Century*, (http://eetd.lbl.gov/EA/Reports/46212 , 1999).
33. 2.11 lbs CO_2 / 1 kWh x 35,474 kWh = 86,367 lbs CO_2.
34. Assuming that the average desktop computer weighs 20 pounds.

35. W. Simpson, *The University at Buffalo's Green Computing Guide*, (Buffalo, NY: University at Buffalo's UB Green Office, 2000).
36. Upgrades prolong the life span of the computer.
37. Energy star computers also have the ability to power down autonomously, thus drawing 0W after long periods of inactivity.
30 watts/computer x 300 computers x 15 hrs/night x 4 weekday nights/week* x 52 weeks/year = 28,080 kilowatt hours/year. * Assuming the computers are off between Friday evening and Monday morning.
38. S. Derber, Personal Communication, (University Park, PA, January 2001).
39. G. Feagley and W. Gallagher, Penn State Salvage, Personal Communication, (University Park, PA, February 2001).
40. Hewlett-Packard, *HP Company Information - Environment*, (http://www.hp.com/hpinfo/community/environment/recycle.htm , 2000).
41. IBM, *Healthy Computing* **-** *PSG Report Product End-of-life Management*, (http://www.pc.ibm.com/ww/healthycomputing/envreport/end.html , 2001).
42. Environmental Solutions Reclaimers, Inc. 9523 Lincoln Way West. St. Thomas, PA 17252. http://www.esrelectronicrecycling.net/ 717-369-2504. esrinc@ccaol.com .
43. *Status Quo*: (279 desktops x 60 watt x 8 hours/day x 5 days/week x 52 weeks/year) + (21 laptops x 15 watt x 8 hours/day x 5 days/week x /52 weeks/year) = 35474 kWh/year

Mueller Potential: (0 desktops x 60 watts x 4 hours/day x 5 days/week x 52 weeks/year) + (300 laptops x 15 watts x 4 hours/day x 5 days/week x 52 weeks/year) = 4680 kWh/year

Reduction: 35474 kWh/year – 4680 kWh/year = 30794 kWh/year; or 30794/35474 = 87%
Electrical savings = $53/ computer x 279 = $14,787 for 8 years or $1,848 /year

44. Union of Concerned Scientists, "How Coal Works", http://www.ucsusa.org/energy/brief.coal.html
Calculations based on 500MW coal plant producing 3.5 billion kWh/year.

number of kW-hr/year	1	
	tons	pounds
coal burned	4.09E-04	8.17E-1
carbon dioxide	1.06E-03	2.11E+00

45. These figures were determined by comparing the cost for energy, new computer procurement, and upgrading related to the *status quo* and the "Mueller Potential" computer-use schemes over eight years. Energy use is determined by the watt draw of the machine .

desktop: 60 watt x 8 hours/day ('on' all day) x 5 days/week x 52 weeks/year x 8 years / 1000 = 998kW-hrs

laptop: 15 watt x 4 hours/day ('off' when not in use) x 5 days/week x 52 weeks/year x 8 years / 1000= 125kW-hrs

For a single year the desktop would draw 125kWh and the laptop 15.6kWh.

Purchasing two new desktop computers over an eight-year span (i.e. a new one every 4 years) costs $2039. Purchasing one new laptop and upgrading it over an eight year span costs $1866. The final cost for computer use, after eight years, then, sums to $2106 for desktops and $1880 for laptops, yielding a difference of $26. The cost for new desktop and laptop computer systems are determined by Dell for a 700 MHZ, 64MB RAM, 20 GB hard drive, and 15" monitor machine. The upgrade cost was determined by COMPWIZ.COM when upgrading a 100MHZ, 16MB RAM, 1.2 GB hard drive machine. As a rule, all laptop prices are considered to be 50% greater than desktop prices.

The cost of electricity was supplied by Mr. Doug Donovan, Personal communication, (University Park, PA, April 2001). Price for electricity avoidance is $0.0233 per kWh saved; electrical demand savings = $7.58 kVA (note: electrical demand savings apply only when retrofits to more efficient devices are completed).

Savings for all of Mueller were calculated by multiplying the savings for a single computer ($226) by 279 (~computers to be upgraded Mueller) = $63,054 for 8 years This is $7,887 per year of that $1,849 is from electrical savings.

46. GodHolly.com, *Recycle Your Computer*, (http://www.godholly.com/news.asp?Recycle , 2001).
47. Environmental Protection Agency (EPA), *WasteWise Update: Electronic Reuse and Recycling*, (http://www.epa.gov/wastewise/ , 2000).
48. R. Horner, Mueller Network Administrator, Personal Communication, (University Park, PA, January 2001 and March 2001).
49. Assuming an average weight of 35 pounds.
50. Environmental Protection Association, Energy Star Labeled Products: Welcome (http://www.energystar.gov/ , 2001).
51. J. Keniry, *Ecodemia: Campus Environmental Stewardship at the Turn of the 21st Century*, (Washington, DC: National Wildlife Federation, 1995). Also draw on an inkjet printer is 6.25W and of a laser printer is 84W.
52. Santa Clara Valley Manufacturing Group, *The SCVMG Guide to Commercial/Industrial Programs*, (http://www.svmg.org/htm/comm_industrial_guide/ch11.html , 2000).
53. Co-op America, *Greening Your Purchasing*, (http://www.coopamerica.org/business/Bgreenng.HTM , 2000).
54. See footnote 44 for conversion factors. 175 watt-hours/day x 5 days/week x 52 weeks/year =45.5kW/yr and yields 37 pounds coal/year and 96 pounds CO_2/year.

55. The cost of electricity was determined from footnote 45.

Determined by comparing previous calculated yearly printer energy requirement and costs against calculated potential energy requirement and costs.

Status Quo: 21 ink-jets x 0.00625 kW/ink-jet x 8 hrs/day x 5 days/ week x 52 weeks/year = 273kWh
50 laser jets x 0.084kW/laser jet x 8hrs/day x 5 days/week x 52 weeks/year = 8,736 kWh
Total Energy consumed = 9,009kWh/yr
CO_2 emissions = 9.5 tons CO_2/year
Energy rate cost = $210/yr

Mueller Potential: (switch to 75% ink-jet and 25% laser; 100% Energy Star; on an average of one hour per day):
53 ink-jets x 0.00625 kW/ink-jet x 1 hr/day x 5 days/week x 52 weeks/year = 86kWh
18 laser jets x 0.084 kW/laser jet x 1hr/day x 5 days/week x 52 weeks/year = 393kWh
Total Energy consumed = 479kWh/yr
From footnote 9, CO_2 emissions = 0.5 tons CO_2/year
Energy rate cost = $11/yr

Energy Rate Savings for Mueller potential = $210-$11 =$199/yr
Energy Demand Savings= 32 conversions x (0.084-0.00625)kW x 12 x $7.58/kW = $226/yr

Total Electrical Energy Savings = $425/yr
CO_2 savings = 9.5 – 0.5 = 9 tons/yr
Total Energy Savings = 8,530kWh/yr

56. Co-op America, *Greening Your Purchasing*, (http://www.coopamerica.org/business/Bgreenng.HTM , 2000).
57. S. Creighton, *Greening the Ivory Tower* (Cambridge, MA: The MIT Press, 1998).
58. Environmental Health Coalition, *Toxic Turnaround* (San Diego, CA: Environmental Health Coalition, 1998).
59. S. Derber, Personal Communication (University Park, PA, January 2001).
60. Derived from both personal communication with R. Horner, Network Administrator and prices for cartridges from the Penn State Bookstore and Laserforce, Inc. (30 laser cartridges/year x $60/laser cartridge) + (30 ink-jet cartridges/year x $40/ink-jet cartridge) = $3000.
61. P. Farwell, Personal Communication (University Park, PA, April 2001). 4 copy machines x 1 cartridge/6 weeks x 52 weeks/year = 35 cartridges/year.
62. Penn State General Stores, *Welcome to General Stores!*, (http://www.generalstores.psu.edu/ , 2001).
63. For self-refilling - 39 cents per refill versus the ~$18 for a refurbished cartridge, PC World, *Beating the High Price of Printer Ink*, (http://www.pcworld.com/resource/article.asp?aid=10575 , 1999).
64. Ink Jet Tech. 9241 Church St. Manassas, VA 20110. 703-369-4700. MHIREZI@aol.com.
65. PC World, *Beating the High Price of Printer Ink*, (http://www.pcworld.com/resource/article.asp?aid=10575 , 1999).
66. Assuming that 75% of the pages printed in Mueller are for draft documents and that only 10% are currently printed in draft mode: 65%x50%= 32.5%; for only the inkjet printers - 30 inkjet cartridges/year which cost $40/ cartridge; 0.325x30/yearx$40/cart. = $390/year savings
67. Hewlett Packard, *HP Company Information Environment*, (http://www.hp.com/hpinfo/community/environment/re_inkjet.htm , 2000). Call 1-888-447-0145 for up-to-date cost of recycling.
68. Savings are calculated by comparing the current cost of printing -- $60/laser cartridge x 30 cartridges/year + $40/ink-jet cartridge x 30 cartridges/year = $3000/year-- against the potential cost of printing which arises from the 32.5% reduction in ink used (derived from a 50% reduction over 65% of the documents that Mueller prints) and the purchase of remanufactured ink-jet cartridges -- $60/laser cartridge x 30 cartridges/year x 67.5% + $17/ink-jet cartridge x 30 cartridges x 67.5% = $1,559.25/year. The difference then is ($3000 - $1,559.25)/year = $1,440.75/year, which is approximately a 48% decrease in cost.
69. If the model policy is followed from printer section 25 additional inkjet printers will be purchased for a total of 45 (2.25X more), and 25 laser printers will be sold/given away with only 15 remaining (0.375X as many currently). Considering only the costs of toner:
Inkjets: 2.25 x 30c/yr x $0.39/c x (1-0.325) for drafting + $17.70 for refill station = $35.47/yr
Laser: 0.375 x 30c/yr x $60 x (1-0.325) for drafting = $455.63
Total = $35.47 + $455.63 = $491.10
Total savings = $3,000 - $491.10 = $2,509
Note: This calculation did not include labor costs to refill the inkjet cartridges in Mueller. However, these costs would be small when compared to the price of the methods of obtaining ink $40 (new) to $0.39 (self refill)
70. Southern Idaho Solid Waste, *Outlook on Recycling*, (http://www.sisw.org/outlook.htm#DISCARDED CDs, 2000) and GreenDisk, *Facts about the software disposal problem*, (http://www.greendisk.com/af1_2.html , 2001).
71. 3 million disks/day x 365 days/year x 1/8 inch think x 1 foot/12 inches x 1 mile/5280 feet = 2160 miles
72. GreenDisk Services, GreenDisk - Manufacturer of High Quality Recycled Diskettes (http://www.greendisk.com/ , 2001). GreenDisk Services, 2200 Burlington, Columbia, MO 65202; 1-800-305-3475

D. Reducing the Furnishings/Renovation Footprint

1. Furniture

An Ecological Profile

U.S. businesses discard approximately 3 million tons of furniture each year, incurring disposal costs of nearly $100 million.[1] Metal furniture requires the use of limited metal ores that have high-energy requirements for acquisition and processing. Wooden furniture, the most often utilized alternative, frequently comes from forests that fail to meet sustainable management criteria. Additionally, furniture adhesives and finishes often contain volatile organic compounds (VOCs) and toxic chemicals, such as formaldehyde, which can be harmful to the furniture user.[2]

The Mueller Connection

Mueller Building occupants collectively utilize over 600 pieces of wooden and metal furniture.[3] New furniture commonly enters the building when new faculty use part of their "start-up" funds to furnish their lab and/or office. A typical turnover time for furniture is 10 years,[4] although in some cases the same furnishings are retained for 20 or more years.

The Mueller Solution

A significant reduction in the impact of Mueller's furniture use is possible without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller occupants: 1) purchase the most environmentally friendly furniture available; and 2) channel unneeded furniture in an environmentally responsible fashion.

Step 1: Purchase the most environmentally friendly furniture available. "Environmentally friendly" furniture has minimal environmental impacts associated with production, use, and disposal. The easiest and most environmentally friendly policy is to reuse old furniture from previous Mueller occupants or to purchase used furniture from Penn State Salvage. The metal furniture found at Salvage has a potential life span of centuries. Necessary functional and aesthetic repairs often require only a fraction of the monetary and energy costs that would be associated with the purchase of new furniture. Business Outlet, Inc. (BOI), a Pennsylvania company, specializes in remanufacturing furniture made by one of Penn State's main suppliers, Herman Miller, Inc. Mueller could have its old Herman Miller furniture refurbished by BOI and reduce energy consumption for "new" furniture by 85-95%.[5]

Should new furniture be required, Mueller occupants could choose to purchase wooden furniture, which is a more sustainable choice than metal, provided that forests are properly managed[6] and pressed wood (i.e. particle board, fiber board, or plywood) products are avoided.[7] Due to the extra cost of certifying sustainable forest management practices, many consumers still prefer to purchase uncertified wooden furniture.[8] Spectra Wood, a local furniture company, provides much of Mueller's new wooden furniture. While a small percentage of their wood (from Lewis Lumber) is certified, none of their products are guaranteed as such. In order to offer furniture from 100% certified wood, Spectra Wood would need to raise product prices by 4-7% to cover the added expense of inspections associated with certification.[9] Mueller could request certified-wood furniture from Spectra Wood and other suppliers and in so doing both decrease the environmental impact of furniture use and also use Penn State's purchasing power to promote "best" forestry practices. Finally, although new steel furniture involves energy-intensive production, it is possible to use 100% post-consumer recycled steel. One of Penn State's current suppliers, Steelcase, currently uses 25-30% recycled steel (10% being post consumer).

Step 2: Channel unneeded furniture in an environmentally responsible fashion. Mueller already performs this step well by channeling its unneeded furniture to Penn State Salvage. Penn State Salvage receives "truck loads" of wooden and metal furniture each day, which it subsequently redistributes throughout campus or sells at auctions. Only a small percentage of incoming furniture is landfilled by Salvage. This waste is entirely composed of broken wooden furniture that no longer serves its purposes.[10]

Ecological Footprint Reduction

Mueller could reduce its environmental impact related to furniture use by moving from "status quo" to "potential practices" (Table 1). Used or refurbished furniture requires the least amount of raw materials. If new furniture is required, then certified wood or post-consumer recycled steel are the most sustainable choices.

Table 1. Percent Occurrence of Environmentally-Responsible Furniture Options in *Status Quo* and *Mueller Potential* Scenarios.*

Furniture Status	***Status Quo***	***Mueller Potential***
Used or Refurbished	14%	100%
Certified Wood	0%	100%
Recycled Steel	25%	100%

*Based on informal survey

Model Furniture Policy

Mueller Laboratory, through its strong commitment to environmental stewardship, seeks to reduce the environmental impact of its furniture use. In order to accomplish this objective, the following steps will be taken:

- Purchase used or refurbished furniture.
- When purchasing new furniture, purchase wooden furniture that comes from sustainably managed forests.
- When purchasing new metal furniture, maximize the post-consumer recycled content of the product.
- Purchase formaldehyde-free and carcinogen-free

wooden products.

- Purchase furniture having low- or no-VOC emitting adhesives and/or finishes.

For More Information

- Lumber
  - -Kane Hardwoods (814) 837-6941
  - -Lewis Lumber (800) 233-8450
  - -Bradford Forest Products (814) 368-3701
  - -Matson Lumber (814) 849-5334
- Business Outlet, Inc. (BOI) http://www.businessoutlet.com

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2. Carpet

An Ecological Profile

Every year, North Americans landfill over 3.5 billion pounds of carpet.[11] In the mid 90s, this contribution to landfills was 40% less than the amount of carpet being installed each year, which indicates that even more carpet will be destined for landfills in the future.[12] Both new and old carpet is most often composed of synthetic, petroleum-based materials like nylon, polyester, and olefin. These carpets do not biodegrade in landfills because tightly bound plastic is an unsuitable substrate for decomposer organisms, and the oxygen and light necessary for photo-oxidation are absent from landfills.[13]

While in use, carpet backings and adhesives can "off-gas" the known carcinogen, styrene butadiene latex, and the suspected carcinogen, 4-phenylcyclohexane (4-PC), as well as other volatile organic compounds (VOCs) which compromise indoor air quality. Off-gassing can lead to eye, nose, throat, and skin irritation; headaches; shortness of breath; and fatigue.[12] Carpets further act as a "sink" for pesticides, dust mites, fungi, and other biological and chemical "pollutants."[14]

The Mueller Connection

The Mueller Building has nearly 12,000 square feet of carpet installed in over 50 offices and workspaces. One hundred percent of Mueller's carpet comes from virgin synthetic fiber. The virgin fiber begins as petroleum deep beneath the earth and ends up as non-biodegradable nylon deep within a landfill. Carpet lasts approximately 10 years in Mueller which means that Mueller disposes of approximately 1800 pounds of carpet each year.[15] By the time each square foot of carpet now in Mueller is disposed of, the combined mass will amount to 9 tons of waste in landfills that will persist for thousands of years.[16]

The Mueller Solution

There is a significant environmental impact in the production, use, and disposal of the carpet that Mueller Lab uses. A significant reduction in the impact of Mueller Building's carpet use is possible without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller: 1) opt for durable tile instead of carpet when possible; 2) purchase the most environmentally-friendly carpet available; and 3) channel scrap carpet after installation and old carpet after its useful life in an environmentally responsible fashion.

Step 1: Wherever possible choose durable tile rather than carpet. A 100% recycled glass tile is now available in nearly any color.[17]

Step 2: Purchase the most environmentally friendly carpet available. This means paying attention to i) carpet raw materials, ii) dyeing technique, iii) carpet type (i.e., broadloom versus modular), and iv) adhesives used in carpet installation. Today, the carpet companies that Penn State has vendor contracts with offer only minimal post-consumer recycled content in their products. [18] Mueller could purchase carpet having high recycled content (e.g. through Interface Inc.) thereby decreasing both the environmental effects of petroleum extraction for virgin nylon fiber and the burden to landfills from carpets.[19]

Traditionally, carpet dyeing was the most environmentally hazardous step in the carpet manufacturing process. Today, solution dyeing of nylon, which adds pure pigment to the polymer solution as the fibers are made, and vegetable dyeing are the most environmentally responsible dyeing methods. Dyeing method is not considered in Mueller's carpet procurement process, but Mueller could consider this aspect of carpet production and restrict its purchases to vegetable or solution-dyed carpets, such as those produced by Interface, Inc.

Purchasing modular carpet, instead of traditional broadloom, provides the opportunity to replace individual carpet sections as they wear out, which greatly reduces carpet waste. Milliken Carpet, a manufacturer of such a carpet, reports that modular carpet has a life cycle economic cost[20] that is over 1.8 times less than that of broadloom.[21] Whenever possible, Mueller could install modular carpets and greatly reduce the amount of waste associated with carpet replacement.

Lastly, the adhesives, which maintain the position of carpet in Mueller, could have low or no-VOC emissions. For example, Ad-vance Airtech offers a selection of low- or zero-VOC emitting adhesives.[22] Mueller could also purchase carpet that comes manufactured with adhesive directly on the back of each carpet module. In addition to reducing VOC emissions, using self-adhering carpet modules reduces wastes associated with applicators.[23]

Step 3: Channel scrap and old carpet in an environmentally responsible fashion. Today 100% of Mueller's old carpet moves from the building to dumpsters on the periphery of campus, and then to a landfill.[24] DuPont's Partnership for Carpet Reclamation works with major carpet installers to recycle any type of old carpet at a cost comparable to that of landfilling.[25] Interface, Inc., on the other hand, could lease broadloom carpet or carpet tiles to Mueller through its "Flexible Financing Program." At the end of their useful life in Mueller, Interface would take the carpet tiles back to a reclamation center and transform them into new carpet.[26] By working with Interface, Mueller could refrain from dumping roughly 1800 pounds of carpet into landfills each year.[15]

Interface carpets cost about $35.00/ square yard (includes installation cost)[27] compared to approximately $25.00/ square yard for Mueller's status quo carpet supplier, America's Carpet Outlet. However, the overall cost may be less with Interface because only the carpet squares in high traffic areas have to be replaced every decade or so; the rest of the carpet lasts indefinitely.

Ecological Footprint Reduction

Mueller could drastically reduce the environmental impact associated with its carpet use if it gives preference, whenever possible, to tile rather than carpet, purchases environmentally-friendly carpets, and disposes of carpets in an environmentally responsible fashion (Table 2). Purchasing carpets having 100% post-consumer recycled content or biodegradable fibers, in conjunction with complete carpet recycling practices could eliminate carpet-related waste. Furthermore, low or zero-VOC carpets and adhesives improve the air quality for Mueller office occupants and Penn State carpet installers.

Table 2. Percent Occurrence of Environmentally-Friendly Carpet Options in *Status Quo* and "Mueller Potential" Scenarios.

Carpet Status	***Status Quo***	***Mueller Potential***
Post-consumer recycled content or biodegradable fiber	<25%	100%
Solution dyed (for synthetic fibers)	0%	100%
Low or zero-VOC adhesive	0%	100%
Old carpet to reclamation center	0%	100%

Model Carpet Policy

Mueller Laboratory, through its strong commitment to environmental stewardship, seeks to reduce the environmental impact of its carpet use. In order to accomplish this objective, the following steps will be taken during the procurement and disposal of carpeting:

- Give preference to tile rather than carpet.
- Purchase carpets having 100% post-consumer recycled content and solution or vegetable dyed fibers.
- Purchase modular, as opposed to broadloom, carpet to the extent that the quality and end-use of the floor covering remains uncompromised.
- Purchase carpets and adhesives having the lowest VOC level available.
- Lease carpet from Interface Inc. or a similar company, or send old carpet to a recycling center.

For More Information

- Environmentally Responsible Carpet Choices, http://www.metrokc.gov/procure/green/carpet.htm

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3. Paint

An Ecological Profile

The U.S. paint industry annually sells 640 million gallons of building paint at a value of over $6.5 billion.[28] That much paint could fill over 40,000 average-size swimming pools each year.[29] The latex paints used for indoor purposes are more environmentally benign than oil paints, though even they generally contain an array of volatile organic compounds (VOCs). In the presence of light, VOCs form ground-level ozone, both a component of photochemical smog and an eye, lung, and skin irritant.[30] Building paints typically contribute 9% of total indoor VOCs, which are at levels up to ten times higher than those outdoors during a typical day, and up to 1000 times higher during paint application.[31] During application, paint fumes can possibly irritate the eyes, lungs, and skin, and lead to headaches, dizziness, nausea; chronic exposure can lead to respiratory ailments, muscle weakness as well as liver and kidney damage.[31]

The Mueller Connection

Mueller Building spends approximately $1,300 on 60 gallons of paint each year.[32] These paints are acrylic-based latex paints and have moderate to high levels of VOCs.[33]

The Mueller Solution

The environmental impact of Mueller Building paint application and disposal affects both building occupants and the natural environment. A reduction in the impact of Mueller Building's paint use is possible without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller: 1) purchase the most environmentally-friendly paint available, and 2) channel "leftover" paint in an environmentally responsible fashion.

Step 1: Purchase the most environmentally-friendly paint available. Green Seal is a non-profit organization that works to promote environmentally-friendly consumer products via its "Green Seal of Approval."[34] This seal rates products according to product-specific performance, environmental impact, and packaging requirements.[35] Specifically, a "Green Seal" paint is one that: is latex-based, has low VOC levels,[36] contains no harmful ingredients and no heavy metals, and effectively performs its intended function.[30]

Penn State currently holds an exclusive vendor contract with M.A. Bruder Paints,[37] though Mueller also purchases paint from Sherwin Williams and Lowes.[32] Each of these companies offers low-VOC products having prices comparable to the standard VOC counterpart.[38] For example, Sherwin Williams offers a "Green Seal" certified line of paints—"harmony" series that has a VOC level of 0 g/liter.

The "harmony" series is available in all shades in both flat and semi-gloss at a cost of approximately $28.00/gallon vs approximately $22.00/gallon for the Mueller *status quo* choice (e.g. Valspar American Tradition semi-gloss; VOC level 250 g/liter).

Today none of the paint that Mueller buys meets Green Seal approval. Mueller could increase this figure to 100%. The U.S. Military's Aberdeen Proving Ground developed its new paint procurement policy in conjunction with Green Seal and not only minimized environmental impact, but saved money in the process.[39]

Step 2: Channel leftover paint in an environmentally responsible fashion. Mueller attempts to minimize paint waste by purchasing just enough paint to prevent unnecessary excess and then storing leftovers for use in touch-up work. Nevertheless, Mueller leftover paints do contribute to the 12,000 pounds/year of waste paint that the Penn State Department of Environmental Health and Safety sends to a hazardous waste vendor, Phillip Services.[40] Phillip Services then sends the paint to Keystone Cement Co., where it is incinerated to fuel kilns.

Ecological Footprint Reduction

Mueller could significantly reduce the environmental impact associated with its paint use if it purchases environmentally-friendly paints and then disposes of them in an environmentally responsible fashion. Policy restrictions on harmful ingredients and heavy metals, as well as VOC levels, in the paints that Mueller procures would benefit Mueller's indoor air quality.

Model Paint Policy

Mueller Laboratory, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its paint use. In order to accomplish this objective:

- Mueller will purchase paints which are "Green Seal" certified or meet the following standard:
  i. The paint is latex-based.
  ii. The paint has a VOC level of less than 50g/liter.
  iii. The paint contains none of the following harmful ingredients: methylene chloride, 1,1,1-trichloroethane, benzene, toluene (methyl benzene), ethylbenzene, vinyl chloride, napthalene, 1,2-dichlorobenzene, di (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, diethy phthalate, dimethy phthalate, isophorone, formaldehyde, methyl ethyl ketone, methyl isobutyl ketone, acrolein, acrylonitrile.
  iv. The paint contains none of the following heavy metals: antimony, cadmium, hexavalent chromium, lead, mercury.
- After use, Mueller will channel unneeded paints to other groups in need, or to a local reclamation center.

For More Information

•Aberdeen Proving Ground Study. *Painting the Town Green*, http://www.epa.gov/opptintr/epp/pdfs/paint.pdf

•Green Seal. *Choosing Green Report: Paints*, http://www.moea.state.mn.us/lc/greenseal/cgr_paints.pdf

•Zero VOC Paint Manufacturers and Telephone Numbers, http://www.aqmd.gov/business/brochures/zerovoc.html

4. Furnishings/Renovation Conclusion

Presently, Mueller furniture, paint and carpeting purchases negatively affect the environment:

- All of Mueller's furniture comes from forests which are not certified for sustainable wood production.
- All of Mueller's carpets are made from 100% virgin synthetic fiber (i.e., petroleum) and all this carpeting is channeled to landfills after use.
- All of Mueller's paints fail to meet "Green Seal" standards for ecologically benign paints.

These shortcomings could be easily corrected but there would be a cost involved (approximately $0 for shift to green furniture, $130 shift to green carpet; $360 shift to green paints = total cost $490/ year).[41] These additional costs might be more than compensated by both the improved environmental health afforded to Mueller residents and the opportunity to contribute to businesses committed to sustainability.

1. Business Outlet, Inc. (BOI), *Recycled Office Furniture: Good for the Environment, Good for Your Business*, (http://www.businessoutlet.com/pdfs/recycle.pdf , 2001).
2. S. Creighton, *Greening the Ivory Tower*, (Cambridge, MA: The MIT Press, 1998).
3. Assuming an average of 5 pieces of furniture per faculty/staff member in Mueller.
4. R. Kessinger, Penn State University Eberly College of Science Facilities Administrative Officer, (University Park, PA, February 2001).
5. Business Outlet, Inc. (BOI), (http://www.businessoutlet.com/about.asp , 2001).
6. M. Wackernagel with J. McIntosh, W. Rees, R. Woollard, *How big is our ecological footprint?* (Discussion Draft, July 1993).
7. Pressed wood is made with resins that off-gas formaldehyde. EPA, *Indoor Air Quality: Formaldehyde*, (http://www.epa.gov/iaq/formalde.html , 2001).
8. A. Friberg, Spectra Wood, Personal Correspondence (State College, PA, January 2001).
9. S. Rountree, Spectra Wood, Personal Correspondence (State College, PA, March 2001).
10. W. Gallagher, Penn State Salvage, Personal Communication, (University Park, PA, February 2001).

11. Royal Architecture Institute of Canada, *Closing the Carpet Recycling Loop*, (http://www.raic.org/wastenot/issues/9901/9901-5.html , 1999).
12. Environmental Building News, Carpeting, Indoor Air Quality, and the Environment, (http://www.buildinggreen.com/features/crpt/carpets.html , 1994).
13. Recycling Council of Ontario, *RCO Fact Sheets / Recyclable Materials*, (http://www.rco.on.ca/factsheet/fs_g04.html , 1992).
14. American Lung Association, *Carpet*, (http://www.lungusa.org/air/air00_carpet.html , 2000).
15. 12,000 sq. ft. x 1.5 lbs/sq. ft./10 years = 1800 lbs/year.
16. 12,000 sq. ft. x 1.5 lbs/sq. ft. x 1 ton/2000 lbs = 9 tons.
17. Sandhill Industries, http://www.sandhillind.com/ (price ~$20/ft^2)
18. Penn State holds vendor contracts with J & J Carpet, Karastan / Bigelow (acquired by Mohawk Carpet), and Lee's Carpet (a division of Burlington Industries). GURU, (http://guru.psu.edu , 2001).
19. In the near future, carpets with biodegradable fibers will be on the market. For example, Interface, Inc. has recently developed a poly lactic acid (PLA) fiber derived from corn, which is a biodegradable alternative to petroleum-based fibers.
20. Life cycle cost considers expected carpet life, price per square yard, freight per square yard, installation per square yard, maintenance, and repairs.
21. Milliken Carpet, *The Advantages of Modular Carpet*, (http://www.millikencarpet.com/Commercial/modular.html , 1998).
22. Advance Adhesives Technology, Inc., *Products, Carpet*, (http://www.aatglue.com/productdescriptions_carpet.html , 2001).
23. Lee's Carpet, *Self Lock*, (http://www.leescarpet.com/Brochures/performance/selflock/sl1.html , 2001).
24. R. Kessinger, Eberly College of Science Facilities Administrative Officer, Personal Communication, (University Park, PA, February 2001).
25. DuPont, *DuPont Carpet Reclamation Program*, (http://www.dupont.com/dcf/dfs/environmental/reclamation.html , 2000).
26. Interface, Inc., *Services: Leasing Options*, (http://www.interfaceinc.com/us/Services/Leasing , 2000).
27. Price quote from Three Sisters Resources, Pittsburgh (412-441-9999), and Interface distributor.
28. National Paint & Coatings Association, *Facts & Figures - Architectural Coatings*, (http://www.paint.org/ind_info/ffarch.htm , 2000).
29. De Fontenay, *Swimming Pool Volume Calculations US Gallons & Metric Conversion Chart*, (http://www.de-fontenay.com/metric.htm , 2000).
30. Green Seal, *Choosing Green Report*, (http://www.moea.state.mn.us/lc/greenseal/cgr_paints.pdf , 1998).
31. Air Quality Sciences, Inc., *Health Problems Caused by Volatile Organic Compounds*, (http://www.aqs.com/vol_org_compounds.htm , 2001)
32. R. Kessinger, PSU Eberly College of Science Facilities Administrative Manager, Personal Communication (University Park, PA, February 2001).
33. Personal communication with supplier, Lowes, concerning Valspar semi-gloss white paint, VOC=200g/liter. March 28, 2001.
34. Green Seal, *Green Seal Homepage*, (http://www.greenseal.org /, 2001).
35. Green Seal, *Green Seal -- Paints (GS-11)*, (http://www.greenseal.org/standard/paints.htm , 1993).
36. Interior: flat, VOC < 50 g/liter; non-flat, VOC < 150 g/liter. Exterior: flat, VOC < 100 g/liter; non-flat. VOC < 200 g/liter. "Zero" VOC paint is defined by the EPA as any paint product having less than or equal to 50 g/liter VOCs.
37. Penn State University, *GURU (General Utility Reference Utility)*, (http://guru.psu.edu /, 2001).
38. K. Czepiel, Technical Service Representative, PPG Architectural Finishes, Personal Communication (University Park, PA, January 2001).
39. R. Solyan (ed.), *Environmentally Preferable Paints Minimize Harm, Maximize Savings*, (http://www.greenseal.org/pdf/paint.pdf , 1999).
40. C. Griffin, Phillip Services, Correspondence, April 2001.
41. Furniture: Assuming savings from less expensive re-used furniture makes up for extra cost of sustainable forest certified products the additional cost is = $0 /year; Carpeting: ($10 extra/yd^2) x (13 yd^2/year) = $130/year; Paint: ($6.00 extra/gallon) x (60 gallons/ year) = $360/year

E. Reducing the Maintenance Footprint

1. Cleaning Agents

An Ecological Profile

Hundreds of millions of tons of cleaning products wash down American drains every year.[1] Some of these products contain chemicals such as chlorine, ammonia, lye, formaldehyde, and petroleum distillates, which can be persistent in the environment, particularly in the water and soil where they eventually settle.[1] These chemicals can also volatize and contaminate the air during application.[2] Furthermore, the cleaning agent's packaging contributes to resource use and landfill waste if it is not reused or recycled.

The Mueller Connection

Mueller annually purchases various cleaning agents such as all-purpose cleaners, floor cleaners, glass cleaners, and disinfectants from a variety of manufacturers, though primarily from Johnson Wax Professional. These products contain ingredients such as 2-butoxyethanol, a compound known to cause reproductive disorders in laboratory animals and possibly in humans.[3] Additionally, the tile cleaner used in Mueller has 0.9 pH and requires protective hand and eye wear during application.[4]

The Mueller Solution

The environmental impact of Mueller Building cleaning agents and their containers and packaging can be reduced without compromising the research, teaching, and administrative activities of building occupants. To achieve this goal requires that Mueller: 1) purchase the most environmentally-friendly cleaning agents available that do not sacrifice performance expectations; and 2) dispose of the packaging and cleaning agent containers in an environmentally responsible fashion.

Step 1: Purchase the most environmentally-friendly cleaning agents available. The EPA's Cleaning Products Pilot Study performed in Philadelphia[13] delineates the following environmental attributes that should be assessed before cleaning agent procurement: irritation potential,[14] chronic health risks,[15] time to ultimate biodegradation,[16] bioconcentration factor (BCF),[17] percentage of volatile organic compounds (VOCs),[18] amount of product packaging,[19] presence of ozone depleters,[20] potential exposure to the concentrated cleaning solution,[21] flammability,[22] presence of cosmetic additives (fragrances and dyes),[23] and energy needs.[24] This requirement list is potentially overwhelming to the environmentally conscious consumer. Fortunately, “Green Seal” maintains a list of recommended industrial and institutional cleaners.[25] Mueller could purchase its cleaning agents from an environmentally responsible manufacturer that considers the ecological impact of its manufacturing procedures and products (Table 1).[26] Despite, the superior health and environmental attributes of environmentally friendly cleaning agents the cost is not necessarily always higher than standard cleaning agents.[27]

Step 2: Dispose of cleaning agent packaging and containers in an environmentally responsible fashion. Purchasing cleaning agents in bulk is a preventive method of reducing waste, which can significantly reduce the raw material, packaging, energy, and landfill space associated with cleaning agent use and disposal. Today, Mueller disposes of its cleaning agent containers in either the trash or the recycling bin. Sending the container back to the manufacturer for re-use is the most environmentally

Table 1. Mueller Current (Status Quo) and Mueller Potential Cleaning Agents.

Cleaning Agent Type	Use Scheme	Name of Product	Green Seal Approval
Glass	Status Quo	Johnson Wax Professional (JWP),[5] Multi-Surface Cleaner	No
	Mueller Potential	*Rochester Midland,[6] Enviro Care All Purpose Cleaner*	Yes
All-Purpose	Status Quo	JWP, Stride Floral	No
	Mueller Potential	*Alfa Kleen,[7] All Purpose Spray* *The Clean Environment,[8] N1 All-Purpose*	Yes Yes
Tub & Tile	Status Quo	JWP, Crew SC	No
	Mueller Potential	*Alfa Kleen, Tile, Chrome, & Porcelain Cleaner* *The Clean Environment, N7 Basin, Tub, & Tile*	Yes Yes
Germicidal	Status Quo	JWP, Virex II 256	No
	Mueller Potential	*Alfa Kleen, Sanitizer and Cleaner* *Rochester Midland, Neutral Disinfectant*	Yes Yes
Restroom	Status Quo	JWP, Crew Multi-Purpose Restroom Cleaner	No
	Mueller Potential	*DynaChem (Alphen),[9] H2Orange 2 Bathroom Cleaner* *Safe Science,[10] Bathroom Cleaner*	Yes Yes
Grease & Oil	Status Quo	JWP, Spitfire Power Cleaner	No
	Mueller Potential	*The Clean Environment, N20 Neutral Degreaser* *Ipax Cleanogel,[11] Green Unikleen Degreaser and Floor Cleaner* *KC Products,[12] ECO 2000 Multiuse Degreaser/Cleaner*	Yes Yes Yes

responsible disposal method. Whenever possible, Mueller should purchase cleaning agents in bulk from companies that permit the return of spent containers. This will help offset the increased purchase cost of more environmentally benign cleaning agents.

Ecological Footprint Reduction

Mueller could reduce the environmental impact associated with its cleaning agent use if it follows the two steps of purchasing environmentally-friendly cleaners and then disposing (or preferably reusing) containers in an environmentally responsible fashion. A restriction on harmful ingredients in the cleaning agents that Mueller buys directly safeguards the health of the staff who clean the building, while also improving Mueller's indoor air quality for all building occupants.

Model Cleaning Agent Policy

Mueller Laboratory, through its strong commitment to environmental stewardship, seeks to reduce the environmental impact of its cleaning agent use. In order to accomplish this objective, the following steps will be taken whenever possible during the procurement of cleaning agents:

- **Purchase cleaning agents that:**
  - are biodegradable and non-toxic to both humans and aquatic life.
  - have phosphate concentrations less than or equal to 0.5% by weight.
  - have VOC concentrations less than or equal to 10% by weight, when diluted.
  - work in cold water.
  - have an acceptable pH level (between 2.5 - 12).
  - are contained and shipped in recycled and recyclable containers.
  - are sold in bulk and in concentrated form.

- **Avoid purchasing cleaning agents that:**
  - have ingredients derived from petroleum.
  - have nonylphenol ethoxylate or other APEs.[28]
  - have EDTA and NTA.[29]
  - contain chlorine bleach or sodium hypochlorite.[30]
  - contain ozone-depleting chemicals.
  - contain arsenic, cadmium, chromium, lead, mercury, nickel, and selenium.
  - have packaging that contains inks, dyes, pigments, stabilizers or any other additives to which lead, cadmium, mercury, or hexavalent chromium have been intentionally introduced.

- **Whenever possible, return cleaning agent containers to company of origin.**

For More Information

- EPA Environmentally Preferable Purchasing Program, *Cleaning Products Pilot Project,* http://www.epa.gov/opptintr/epp/pdfs/cleaner.pdf
- Green Seal, *Choosing Green Report: Industrial and Institutional Cleaners,* http://www.dgs.state.pa.us/comod/QA/green/cleaners.pdf

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2. Pest Control

An Ecological Profile

Pesticides are some of the most toxic chemicals people encounter on a daily basis. Despite regulation by the EPA and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), both active and inert ingredients in pesticides can cause health problems and contaminate the environment. Additionally, "inert" ingredients are not required to be listed on labels, despite the fact that they are not necessarily biologically, chemically, and/or toxicologically inert.[31]

The Mueller Connection

The majority of pest problems in Mueller Lab are associated with the American cockroach. To control cockroaches Mueller pays approximately $560 annually to ChemTech.[32] Some of the active ingredients used in ChemTech's pest control program include: hydramethylnon ("highly to very highly toxic to fish;" capacity to bioaccumulate),[33] Baygon (a neurotoxin that may cause tingling, tremor, respiratory distress, and/or convulsions),[34] and Lambda-cyhalothrin (a neurotoxin that is known to be highly toxic to some wildlife species).[35]

The Mueller Solution

Mueller occupants could reduce the amount of pesticides used in Mueller without sacrificing the integrity of work, research, or education by adopting Integrative Pest Management (IPM) strategies. IPM programs utilize various levels of pest prevention and management beginning with cultural modification, physical barriers, biological control, and only when necessary resorting to "safe" pesticides.

ChemTech service technicians currently utilize stationary forms of pesticides (i.e. gels, bait stations, and glue traps) resorting to sprays only when necessary or if a customer insists on it. In order to adopt a complete IPM program Mueller would need to commit to: 1) eliminating suitable habitat for pests, and 2) eliminate avenues of pest entry.

Step 1: Eliminate suitable habitat by maintaining an indoor environment that does not provide habitat (i.e. adequate food, water, or shelter) for pests. In the case of the American cockroach, this entails: 1) keeping maintenance/janitorial rooms clean and free of standing water, 2) storing old magazines and paper products in a manner that will not encourage pests, and 3) storing all food products in sealed containers.

Step 2: Eliminate avenues of pest entry. This requires determining where pests enter the building and sealing these entrances with screens, caulking, or other suitable material. The role of physical maintenance and barriers is particularly important in an older building such as Mueller.

Ecological Footprint Reduction

By implementing the above procedures, the amount of pest-control chemicals used could be significantly reduced and ultimately eliminated entirely. It should be noted that initially there would be a cost increase due to labor for the addition of physical barriers. However, after this initial outlay, there would be minimal maintenance of these areas and a reduction of chemical use and labor from ChemTech.

Model Pest Control Policy

In accordance with Mueller Building's commitment to the environment, a full IPM strategy will be implemented through the following:

- Education and cultural modification to reduce pest habitat.
- Assessment of pest routes and appropriate physical barriers to eliminate pest entry.
- Medium-term goal of completely eliminating reliance on chemicals to control pests.

For More Information

- Beyond Pesticides: National Coalition Against the Misuse of Pesticides, www.beyondpesticides.org
- The Pennsylvania IPM Program, http://paipm.cas.psu.edu/index.html
- ChemTech Exterminating, (814) 234-1667

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3. Landscaping

An Ecological Profile

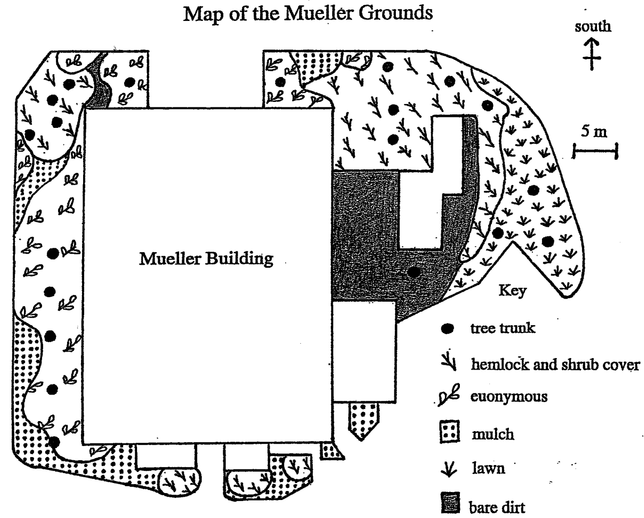
Maintaining the grounds of Penn State's University Park campus costs approximately 3.5 million dollars each year. Labor is by far the most expensive component of caring for the campus grounds comprising about 60% of the grounds budget. Equipment, fuel, and chemical treatments (fertilizers, pesticides, herbicides) are the next most expensive categories, followed by water, seed, plants and mulch.[36]

Energy in the form of fossil fuels for lawn mowers, shrub trimmers, leaf blowers, etc. is required to maintain the campus landscape. Air and noise pollution are created by the use of such equipment. Pesticides, herbicides and fertilizers have the potential to contaminate surface and groundwater and also have energy footprints and health risks associated with them. Certain chemicals used on Penn State's campus are eye and nose irritants and known carcinogens. The prevalent use of exotic plants in campus landscaping can increase maintenance costs and contribute to the decline of native vegetation and habitats. Penn State currently has no policy concerning the use of exotic plants in campus landscaping.[37]

The Mueller Connection

The Mueller grounds include approximately 900 square meters of land.[38] Trees and shrubs occupy 25% of this area; the exotic groundcover, Euonymous fortunei, accounts for another 25% of cover; Kentucky bluegrass, likewise, covers about 25%; and the remaining quarter contains either bare ground or mulch (see map below).

Map of the Mueller Grounds



Of the plants intentionally incorporated into Mueller's landscape, only four species are native whereas nine are exotics. Three yew shrubs have been planted on north side of the building. The eastern grounds are dominated by Euonymous sp. and a few trees, such as red oak and flowering dogwood. Native hemlocks grow on the southern corners of the building with exotic dogwoods, Euonymous fortuneii, Spirea japonica, and several cultivars of a native viburnum planted amongst them. The western side of Mueller has four large native trees, Kentucky bluegrass, and a dense planting of yew, but the noisy HVAC fan system makes this an unwelcoming environment.

In addition to these plantings, some species, such as white mustard, white clover and several species of Veronica, have colonized the Mueller grounds on their own.[39] Of this "volunteer" flora, four species are native and 14 are exotic. Of the 31 total species of trees, shrubs and herbaceous plants growing on the grounds adjacent to Mueller, 74% are non-native.[40]

The Mueller Solution

The grounds around Mueller could be more than just a frame for the building. Instead, they could be designed to illustrate biological diversity and fundamental ecological processes. For example, representatives from the most common plant families of Pennsylvania could be cultivated; medicinal and edible plants native to the Northeast could placed in special beds with labels; butterfly gardens could provide a site for the study of pollination; decomposition could be demonstrated with a compost bin that would yield fertilizer for the grounds (in order to regenerate soil).

Benches and picnic tables constructed from recycled materials[41] could be placed on the grounds for meetings and the leisurely enjoyment of the outdoors (e.g. southeast corner of building). Maintenance-free recycled plastic lumber products (such as hexagon picnic tables) are available in a wide variety of sizes and colors. They are fabricated with HDPE (high density polyethylene, commonly known as #2 plastic), one of the most popular types of discarded plastic. Examples of this are milk & water jugs, bleach containers, etc. Instead of going to the landfill, these plastics can be recycled into products that increase the aesthetics and utility of the Mueller grounds.

The students, faculty and staff of Mueller could help decide how the grounds should be used to reflect the diversity of not only life, but also aspects of the research that takes place in Mueller. In this way, the Mueller grounds might be transformed into a landscape that stimulates observation and thought, engagement with life—the subject of biology.

Ecological Footprint Reduction

Although the Mueller grounds are relatively small, energy is required to maintain the grass and shrubs and spread mulch, fertilizers, and pesticides. Changing the design and maintenance practices utilized for the Mueller landscape could reduce the landscaping footprint created by these activities. Integrated Pest Management (IPM) could eliminate the use of pesticides. Transformation of the lawn into gardens planted exclusively with native perennials would result in less fuel usage and less air and noise pollution while increasing biodiversity.

The lessons taught by a Mueller landscape that has higher biodiversity, uses less energy for maintenance and is more educationally engaging might serve as an inspiration for other Penn State departments.

Model Landscaping Policy

Mueller Building, through its strong commitment to environmental protection, seeks to reduce the environmental impact of its grounds design and maintenance. In order to accomplish this objective, the following steps will be taken:

- Native plants will be chosen for landscaping and the presence of exotic species will be gradually eliminated.
- Mueller grounds will be maintained without direct fossil fuel inputs.
- Integrated pest management strategies will be adopted and the use of all pesticides will be eliminated.
- Mueller occupants will have the opportunity to play an active role in the design, construction and maintenance of the Mueller grounds.
- Mueller grounds will contain areas encouraging conversation constructed with recycled materials.
- The grounds will be designed in ways that encourage an interest in the study of biology and that foster a sense of biophilia.

4. Maintenance Conclusion

If we could somehow dissolve away the physical structure of Mueller building, leaving behind only the water-soluble chemicals covering Mueller's interior surfaces, we would still see a near perfect image of the entire building. Indeed, chemicals, some benign, some problematic, cover all of Mueller surfaces--chemical reagents in Mueller's laboratories and classrooms; chemical cleaners covering floors and bathrooms, and chemical pesticides used throughout the building as well on the grounds surrounding Mueller.

For hundreds of thousands of years humans have lived in an environment of only naturally occurring chemicals; then about fifty years ago we began synthesizing thousands upon thousands of chemicals, many of which were utterly new and outside of our evolutionary experience. Given the magnitude of this "experiment", should it really surprise us that recently there have been a proliferation of previously rare cancers, that the human sperm count may be declining, and that reproductive abnormalities are increasingly common? *

This is an area where cost is of minor concern when compared to the importance of human health and safety. Rather than relying on potentially hazardous chemicals for cleaning, pest control, and grounds maintenance, Mueller could formally adopt and apply the Precautionary Principle by only using chemicals that have been comprehensively tested and proven safe.**

* See Colburn, T., Dumanoski, D., Myers, J. P. 1996. Our Stolen Future. Dutton, NY

** It may well be that the most serious chemically-related threats Mueller occupants face are from laboratory chemicals. Numerous studies published over the last three decades in journals such as the British Journal of Cancer, Environmental Research, the American Journal of Public Health, and the Journal of Occupational Medicine, reveal that people working in environments with high concentrations of synthetic chemicals (e.g., golf course managers, chemists, oil refinery employees, research technicians) have disproportionately high rates of certain types of cancers (e.g., cancer of the pancreas, leukemia and lymphatic cancers (Zimmerman, M. 1995. Science, Nonscience, and Nonsense. The Johns Hopkins University Press, Baltimore, MD).

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1. Green Seal, *Green Seal -- Choose Green Report*, (http://www.greenseal.org/choose.htm , 2000).
2. A Real Life, Inc., *A Real Life*, "Ms. Clean is back," trial issue no. 1, (New York, NY: A Real Life, Inc.).
3. Ohio State, *MSDS File*, (http://www.biosci.ohio-state.edu/~jsmith/MSDS/FinalMSdSPage.htm , 2001)
4. MSDS-SEARCH.com, Inc., *MSDS Search - The National MSDS Repository*, (http://www.msdssearch.com/ , 2001)
5. Johnson Wax Professional (JWP). http://www.jwp.com

. 262-631-4001. pH values from MSDS World, http://www.msdsworld.com/jwp/.
6. Rochester Midland. 800-762-4448.
7. Alfa Kleen. 724-524-2530.
8. The Clean Environment. 402-464-0988.
9. DynaChem. 800-281-9604.
10. Safe Science. 607-422-0674 -- extension 102.
11. Ipax Cleanogel. 313-933-4211.
12. KC Products. 800-927-9442.
13. EPA, *Cleaning Products Pilot Study*, (http://www.epa.gov/opptintr/epp/pdfs/cleaner.pdf , 1997).
14. "The potential for adverse skin reactions from dermal exposure to the product."
15. "The likely chronic health risks from dermal and inhalation exposure to the product."
16. "Toxic chemicals usually degrade to less toxic forms. The faster a chemical degrades, the lower the exposure potential."
17. "The higher the BCF value, the more likely the ingredient is to accumulate in the food chain."
18. "VOCs are known to contribute to smog formation."
19. "Products with reduced packaging (sold as concentrates) decrease the volume of waste that must be disposed of."
20. "Ozone depleting components should be minimized."
21. "The product dispensing method should include safety precautions designed to minimize exposure to the concentrated solution."
22. "Non-flammable products are preferred."
23. "Cosmetic additives can be considered unnecessary additives that increase overall life-cycle impacts and that could increase health and safety and ecological concerns. However, cosmetic additives may be required to help custodians distinguish among cleaning products and determine proper dilution strengths."
24. "Products that work effectively in cold water reduce energy consumption."
25. Green Seal, *Choose Green Report: Industrial and Institutional Cleaners*, (http://www.dgs.state.pa.us/comod/QA/green/cleaners.pdf , 1999).
26. Bio-Pac, http://www.bio-pac.com/ , is such a company and donates 10% of profits to wilderness preservation, never tests its products on animals, and utilizes bulk packaging that the consumer returns when finished.
27. Some standard cleaners are more expensive than environmentally friendly cleaners (e.g. Ajax Expert Tub and Tile Cleaner - $21.45/gallon vs. Alfa Kleen's Tile, Chrome, and Porcelain Cleaner -$16.95/ gallon). However, in some cases they are more expensive than the standard (e.g. JWP Stride Floral costs only $19.14/ 5 gallons while Alfa Klen's All Purpose spray sells for $49.95/ 5gallons). www.alfakleen.com Penn States General store www.eway.com/eway/ui
28. Nonylphenol oxylate, one of a collection of Alkyl Phenol Ethoxylates (APE), is not completely biodegradable. Furthermore, when it breaks down, the chemicals formed are more harmful and persistent than the original (Green Seal -- *Choose Green Report*).
29. EDTA (ethylenediaminetetraacetic acid or ethylene dinitrilotriacetic acid) and NTA (nitriolotriacetic acid) are suspected carcinogens, encourage plant growth and algal blooms, and are not readily biodegradable (Green Seal -- *Choose Green Report*).
30. In wastewater, these chlorine-containing chemicals can react to form chlorinated organic compounds which are possibly toxic and carcinogenic (Green Seal - *Choose Green Report*).
31. Safety Source for Pest Management, *What's in a Pesticide?* (www.beyondpesticides.org/infoservices/pcos/ingredients.htm , 2001).
32. J. LeHota, Personal Communication, (University Park, PA, April, 2001).
33. EXTOXNET, Hydramethylnon, (ace.orst.edu/cgi-bin/mfs/01/pips/hydramet.htm , 1996).
34. Environmental Health Coalition, *Toxic Turnaround*, 1998.
35. EXTOXNET, Lambda cyhalothrin, (http://ace.orst.edu/cgi-bin/mfs/01/pips/lambdacy.htm , 1996).
36. Saari, Steven A. 1999. Paradise Lost? An Examination of the Ecological, Economic and Educational Impacts of the Suburban and University Landscape. Master's Thesis in Ecology. Pennsylvania State University, University Park, PA.
37. Pennsylvania State University Indicators Report, 2000.
38. The grounds considered for this analysis were the area between Mueller and the nearest paved walkway.
39. Plants were identified with the assistance of Daniel Laughlin and Joel McNeal of Penn State University on May 2, 2001.
40. For comparison, of the 3,318 plant species identified in Pennsylvania, 37% are non-native (Rhoads, Ann Fowler and William McKinley Klein Jr. 1993. *The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas*. American Philosophical Society, Philadelphia). On Penn State's University Park campus, over half of the vegetation is non-native, some of which has been planted for educational purposes (Pennsylvania State University Indicators Report 2000).
41. American Recycled Plastics Inc. http://www.itsrecycled.com/

    Recycled plastic lumber is a superior product because it will never dry-rot, split or check; is completely waterproof, will not rust; is not affected by termites, ants, or insect infestation like wood is; never needs to be primed, painted or sealed; is completely splinter-proof with great impact and abrasion resistance; it screws, nails, cuts and routes just like wood; looks clean, neat and new year after year; and is virtually maintenance-free, requiring only an occasional surface cleaning.

F. Reducing Mueller's "Food" Footprint

1. Coffee

An Ecological Profile

Coffee, one of the world's most traded agricultural commodities, is grown in the tropics. The land area devoted to coffee cultivation is equivalent to a one-mile-wide band stretching all the way around the equator.

There are two general approaches to coffee cultivation: traditional and industrial. In the traditional approach, "shade-grown" coffee is cultivated under a forest canopy on small family farms; chemicals are used sparingly, if at all.[1] This contrasts with the "industrial" approach in which coffee is grown in large company-owned clearings in "full sun" and is tended by hired laborers.

Crop yields are higher on industrial coffee plantations, but so are the ecological impacts (e.g. deforestation, water contamination by agrochemicals, biodiversity loss). Because the traditional coffee "farms" are essentially managed forests, birds, insects, mosses, and other life forms thrive. In traditional (less than 15 acres) coffee farms in Central America, researchers tallied as many as 150 bird species, most of which were forest-dependant migrants from North America.[2] The nearby industrial coffee plantations, lacking a forest canopy, and receiving regular dousings of herbicides and pesticides, had 94-97% fewer bird species.[3]

The Mueller Connection

During the year 2000, Mueller spent $796 on 125 pounds of coffee ($6.37/pound). Mueller's coffee provider, Rich Coast, claims that their coffee costs just pennies per cup. This estimate ignores significant environmental costs. As is the case with most coffees on the market today, Rich Coast's coffee is a product of the "industrial" coffee production model. Rich Coast does not offer coffees that are shade-grown or organic.

Coffee is often consumed in styrofoam cups. Styrofoam does not biodegrade and ozone-depleting gases are a byproduct of Styrofoam.

The Mueller Solution

Mueller could shift its patronage to a company that offers its customers a coffee that seeks to minimize environmental impacts on biodiversity, eliminates pesticide and herbicide use, and improves the economic well being of small farmers. For example, Mueller could purchase shade-grown, organic coffee from a company like Equal Exchange. Equal Exchange buys directly from democratically organized small farmer co-ops and trades a wide selection of organic and shade-grown coffees; it is sold by a variety of distributors, including Pittsburgh based Frankferd Farms.[4]

For an extra $65 per year--that's roughly an extra fifty cents/person/year--Mueller could support ecologically responsible agriculture and businesses.[5]

Furthermore, Mueller could switch to plastic or ceramic mugs for coffee drinking. Perhaps ceramics students could be commissioned to produce original and functional pieces, complete with a Biology department logo. They could be washed and re-used thereby eliminating waste from styrofoam cups.

Ecological Footprint Reduction

At present, Mueller, through its patronage of Rich Coast Coffee, supports a production model that has destructive effects on the health of tropical ecosystems. Mueller could protect tropical biodiversity and reduce its coffee footprint by purchasing shade-grown organic coffee from small farmer cooperatives in Mexico and Central America. In addition, Mueller could refuse to purchase unnecessary styrofoam cups and thereby reduce the waste flow to landfills and the release of ozone-depleting gases.

Model Mueller Coffee Policy

Mueller Building, through its strong commitment to environmental stewardship, seeks to reduce the ecological impact of its coffee consumption. In order to accomplish this objective, the following steps will be taken:

- Purchase organic, shade-grown coffee from Equal Exchange or similar sources.
- Stop purchasing styrofoam cups.
- Encourage staff to use their own reusable mugs.
- Provide reusable plastic mugs to visitors.

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2. Cookies

An Ecological Profile

Part of a cookie's ecological profile is on the label. One type of cookie that is frequently purchased by Mueller is Oreos. Ingredients: sugar, enriched wheat, flour (contains niacin, reduced iron, thiamine mononitrate (vitamin B1), riboflavin (vitamin B2), folic acid), vegetable shortening (partially hydrogenated soybean oil), cocoa (processed with alkalai), high fructose corn syrup, corn flour, whey, cornstarch, baking soda, salt, soy lecithin (emulsifier), vanillin (an artificial flavor), and chocolate. Behind the list of ingredients--hidden from view--is the "story" of the energy used to grow, harvest, process, mix, bake, package, and transport the cookies. **About ten times more energy--in the form of fossil fuels--goes into producing a cookie as compared to the energy actually contained in the cookie.** Also hidden from view are the environmental and labor practices of the companies involved in manufacturing and distributing the cookie.

The Mueller Connection

In 2000, Mueller spent $260 on approximately 100 pounds of cookies. Two common brands purchased were

Oreo and Chips Ahoy. Most people have fond associations with these cookie brand names. We sing the jingle "who's that kid with the Oreo cookie!?"; we think "Chips Ahoy": "betcha bite a chip." But, few people think of the ecological and social "stories" behind the foods they purchase.

Consumer advocate groups can help us become informed, offering environmental and social profiles of corporations, including cookie companies. A visit to responsibleshopper.com revealed that both Oreo and Chips Ahoy are subsidiaries of Nabisco, which is owned by Kraft, which is owned by Phillip Morris. Nabisco has been involved in several human rights class action law suits for their treatment of employees, and continues to rely on animal testing.[6] Phillip Morris has an especially troublesome environmental and social record. The Council of Economic Priorities (CEP) analyzes and grades corporations in several areas. In their environmental assessment, Phillip Morris earned a "D."[7] Phillip Morris has also been highly criticized for its corporate influence (e.g. spent $23 million lobbying in 1998-the year Congress was considering a bill to settle anti-tobacco lawsuits) as well as for its attitude towards its tobacco customers (e.g. currently seeking immunity from future lawsuits, and urging drug companies to stop encouraging smokers to quit!).[8] For these and other reasons, Phillip Morris has been named by MultiNational Monitor Magazine as one of the ten worst corporations.[9]

The Mueller Solution

Through its purchasing decisions, Mueller has the opportunity to support companies that embody ecological and social responsibility. For example, instead of Nabisco-brand cookies, Mueller could purchase "Newman's Own Organic Chocolate Chip Cookies." Newman's Own donates 100% of their after-tax profit to charities such as Habitat for Humanity and the Organic Farming Research Foundation.[10] Pittsburgh distributor, Frankferd Farms offers Newman's Own, as well as other brands of "socially responsible" cookies and snacks.[11]

The cost of Newman's cookies is approximately $4.13/lb versus approximately $2.60/lb for Chips Ahoy. A shift to Newman's cookies would increase Mueller's cookie budget by $153.00/year or $1.24/person/year.[12] However, Mueller cookie eaters could have the satisfaction of knowing that their money is supporting sustainable agricultural practices and worthwhile charities.

Ecological Footprint Reduction

The most straightforward way to reduce the footprint associated with Mueller cookie consumption would be to simply purchase and eat fewer cookies. Highly processed foods like cookies, chips, cereals, and candies, gram-for-gram, have much higher footprints than non-processed foods (e.g. raw grains, beans, vegetables, eggs). Apart from this solution, the purchase of snacks with certified organic ingredients, at least, helps ensure that the farming practices used to grow the snack do not unnecessarily degrade farm soils or pollute the environment.

Model Mueller Snack Policy

Mueller Building, through its strong commitment to environmental stewardship, seeks to reduce the ecological impact of its snack consumption. In order to accomplish this objective, the following step will be taken:

- Order certified-organic snacks (e.g. Newman's Organic Chocolate Chip Cookies) from distributors such as Frankferd Farms (www.frankferd.com)

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3. Pizza

An Ecological Profile

Pizza seems appropriate for nearly every occasion: movie marathons, ball games, meetings, not to mention lunch and dinner. All in all, the average American eats forty-six slices of pizza in one year.[13]

Each pizza pie has a story of its own--the story of how each ingredient was grown, harvested, processed, packaged, transported and finally combined in the making of the pizza. A typical plain cheese pizza contains twelve different ingredients, each one shipped from hundreds of miles--often thousands of miles--away.

In most communities, pizza vendors are either small family-run operations or large national chains. National pizzeria chains rely heavily on long-distance shipping, have centralized decision-making, and shunt profits back to company headquarters. Locally owned establishments, by contrast, are usually responsive to community interests, keep profits circulating in the local economy, and are more likely to purchase ingredients from nearby sources.

The Mueller Connection

Each week scores of pizzas are devoured in Mueller. Of State College's many pizzerias, Mueller residents usually order from the nation-wide chain, Papa John's. In December 1999, there were 2,280 Papa John's in operation.[14] Papa John's is headquartered in Kentucky. National chains, like Papa John's siphon dollars from local economies

The Mueller Solution

There are several locally owned pizzerias in State College (e.g. Home Delivery, College Pizza, and Goppers) that represent “pizza solutions”. Goppers offers a particularly interesting alternative. They purchase all of their ingredients and paper products from Pennsylvania distributors, and will soon support local farmers through the State College farmers' market.[15] At the same time, ordering from Goppers would save money; a sixteen-inch Goppers cheese pizza costs $5.99, while chain pizzerias in State College charge approximately $11.00.

Ecological Footprint Reduction

By contributing its dollars to locally owned pizza establishments, Mueller would support State College's local business people and, by extension, possibly local farmers and distributors.

Model Mueller Pizza Policy

Mueller Building, through its strong commitment to environmental protection, seeks to reduce the ecological and social impacts of its pizza consumption. In order to accomplish this objective, the following step will be taken:

- Order pizzas from local pizzerias such as Home Delivery and Goppers.

4. Food Conclusion

Compared to the other sections of this report the food section might seem almost trivial to some readers. After all, why worry about coffee, cookies and pizza when they represent such a small segment of Mueller's overall environmental impact. We include the food sections mostly for illustrative purposes. Indeed, there are scores of relatively minor things (e.g., pencils, markers, staples, chemwipes, mousepads) that Mueller purchases each year. Individually these purchases are inconsequential, but in aggregate they have a measurable environmental impact. For most, if not all of these "minor" products, there are alternatives to choose among, as we have seen in the cases of coffee, cookies and pizza. Some choices will invariably have smaller environmental impacts than others. Seen in this way, each dollar that Mueller spends is, in effect, a political act--it can be used to support enterprises that promote environmental stewardship or that undermine ecological health.

1. www.equalexhange.com
2. Kenworthy, Eldon and Eric Shaeffer. "Coffee: The Most Teachable Commodity*?" The Journal of Environmental Education*. (http://www2.shastacollege.edu/wc/living/styro/)
3. www.audobon.org
4. www.frankferd.com
5. $6.89/lb for Equal Exchange coffee through Frankferd Farms x 125lb/yr =$861.25/yr
   $6.37/lb for Rich Coast Coffee x 125lb/yr = $796.25/yr
   $861.25 - $796.25 = an extra $65.25/yr
6. www.responsibleshopper.com
7. Criteria for Council on Economic Priorities' environmental assessment includes: environmental impact, corporate environmental policy, environmental audits, employee training/accountability, waste management and pollution prevention, corporate environmental reporting, and resource/energy usage. (www.cepnyc.org/sbwgradingcriteria.htm)
8. www.responsibleshopper.com
9. www.essential.org/monitor/monitor.html
10. www.newmansownorganics.com
11. www.frankferd.com
12. Newman's Own Organic Cookies can be purchased for $4.13 per pound through Frankferd Farms cost $4.13/lb x 100 lb/yr = $413.00/yr. Nabisco cookies cost $2.60/lb x 100 lb/yr = $260.00/yr. $413.00 - $260.00 = an extra $153.00/yr.
13. Packaged Facts, NY; from www.dominos.com
14. www.papajohns.com
15. Goppers is the only pizzeria in town that has reacted to the demand for vegan pizza with soy cheese, and is in the process of creating a wheat-free crust.

III. Moving from Theory to Practice

A. Incorporating Environmental Stewardship into Purchasing Policy

The foregoing analysis makes it clear that Mueller Building's environmental impact is the result, not just of the amounts of materials purchased BUT, also, of the types (brands) of materials purchased. In the case of paper, for example, it is not just the amount of paper Mueller buys each year that counts, but also the type of paper (e.g., 0% vs. 100% recycled content) that influences the size of the building's 'footprint.' The same is true for computers, printers, carpeting, cleaning agents, and so forth.

Perhaps the single most important thing Mueller, and by extension Penn State, could do to lessen its impact on the environment is to adopt policies that restrict purchases, to the extent possible, to products that:

1) have high recycled content
2) are produced in an environmentally sustainable manner
3) demonstrate maximum durability or reparability,
4) are energy efficient, non toxic, and recyclable.[1]

Mueller lab could take a lead in demonstrating how this could be done by adopting the following Purchasing Guidelines:

- **Lighting.** Artificial lighting should be used only when necessary – accomplished via individual actions or occupancy sensors. Replace all incandescent light bulbs with compact fluorescent light bulbs and replace all T-12 fixtures with T-8 or T-5 fixtures.
- **Paper.** When possible, purchase paper: i) having 100% post-consumer recycled content, ii) manufactured by a "totally chlorine free" (TCF) process, iii) containing wood fiber from sustainably managed forests, and iv) originating from within the Mid-Atlantic region.
- **Computers.** Insist on Energy Star computers. Purchase laptops (instead of desktops) whenever possible. When purchasing laptops, choose modular and/or PCMCIA-type devices over "internal" devices (this makes upgrading easier). Purchase TFT flat panel displays instead of cathode ray tube monitors for desktop computers.
- **Printers.** Purchase Energy Star printers. When possible, choose ink-jet over laser-jet printers. Keep printers turned "off" when not in use.
- **Printing.** Purchase re-filled ink-jet cartridges from a remanufacturing facility. Send spent ink-jet cartridges back to facility OR refill ink-jet cartridges on site. Send spent laser cartridges to Laserforce and purchase re-filled cartridges from Laserforce.
- **Paint.** Purchase paints that are "Green Seal" certified or that meet the "Green Seal" standard.
- **Carpet.** Purchase carpet having: i) 100% post-consumer recycled content, ii) solution or vegetable dyed fibers, and iii) the lowest VOC level available; direct carpet purchases to Interface, Inc or a similar company which offers modular carpet and transforms old carpet into new carpet.
- **Furniture.** Purchase furniture in the following order: i) refurbished from Penn State Salvage, ii) refurbished from other companies, iii) metal furniture having a high percentage (> 50%) of post-consumer materials, and iv) new wooden furniture from sustainably managed forests.
- **Cleaning agents.** Purchase the most environmentally friendly, effective cleaning agent available, utilizing the "Green Seal" standard for comparison.
- **Pest control.** Adopt a full IPM strategy including cultural and physical modifications and an overall goal of eliminating pesticide use.
- **Landscaping.** Adopt IPM strategies for grounds keeping. Replace exotic plant species with native plant species.
- **Food.** Support local businesses, certified-organic foods and sustainable farm practices.

Although all of the proposed changes in this document will benefit the working and learning environments for those who use Mueller, some save money and some cost more than the status quo. For this reason it is imperative to consider the improvements in aggregate, thus using the money saved from highly cost-effective improvements to finance the less cost-effective improvements. In this way the operation of Mueller building will still cost less after the changes and its users will be able to enjoy all the benefits of the proposed changes.

Penn State's new (March 2001) Finance and Business (F&B) Strategy for Environmental Stewardship opens the way for incorporating sustainability into Mueller's purchasing decisions. For example, the F&B strategy specifically encourages the purchase of goods "that minimize waste products, have high recycled content, use environmental production methods, demonstrate maximum durability or biodegradability, reparability, energy-efficiency, non-toxicity, and recyclability."

Of course, the largest purchase Mueller makes every year is energy. A startling amount of Mueller's ecological impact is associated with this energy and, in particular, the energy associated with heating and cooling the building. Currently, Penn State equates the price of energy with its value—we look at the price of energy and consider whether the usefulness we will get from it is worth the money – but some energy costs are not included in utility bills, nor do the companies that produce or sell the energy pay for them. These include damage to land from coal mining and to miners from black lung disease; environmental degradation caused by global warming, acid rain, and water pollution; national security costs, such as protecting foreign sources of oil; and human health problems caused by air pollution from the burning of coal and oil.[2] For example, the National Resource Defense Council recently released a report entitled *BREATH-TAKING* that showed that every year, approximately 64,000 people die prematurely from cardiopulmonary causes linked to particulate air pollution.[3] Since such costs are indirect and difficult to determine, they have traditionally remained external to the energy pricing system, and are thus often referred to as externalities. Since the producers and the users of energy do not pay for these costs, society as a whole must pay for them. [4]

It is obviously rational to include the real costs of fossil fuel combustion into the price of energy. Some states have already started considering these costs in energy policy analyses. For example, Oregon has an order that requires utilities to perform sensitivity analyses for common pollutants using the following range of values (NOx: $2,000 - $5,000/ton; CO_2: $10 - $40/ton).[5] To put these numbers into perspective, Mueller building would have to pay an extra $309,000/year if the estimated impacts of only these two gases from the real cost of coal-fired energy were taken into account. This works out to an extra 5½ cents per kW hr.[6] Pennsylvania, on the other hand, does not require consideration of such "externalities". This partially explains why Penn State's electrical rate is only $0.0233/kW-hr – less than it costs to generate electricity from coal-fired power plants (~$0.03/kW-hr) and less than ½ of the estimated cost of CO_2 emissions alone! Penn State could set a good example for the Commonwealth and begin including externalities in its energy analysis. This "good example" could start with Mueller building by taking into account the true cost of energy when considering investments in energy saving improvements for Mueller. If this were done many of the suggestions outlined in this report would become cost-effective as the payback times would be reduced by approximately a factor of four.

B. Incorporating Environmental Stewardship into Job Descriptions

Mueller and other Penn State campus buildings will not be able to cut their ecological footprint in half from one year to the next but with commitment and leadership this goal could be achieved over a five to ten year period. Indeed, across the U.S. and around the world, organizations, companies, and government bodies are publicly committing themselves to dramatic footprint reductions. Some examples: i) staff at World Resources Institute in Washington D.C. recently made a public commitment to reducing that organization's greenhouse gas emissions to zero by 2005; ii) Xerox Corporation has announced its goal of recycling or reusing 99% of its copy machine components; and iii) the Netherlands has set a national waste reduction goal of 90%.

Mueller Accounting Office.

University departments do a good job of accounting for the flows of money--i.e. the cash coming in and leaving the unit. But money is not the only kind of capital that deserves our attention; there is also, so-called, "natural capital"--the stocks of soil, water, forest, and biodiversity. Indeed, the health of our cash economy ultimately depends on the abundance and status of these "natural capital" stocks.

This has relevance to Mueller. To the extent that the consumption of energy and materials in Mueller remains high, the building's occupants inevitably contribute to the depletion of the Earth's "natural capital" stocks. On the other hand, if Mueller ratchets down consumption, building occupants will conserve natural capital and reduce their 'footprints.'

The staff in the Mueller Accounting Office has the expertise to track changes in Mueller's environmental impacts and to convey these results to Mueller's occupants. The key accounting tasks necessary to chart changes in the environmental impacts of Mueller's activities are:

- Conduct yearly review of purchases to explore what Mueller buys (by category) and new, more sustainable substitute products that may have appeared during the year (1 person; 2 days/year).
- Conduct yearly review of what Mueller throws out to explore ways of shifting purchasing to companies that employ clean production technologies, minimal packaging, and which take back products at the end of their life and return the components to the production stream (1 person; 2 days/year).
- Organize yearly building "clean-up day" dedicated to collecting and recycling computer disks, CDs, old printer cartridges, used transparencies, paper in "second-life" category, old computers, printers, and copiers. (1 person; 2 days/year).
- Conduct yearly ecological assessment showing Mueller trends in energy, water, and dry material consumption and waste production. Combine this with a critique of effectiveness of present Mueller actions, recommendations for future actions, and "how-to" educational documents (1 person; 15 days/year).

TOTAL TIME: 21-25 days/year (i.e., 1/12th of one salary).[7]

Mueller Computer Support Specialist.

Part of Mueller's environmental impact is associated with computing. Building personnel, through their choice of computer equipment and computer-related energy conserving practices, have an important role to play in mitigating these negative environmental impacts. Mueller's Computer Support Specialist (CSS) could help mitigate these impacts as follows:

- Power-saving options. Turn on or, if necessary, install power-saving options on all computers. The CSS may have to write instructions and/or teach users how to install and activate these options. Similarly, set printer options default to "draft-mode" + duplex mode OR teach users how to do this themselves.
- Upgrade computers. The impact of computer production and waste can be significantly reduced by increasing the average lifetime of computers from the standard 3-4 years to 8-10 years. The CSS could help to ensure that this occurs by keeping a record of building computers by type, date of purchase, and upgrade status. Then, every other year the CSS could offer to perform upgrades.

TOTAL TIME: 10-15 days/year.

C. Incorporating Environmental Stewardship into the Design of New Buildings

It is well past time for Mueller and Penn State, as a whole, to move beyond its highly wasteful and polluting building system to one that cleaner and efficient. The ideal approach to accomplish energy and material efficiency is to employ green design. Green design utilizes an integrated process of design in order to minimize redundancies between systems, maximize their efficiency and, thereby, downsizes or entirely eliminates systems or components.

Pennsylvania's Department of Environmental Protection's Cambria office (designed by a Penn State graduate) offers an excellent example of green design in practice. The Cambria building's energy features comprise[8]:

- Ground source heat pumps, which provide heating and cooling services as well as domestic hot water.
- Raised access flooring, which provides an under floor supply air plenum for displacement heating and cooling through floor-mounted air diffusers.
- A 14 kW photovoltaic electric array mounted on the south-facing roof. The photovoltaic power generation will be sold to a green power marketer and offset a portion of building energy use and also reap tax savings.
- Heat recovery air-handling units provide ventilation make-up air separated from conditioned air. Ventilation air is preconditioned through energy recovery, which also provides dehumidification for the system.
- Light shelves on south-facing windows, which increases lighting levels by reflecting natural light deeper into interior spaces; at the same time cooling loads are reduced by shading windows from direct sun.
- Site-specific reverse-baffle solar shading devices, which shade other south-facing windows from summer sun while allowing winter sun to penetrate into interior spaces. Second floor south-facing windows are shaded via integral roof overhangs.
- Lighting power density is reduced to an average of less than 0.7 watts per square foot, which significantly reduces both electrical energy consumption and cooling loads. This was accomplished by integrating the following components:
    - split task-ambient lighting scheme;
    - indirect fluorescent lighting fixtures with T-8 lamps and electronic dimming ballasts controlled by light sensors;
    - natural daylighting via clerestory window monitor;
    - occupancy sensor switching at workstations, toilet rooms, and conference room;
    - roll-down solar shades on south-facing windows;
    - compact fluorescent lighting fixtures with vertical lamp configurations; and
    - L.E.D. exit lights.
- The building's thermal envelope achieves high-performance levels by integrating the following components:
    - exterior walls constructed of R-30 insulated concrete forms; high density fiberboard roof decking laminated with an interior reflective surface and 4" of rigid insulation provide a composite roof insulation of R-33;
    - pre-manufactured aluminum-clad wood windows provide triple-glazed low-e-coated, argon-filled insulating glass with a full-unit U-value of 0.29;
    - storefront windows include high-performance thermally broken frames and triple glazed, low-e coated, argon filled insulating glass with a full unit U-value of 0.26;
    - concrete floor slab on grade is insulated with 2 inches of EPS rigid insulation around the perimeter.

All of the above systems are integrated to achieve a simulated annual energy cost reduction of 55 percent compared to the requirements of the American Society of Heating, refrigerating, and Air-Conditioning Engineers standards (ASHRAE/IES Standard 90.1-1989) and equates to less than 25,000 btu/ft^2. Mueller's performance (216,155 btu/ft^2)[9] is embarrassing by comparison. Thus, the Cambria office is 8 times more efficient (total energy per square foot) than Mueller! Mueller building is not an anomaly. The most recent buildings in the College of Science's "fleet", Wartik and Thomas, both are actually higher in energy use than Mueller at 220,173 btu/ft^2 and 287,583 btu/ft^2 respectively.[9]

The energy savings for the Cambria building are remarkable but the most stunning figure about green buildings is that they do not cost more. The building construction costs for the Cambria Office are estimated at $90.00 per square foot, well within the range of cost for a similar conventionally constructed office building in this area.

Cambria Office Building showing building integrated photovoltaic panels and light shelves.

It is past time that Penn State began taking advantage of the enormous potential monetary savings from energy conservation measures in both new construction and retrofits of existing buildings. Mueller's energy performance is an embarrassment to the University. Contrary to our spirit of "making life better"- the poor design of Mueller succeeds only in "making life worse" for the faculty, staff, and students that use it. Other Universities have taken the lead in environmental stewardship. For example, Oberlin College in Ohio has just completed a "green" environmental science building (see below)[10] that is projected to be a net energy producer by virtue of its efficient design and start-of-the-art photovoltaic system. The Oberlin building has also been equipped with a living machine to ensure that the wastewater discharged from the building is at least as clean as the water that enters it.

Oberlin's new Environmental Studies Building

Oberlin's photovoltaic system represents a particularly poignant challenge to Penn State. The Eberly College of Science in collaboration with the College of Engineering house one of the top photovoltaic research centers in the country, yet P.S.U. only has a 2kW system (only enough power for one small home) installed on a campus building. Oberlin's Environmental Studies Building is powered by amorphous silicon solar cells – invented by a current Penn State professor. Penn State should be leading not only scientific research into superior energy generation technologies but their adoption as well.

The examples above, of course, have great relevance for the College of Science RIGHT NOW as it breaks ground for its new Life Sciences Building (as seen below).[11] The new Life Science Building is being built to meet increased student demand in the life sciences (i.e. 2,000 students enrolled in biological sciences in the Eberly College of Science, 1,600 in life sciences-related majors in the College of Agricultural Sciences, and 1,000 students in the College of Health and Human Development). This new Life Science Building will take advantage of the exploding research opportunities of the 21st Century requiring interdisciplinary collaboration. The building also offers the opportunity to demonstrate Penn State's leadership role in smart design and environmental stewardship. The new Life Science Building could be a demonstration of superior design or it could be just another Mueller.

Mueller has a lesson to teach:

The building was constructed at a time when most people imagined that our supplies of energy were nearly inexhaustible and when almost no one had made the connection between fossil fuel use and climate disruption. But now we live in another time. We know much more which means that we need to do much more. All new buildings on the Penn State campus should outperform Mueller by at least a factor of five (a conservative goal -- 8X is technically attainable). Indeed, given the range and depth of knowledge and creativity Penn State commands, we surely have the means to build the most sustainable and life affirming buildings in the history of North America. To do less compromises both our spirit and our destiny.

Proposed Life Science Building at PSU

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1. Keniry, *Ecodemia*, National Wildlife Federation, 1995.
2. http://www.ucsusa.org/energy/brief.hidden.html
3. *BREATH-TAKING: Premature Mortality Due to Particulate Air Pollution in 239 American Cities*, a May 1996 report by the Natural Resources Defense Council. See the online report to view mortality data for individual cities and states. http://www.nrdc.org/air/pollution/nbreath.asp
4. http://www.theenergyguy.com/externalities.html
5. www.eia.doe.gov/cneaf/electricity/external/external.pdf
6. Mueller's total energy use is 5,436,229 kW-hrs/year which produces 5,750 tons of CO_2 and 15.8 tons of NOx

Extra cost for CO_2= 5,750 tons x $40/ton = $230,000
Extra cost for NOx = 15.8 tons x $5,000/ton =$79,000
Total extra cost = $309,000
Extra cost Per kW-hr = $309,000/5,436,229kW-hrs = $0.0568

7. The accounting protocols could be developed over one semester by a graduate student RA under C. Uhl's supervision.
8. DEPARTMENT OF ENVIRONMENTAL PROTECTION CAMBRIA OFFICE BUILDING http://www.gggc.state.pa.us/building/Cambria/2300DEPCambriaDOBldg.pdf
9. Univ. Park Energy Use by Facility. This data is from the 97-98 fiscal year (7/1/97 - 6/30/98). http://energy.opp.psu.edu/engy/Consumpt/UP/Facility/BTUSQFT.htm
10. http://www.oberlin.edu/~envs/
11. www.development.psu.edu/Buildings/LifeSciBldg.asp

IV. Epilogue

As ecologists look at the world, they see a finite planet being overwhelmed by human activities. A while back, humans imagined that we could take from the Earth forever. Now we know that Earth's bounty is limited and cannot be taken for granted. The solution to our problems is not continual growth, as we once thought, but sustainable living--an approach to life that is mindful of limits and that emphasizes quality rather than quantity. The concept of sustainability--meeting present needs without compromising the ability of future generations to meet their needs--challenges all of us to pay attention to the myriad of ways in which we depend on the Earth and to seek ways of significantly reducing our ecological footprint.

This report outlines what one building on the Penn State campus, Mueller Lab, could do to dramatically reduce its ecological footprint. The analysis reveals that Mueller, among other things, could:

- Cut coal consumption by 755 tons and in the process cut CO_2 emissions by nearly 2,000 tons per year.
- Cut water use by over 100,000 gallons a year.
- Cut paper consumption by 67%.
- Dramatically reduce waste associated with the disposal of transparencies, diskettes, computers, carpeting, furniture, and printer cartridges.
- Significantly reduce VOCs, and caustic and toxic chemicals associated with carpeting, paints, cleaning agents and pest control.

All these things could be done while in no way compromising the research, teaching, and administrative functions of Mueller occupants. Furthermore, pursuing these changes would promote a healthy work environment in Mueller, save money, and foster environmental stewardship in society as a whole.

Mueller, of course, is just one of 11 buildings that house The College of Science at University Park.[1] If we assume that Mueller's resource consumption and waste generation for basic materials (e.g., of paper, computing devices, electricity) are typical of other PSU science buildings, then the College's ecological impact, as well as its potential to reduce these impacts is noteworthy. For example, based on square foot ratios between Mueller and other College of Science buildings, we estimate that adopting "best practices" could cut the College of Science's energy consumption and in so doing reduce greenhouse gas emissions by over 20,000 tons.[2]

<u>This reduction in energy use could save the Eberly College of Science nearly half a million dollars per year.</u>

Table 1. Potential Savings for the Eberly College of Science, Penn State University.

Building	**BTUs per square foot**	**Estimated Cost Savings**
Mueller	216,155	$45,515
McAllister Building	64,530	$13,587
Thomas Building	287,583	$60,553
North Frear	133,240	$28,055
South Frear	223,409	$47,041
Osmond Laboratory	58,781	$12,377
Wartik Laboratory	220,173	$46,360
Pond Laboratory	155,064	$32,650
Whitmore Laboratory	127,660	$26,880
Chandlee Laboratory	328,242	$69,115
Althouse Laboratory	222,323	$46,812
Davey Laboratory	196,309	$41,335
Total		$470,281

The Department of Biology, in particular, and the College of Science, in general, is well positioned to take a leadership role in modeling sustainable practices for the entire University Park community. University leadership in Old Main could hasten this process by creating policy mechanisms that ensure that cash savings achieved through resource and waste reduction measures (such as those described in this report) find their way back to the Colleges and Departments realizing those savings.

In closing, let us remember that Penn State is an institution of higher learning--a place that, at its best, nourishes the search for truth and cultivates wholeness, health and balance. Penn State fails to achieve this ideal when its actions and practices are wasteful and harmful to human health and the environment. Biology--with its concern for the complexity and intricacy of life systems--has an opportunity to join its knowledge of life with actions that respect and nurture life. The Biology Department could do this by integrating "The Mueller Solutions" detailed in this report into daily practices.

Mueller's example could spread to other departments across the University and even to other universities across the nation. Indeed, the time is right for such an initiative: President Graham Spanier has just approved a Faculty Senate resolution to "promote ecological literacy at Penn State by modeling sustainable practices." The biggest beneficiaries of this change will be Penn State students. If academic departments can make sustainability manifest through their daily practices, Penn State graduates will learn life's important lessons the best way possible--through example.

1. Penn State, Biology, *Building Locations and Directions*, (http://www.bio.psu.edu/General/location.stm , 2001).
2. Determined by assuming Mueller Building's potential energy consumption savings are typical of other buildings in the Eberly College of Science.

Total Fiscal savings per year for suggestions: Lights $4,421) + Building tune-up ($12,849) + Temperature setback ($2,140) + Computers ($1,850) + Printers ($425) + Elevators ($85) + Ceiling fans ($23,743) = $45,515

Mueller Conversion factors:
Money Saved = $45,515 /216,155 (btu/$ft^2$)
=0.21056$/btu/$ft^2$
kW-hrs saved = 1,848,611kW-hrs/216,155 btu/ ft^2 =
8.55 kW-hrs/ btu/ft^2

Eberly total possible electrical savings found from summing btu/ft^2 to gain a "total" and multiplying by conversion factor: 2,233,469 btu/ft^2 x 8.55 kW-hrs/ btu/ft^2 =1.90962E7 kW-hrs which would prevent emissions of 20,187 tons of CO_2

Calculations for carbon dioxide emission prevention details are in footnote 3 of the energy chapter.
Data on energy use per square foot from:
http://energy.opp.psu.edu/engy/Consumpt/UP/Facility/BTUSQFT.htm

V. Addendum: Model Standards for Future PSU Building Construction

Penn State University has embarked on a course of continued growth for the first decade of the 21st Century. The energy and materials that supply the buildings that make up the physical infrastructure of Penn State determine the majority of Penn State's toll on the natural environment. In order to minimize this environmental impact, building energy use must be minimized and material efficiencies must be maximized. It is far easier to accomplish this from the beginning in the design of a building rather than trying to improve a flawed building with "band-aid" solutions. The key to designing technically and environmentally superior buildings is to utilize an integrated process of design to minimize redundancies between systems, maximize their efficiency and, thereby, downsize or entirely eliminate systems or components. The standards outlined below were adapted from Leadership in Energy and Environmental Design (LEED) Standards and offer a method for Penn State to construct new campus facilities while maintaining its commitment to environmental stewardship.

The Green Destiny Council proposes that the following standards be met for future buildings at The Pennsylvania State University:

1. Sustainable Site Selection

a. Erosion & Sedimentation Control. Create a site sediment and erosion control plan that conforms to best management practices in the EPA's Storm Water Management for Construction Activities (EPA Document No. EPA-832-R-92-005, Chap. 3). The plan should meet the following objectives: prevent loss of soil during construction by storm water runoff and wind erosion, protect topsoil by stockpiling for reuse, and prevent sedimentation of storm sewers.

b. Site Selection. Ensure a clear southern line of sight from roof and avoid shading existing buildings to utilize passive and active solar applications (see Standard 3, below).

c. Alternative Transportation. Reduce pollution and land development impacts from automobile use by making new buildings easily accessible by walking from the center of campus (i.e., do not build on the periphery of campus) and providing covered bicycle racks for bicycle commuters. Ensure that car parking needed for the building is constructed from porous paving and/or contains an integrated photovoltaic canopy.

d. Reduced Site Disturbance. Conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity. This can be achieved, in part, by limiting site disturbance, including earthwork and clearing of vegetation, to 40 feet beyond the building perimeter, 5 feet beyond roadway curbs, walkways, and main utility branch trenches, and 25 feet beyond pervious paving areas.

e. Stormwater Management. Limit disruption of natural water flows by minimizing stormwater runoff (i.e., allow no net increase in the rate and quantity of stormwater runoff from existing conditions), increasing on-site infiltration by installing pervious paving); collect and reuse stormwater for non-potable uses such as landscape irrigation and custodial uses; and install natural treatment systems such as constructed wetlands, vegetated filter strips, and bioswales to treat stormwater leaving the site.

f. Landscape & Exterior Design to Reduce Heat Islands. Reduce heat islands (thermal gradient differences between developed and undeveloped areas) by providing shade (within 5 years) on at least 50% of non-roof surfaces on the site, including parking lots, walkways, plazas, etc. Plant shade trees in vicinity of new building (not shading roof)--pines and evergreens on northern exposures (to reduce winter heating loads) and deciduous tress on southern, eastern and western exposures (to reduce summer cooling loads). Install a "green" (vegetated) roof for north-facing roofs.

g. Light Pollution Reduction. Eliminate light "trespass" from the building site by not exceeding IESNA foot-candle level requirements (Recommended Practice Manual: Lighting for Exterior Environments, IESNA) and by designing interior and exterior lighting such that zero direct-beam illumination leaves the building site. Finally, install light detectors to control external lights to eliminate unneeded artificial illumination.

2. Water Efficiency

a. Water Efficient Landscaping. Eliminate the waste of potable water for landscaping by using rainwater collected from roof for watering and landscape using only native vegetation, which needs minimal artificial watering.

b. Innovative Wastewater Technologies. Reduce the generation of wastewater while increasing the local aquifer recharge by installing a "Living Machine" wastewater treatment facility. Monitor facility to ensure that the wastewater discharged from the building is at least as clean as the water that enters it.

c. Water Use Reduction. Maximize water efficiency within buildings to reduce the burden on water supply and the PSU wastewater system by installing waterless urinals, composting toilets, and faucet aerators. The compost from the toilets can be utilized as fertilizer on building landscaping, substituting the use of chemical fertilizers.

3. Energy & Atmosphere

a. Fundamental Building Systems Commissioning. In order to verify and ensure that fundamental building elements and systems are designed, installed and calibrated to operate as intended, undertake continuous commissioning similar to that accomplished at the Material Research Institute Building.

b. Minimum Energy Performance. All new PSU buildings should equal the PA Department of Environmental Protections Cambria Office's energy performance of 25,000 btu/ft2. This can be accomplished by following the suggestions outlined in 3d and 5i (See below).

c. CFC Reduction and Ozone Layer Protection. Reduce ozone layer depletion by utilizing no CFC-based refrigerants or halons in any HVAC, refrigeration equipment, and fire suppression systems.

d. Optimize Energy Performance. Design the building envelope and building systems to maximize energy performance by: designing building to be passive solar heated, cooled, and lit; only using artificial lighting when necessary (installation of occupancy sensors); restricting artificial lighting to compact fluorescent bulbs and T-5 fixtures; using highly reflective tiles on ceilings; installing fractional lighting controls for all fixtures; programming the HVAC system to decrease temperatures during the night in the winter and to raise them at night during the summer; using temperature setbacks on weekends and holidays; adjusting thermostats to environmentally friendly levels (78 in the cooling season and 72 in the heating season); installing ceiling fans in place of AC systems; installing roll-down solar shades on south-facing windows; using light emitting diodes (LED) for both exit lights and security/emergency lights (lights which must remain on 24-7); and restricting elevators use to handicapped personnel and equipment movers.

e. Renewable Energy. Encourage increasing levels of self-supply through emerging high-tech renewable technologies by installing a building integrated photovoltaic (PV) array covering the entire surface area of south-facing roofs and/or use partially transparent PV in place of architectural glass on south wall of building. PV power generation in excess of the building needs can be sold to a green power marketer and also lead to tax savings. Flexible solar cells can conform to any surface or flat panel modules can be used in place of standard roofing material.

f. Green Power. Encourage the development and use of grid-source energy technologies by purchasing electricity, not supplied by the PV roof array, from renewable energy providers.

g. Measurement & Verification Intent. Provide for the ongoing monitoring and optimization of building energy and water consumption performance in compliance with the US DOE's International Performance Measurement and Verification Protocol for the following: lighting systems and controls, constant and variable motor loads, variable frequency drive operation, chiller efficiency at variable loads, air and water economizer and heat recovery cycles, air distribution static pressures and ventilation air volumes, boiler efficiencies, building specific process energy efficiency systems and equipment, and indoor water risers and outdoor irrigation systems. Model the energy and water systems to predict savings. Design the building with equipment to measure energy and water performance. Draft a Measurement & Verification Plan to apply during building operation that compares predicted savings to those actually achieved in the field.

4. Materials & Resources

a. Storage & Collection of Recyclables. Facilitate the reduction of waste generated by building occupants that is disposed in landfill by recycling glass, plastic, office paper, newspaper, and cardboard via the Centre County Waste Authority; and organic wastes on campus.

b. Construction Waste Management. Divert construction, demolition, and land clearing debris from landfill disposal and redirect at least 75% by weight back to the manufacturing/construction process. Waste diversion includes the donation of materials to charitable organizations such as Habitat for Humanity.

c. Resource Reuse. Extend the life cycle of building materials by reducing environmental impacts related to materials manufacturing and transport. This can be done by using salvaged or refurbished materials for at least 10% of building materials and forming all concrete in the building using fly ash from campus steam plants. Identify opportunities to incorporate salvage materials into building design such as beams and posts, flooring, paneling, doors and frames, cabinetry and furniture, and brick.

d. Recycled Content. Increase the demand for building products that have incorporated recycled content materials, therefore reducing the impacts resulting from the extraction of new materials. Ensure that construction materials that contain an aggregate are composed of 50% recycled material and that other materials contain a minimum weighted average of 25% post-consumer recycled content material, or, a minimum weighted average of 50% post-industrial recycled content material.

e. Local/Regional Materials. Increase demand for building products that are manufactured regionally, thereby reducing the environmental impacts resulting from transportation and supporting the local economy. This can be done by using a minimum of 25% of building materials that are manufactured regionally (i.e., within a radius of 500 miles of the building site).

f. Rapidly Renewable Materials. Reduce the use and depletion of finite raw, and long-cycle renewable materials by replacing them with at least 10% rapidly renewable materials such as bamboo flooring, strawboard, cotton batt insulation, linoleum flooring, sunflower seed board, and wheat grass cabinetry.

g. Certified Wood. Encourage environmentally responsible forest management by demanding that 100% of wood-based materials are certified in accordance with the Forest Stewardship Council Guidelines.

h. Building Reuse Intent. The life cycle of existing building stock should be extended to conserve resources, retain Penn State history, reduce waste, and reduce environmental impacts associated with new building construction. This can be done by maintaining 100% of existing building structure and shell (exterior skin and framing excluding window assemblies) while removing elements that pose contamination risk to building occupants and upgrading outdated components such as windows, mechanical systems, and plumbing fixtures.

i. Life Cycle Analysis (LCA) of Material Choices. In order to minimize the environmental impacts of material choices for new buildings Penn State students can be hired to do LCA studies of proposed materials. LCA is a means of quantifying how much energy and raw material are used and how much waste is generated at each stage of a product's life.

5. Indoor Environmental Quality

a. Minimum Indoor Air Quality (IAQ) Performance. Establish minimum IAQ performance to prevent the development of indoor air quality problems in buildings; maintain the health and well being of building occupants by meeting the minimum requirements of voluntary consensus standard: ASHRAE 62-1999.

b. Environmental Tobacco Smoke (ETS) Control. Ensure Zero exposure of building occupants to ETS. In addition to prohibiting smoking within the building following University policy, prohibit smoking within 10 yards of building air intake and entrances, and do not provide ashtrays on outdoor refuse bins.

c. Carbon Dioxide (CO_2) Monitoring. Provide capacity for IAQ monitoring by installing a permanent CO_2 monitoring system that provides feedback on space ventilation performance necessary to maintain indoor CO_2 levels no higher than 530 ppm above ambient outdoor levels at any time.

d. Increase Ventilation Effectiveness. Provide for the effective delivery and mixing of fresh air to support the health, safety, and comfort of building occupants by using either a mechanical ventilation system that results in an air change effectiveness greater than 0.9 as determined by ASHRAE 129-1997; or for naturally ventilated systems demonstrate a distribution and laminar flow pattern that involves at least 90% of the room or zone area in the direction of air flow for at least 95% of hours of occupancy. This can be accomplished by including displacement ventilation, low-velocity ventilation, operable windows, and raised-access flooring (provides an under-floor supply air plenum for displacement heating and cooling through floor-mounted air diffusers).

e. Construction IAQ Management Plan. Prevent indoor air quality problems during construction by exceeding minimum requirements of the SMACNCA IAQ Guideline for Occupied Buildings under Construction, 1995; protect stored on-site or installed absorptive materials from moisture damage, and replace all filtration media (with a MER of 13 as determined by ASHRAE 52.2-1999) immediately prior to occupancy. Conduct a minimum two-week building flush out with new filtration media after construction ends and prior to occupancy, or conduct a baseline indoor air quality testing procedure following current EPA Protocol for Environmental Requirements, Baseline IAQ and Materials, for the Research Triangle Park Campus, Section 01445. Adopt an IAQ management plan to protect the HVAC system during construction, control pollutant sources, and interrupt pathways for contamination. Sequence installation of materials to avoid contamination of absorptive materials such as insulation, carpeting, ceiling tile, and wallboard.

f. Low-Emitting Materials. Reduce the quantity of indoor air contaminants that are odorous or potentially irritating to the installer's and occupant's health and comfort. Meet or exceed volatile organic compound (VOC) limits for adhesives, sealants, paints, composite wood products, and carpet systems as follows:

i. Adhesives must meet or exceed the VOC limits of South Coast Air Quality Management District Rule #1168, and all sealants used as filler must meet or exceed Bay Area Air Quality Management District Reg. 8, Rule 51.

ii. Paints and coatings must contain 0 g/liter VOC and comply with the chemical component limits of the Green Seal requirements. After use, channel unneeded paints to a local reclamation center.

iii. Carpet systems must meet or exceed the Carpet and Rug Institute Green Label Indoor Air Quality Test Program. Carpet tiles should be leased from Interface, Inc. through its "Flexible Financing Program." At the end of their useful life, Interface takes the carpet tiles back to a reclamation center and transforms them into new carpet. Wherever possible choose durable tiles made from 100% recycled glass rather than carpet.

iv. Composite wood and agrifiber products must contain no added urea-formaldehyde resins.

g. Indoor Chemical & Pollutant Source Control. Avoid exposure of building occupants to potentially hazardous chemicals that adversely impact air quality. Design to minimize cross-contamination of regularly occupied occupancy areas by chemical pollutants by: employing permanent entryway systems (grills, grates, etc.) to capture dirt, particulates, etc. from entering the building at all high volume entry ways; providing areas with structural deck to deck partitions with separate outside exhausting; ensuring no air re-circulation and negative pressure where chemical use occurs (including laboratories, housekeeping areas, and copying/print rooms); providing drains plumbed for appropriate disposal of liquid waste in spaces where water and chemical concentrate mixing occurs; and designing separate exhaust and plumbing systems for rooms with contaminants to achieve physical isolation from the rest of the building.

h. Controllability of Systems. Provide a high level of individual occupant control of thermal, ventilation, and lighting systems to support optimum health, productivity, and comfort conditions by providing a minimum of one operable window and one lighting control zone per 200 SF for all occupied areas within 15 feet of the perimeter wall and controls for airflow, temperature, and lighting for 100% of the non-perimeter, regularly occupied areas. Overall, design the building with occupant controls for airflow (under-floor HVAC systems with individual diffusers), temperature (ceiling fans), and lighting (task lighting).

i. Thermal Comfort. Provide for a thermally comfortable environment that supports the productive and healthy performance of the building occupants by complying with ASHRAE Standard 55-1992, Addenda 1995, including humidity control within established ranges per climate zone. Design the building envelope and HVAC system to maintain these comfort ranges using computer modeled passive solar techniques.

The building's thermal envelope can achieve high-performance levels by integrating the following components: exterior walls constructed of R-30 insulated concrete forms; high-density fiberboard roof decking laminated with an interior reflective surface and 4" of rigid insulation provides a composite roof insulation of R-33; pre-manufactured aluminum-clad wood windows provide triple-glazed low-e-coated, argon-filled insulating glass with a full-unit U-value of 0.29; storefront windows include high-performance thermally broken frames and triple glazed, low-e coated, argon-filled insulating glass with a full unit U-value of 0.26; concrete floor slab on grade is insulated with 2 inches of EPS rigid insulation around the perimeter.

Install and maintain a temperature and humidity monitoring system in the building to automatically adjust building conditions as appropriate.

j. Daylight & Views. In order to increase productivity and decrease sick days provide a connection between indoor spaces and outdoor environments through the introduction of sunlight and views into the occupied areas of the building. Achieve a minimum Daylight Factor of 2% (excluding all direct sunlight penetration) in 75% of all space occupied for critical visual tasks (not including copy rooms, storage areas, mechanical, laundry, and other low occupancy support areas). Exceptions include those spaces where tasks would be hindered by the use of daylight (photolithography rooms) or where accomplishing the specific tasks within a space would be enhanced by the direct penetration of sunlight (personal fitness facilities).

Overall, design the building to maximize daylighting and view opportunities by using shallow floor plates, increased building perimeter, exterior and interior shading devices, fiber-optics, high performance glazing, and photo-integrated light sensors.

6. Sustainable Education

Provide plaques and/or computer readouts displaying the building's design innovations and superior performance so that building occupants, students, and PA citizens can learn the details of sustainable design first hand.

7. Innovation in Design Intent

To receive recognition for superior PSU building design use the LEED Credit Equivalence process to identify the intent of all proposed innovation credits, the proposed requirement for compliance, the proposed submittals to demonstrate compliance, and the design approach used to meet the required elements.

Following these guidelines will guarantee that all new buildings at PSU will surpass the LEED Platinum level standards (the highest level of achievement in sustainable design).

Reviewers Comments

My hope for this report is that it's read from cover to cover by all Penn State students, faculty and administrators. Why? Because so many of us learn, work, and live in wasteful, ugly and in many ways "unwell" environments. With meticulous investigation and spirited reason, this report shows how a single, rather mundane building—and an entire campus—can be revitalized for the 21st century.

Ken Tamminga
Associate Professor of Landscape Architecture
College of Arts and Architecture

The Mueller Report: Moving Beyond Sustainability Indicators to Sustainability Action at Penn State is an excellent document, and should be used for guidance in plans for future buildings at Penn State. In addition, many, if not most or all of the findings could also be applied immediately to current buildings. Lighting and HVAC are the two most prominent areas (for the four key parameters: energy savings, coal consumption, CO_2 emission and dollar savings) noted in the report, and are two that are very visible to any observer--buildings with lights on all night in most rooms; rooms too cool in the summer, etc. I hope that this timely and relevant study is heeded by the University community. Significant benefits, both financial and environmental, would result if action were taken on lighting and HVAC alone. I applaud the efforts of those participating in producing this report.

Larry C. Burton
Associate Dean for Administration and Planning
Professor of Electrical Engineering
College of Engineering

My overall impression is that the Mueller Report is a good start to the process of identifying specific solutions rather than continuing to philosophically muse about the nature of the problem. It is a wise strategy to bring the problem home, to the authors' building, indicating that we all share in the problem, and therefore, all share in the solution. Assigning blame to others (suppliers) rather than to ourselves (consumers) is easy and fashionable, yet intellectually dishonest. This report will go a long way to educating readers that sustainable living in the workplace is a choice. Technological advances have given us the opportunity to choose between a more sustainable and less sustainable option in almost every workday activity. I am not an advocate of mandated practices, rather strongly support the concept of people, and after all the University is but a collection of people, making informed choices and decisions. The Mueller report informs readers with concrete examples of the choices they have and should make in the workplace. I therefore endorse releasing the report to the University community.

Alan Scaroni
Head of Department of Energy and Geo-Environmental Engineering
College of Earth and Mineral Sciences

I found the Mueller Report to be a fascinating read and highly relevant to the university's planning efforts and to anyone with an interest in preserving the natural environment. I especially liked the concreteness of focusing on a particular building and the highly specific recommendations regarding what can be done to reduce the ecological footprint. But, most of the report would apply equally to many other buildings on campus. I appreciate all the careful work that went into this report. I hope that the administration will take the report seriously and consider how it can implement the recommendations.

Linda Klebe Treviño
Professor of Organizational Behavior and
Franklin H. Cook Fellow in Business Ethics
Chair, Department of Management and Organization
The Smeal College of Business Administration

This is an impressive document in the breadth of topics that it covers regarding the "footprint" of Mueller Lab and depth of the literature research involved. The process that created it is exciting to me because so much of it was driven by students, both undergraduate and graduate. The document provides many alternatives that could substantially reduce the "footprint" of buildings within the Penn State system. I hope that we will see some of them put into practice soon.

Thomas A. Litzinger
Director Leonhard Center for the Enhancement of Engineering Education
Professor of Mechanical Engineering
College of Engineering

The report is quite impressive - obviously a lot of work to put together. It should serve as a model for similar audits of other buildings on campus. Statistics provide a strong argument for encouraging people to conserve. Certainly much of what you recommend appears to be doable by individuals and the department (e.g., smaller fonts, wider margins, recycled paper, less printing, reduced artificial lighting, monitor shut downs, etc.) with essentially no expense and negligible effort. I hope that residents of the building (at least) will take the time to read the report and make an extra effort in their daily routine to conserve energy and resources.

Blair Hedges
Associate Professor of Biology and Mueller resident
Eberly College of Science

The report represents an important step in the process of reducing the adverse environmental impacts of Penn State University operations by making detailed, site-specific, action-oriented recommendations pertaining to a specific Penn State building. The report is detailed and comprehensive -- with recommendations ranging from those of broader scope, such as replacing Mueller's water flushing toilets with composting toilets, to those that are much more focused, such as purchasing Newman's Own chocolate chip cookies instead of Chips Ahoy chocolate chip cookies. The authors make the point effectively that details do count as part of a holistic approach to reducing the ecological impacts of our campus operations -- building by building, facility by facility. A key point is that we must examine all of our facility design, construction and operating details in order to maximize the amount of ecological improvement we will be able to realize on our campus. To achieve the goals of the Green Destiny Council, there must be a broad-based shift in the way Penn Staters think, act, and prioritize. The Mueller Report provides a relevant example of how specific actions can be taken on a specific building. The report has the potential to serve as a template for performing similar evaluations on other Penn State facilities.

Richard Behr
Department Head and Professor of Architectural Engineering
College of Engineering

It is surprising that we are so used to life as usual that many of us do not pause to consider our actions and the impact they may have on our environment. I found the report absorbing and thought provoking. Thank you for raising our awareness on such fundamental issues. As you so rightly suggest, maybe with a little bit of thought, one can not only make the environment better but also save money while doing it.

Jayanth R. Banavar
Head of Physics Department
Eberly College of Science

I have reviewed your ecological analysis of Mueller Lab, which I found to be very comprehensive. In general I agree with your findings and suggestions related to the purchase of products. Although many good alternative products are available it will require faculty/staff acceptance to make the program successful. PSU Purchasing can only buy what our consumers will accept and use. I do believe with extensive education and communication our F/S will begin to specify the alternative products you describe. I do not believe a mandate or unilateral decision to buy alternative products will sustain long-term success. Thank you for the opportunity to review your report.

H. James Dunlop
Director of Procurement & Materials Management
The Pennsylvania State University

Penn State's structural footprint of building and growth need not crush the delicate balance of natural environment and population density that share the University Park and Campus College domains. That is the good news from Green Destiny Council, a community of students, staff and faculty, in this call to arms to reverse unsustainable practices. Their research findings and the implications for action they generate are reasoned and sobering. The Mueller Report is a scholarship of civic engagement and outreach, and a reminder that the complex problems and issues we confront as an academic community carry with them an obligation to bring the best of our community to their solution.

Jeremy Cohen
Associate Vice Provost for Undergraduate Education
Professor of Communication

What a document! Dr. Uhl and his students found common sense ways to "green" retrofit the Mueller building on campus primarily altering purchasing and operational practices. The main cost is intellectual in perceiving opportunities. Penn State: implement and let the revolution proceed.

Jack Matson
Professor of Environmental Engineering
College of Engineering