Electrical Energy Assessment at Towson University:

How much do we use, how much could we save?

ENVS 491
Senior Seminar
Fall 2004

Matthew Bechtel
Dan Bianca
Justin Callahan
Dennis Coyle
Jared Dubrowsky
Mike Hauser
Jenni Hayter
Janice Hilliard
Debra Joseph
Kate Kritcher
Chiharu Koda
John Maciolek
Ephraim Maduabuchi
Jessica Maszaros
Jon Moore
Jesse Quinn
Keith Shepherd
Amanda Stansburge

image: courtesy Michigan State University Extension

Acknowledgements

The students of Environmental Science and Studies Senior Seminar 2004 would like to thank the following people for their assistance in developing and completing this project.

Mr. Dennis Bohlayer, Director Operations and Maintenance, Facilities Management, Towson University;

Mr. LeRoy McKee, Energy Coordinator, Towson University

Dr. Marion Hughes, Professor, Department of Sociology, Anthropology and Criminal Justice, Towson University

Dr. Douglas Pryor, Professor, Department of Sociology, Anthropology and Criminal Justice, Towson University

Dr. Charles Schmitz, Department of Geography, Towson University

Mr. John Propst, Property Management, Towson University

Ms. Carolyn Simonds, Senior, Sociology-Anthropology major, Towson University

Mr. Michael Austin, Maintenance Mechanic, Towson University

Mr. Joe McGrath, Sales Representative, Watt Stopper, Inc.

Mr. Charlie Wise, Account Manager, Verdiem Inc.

Mr. Mike Fisher, Executive Vice President, Easylite, LLC

Dr. Jane Wolfson, Director, Environmental Science and Studies

Table of Contents

Figures and Tables

Final editing of this project was the responsibility of Jesse Quinn and Debra Joseph.

PREFACE

All students completing the Environmental Science and Studies major enroll in ENVS 491, Senior Seminar, during their senior year. In this course, students are presented with an environmental problem and ‘charged’ with assessing it, investigating it, and developing solutions/suggestions that are economically sound, logistically feasible and that incorporate stakeholder needs and constraints.

This year the class received its ‘charge’ from Mr. LeRoy McKee, Energy Coordinator, and Mr. Dennis Bohlayer, Director of Operations and Maintenance, Facilities Management at Towson University. The University is faced with increasing amounts of electrical consumption associated with the increased size of the student body and an increased dependence on technology, which is expected to increase 2-3% (Bohlayer 2004). This consumption of electrical energy is costly ($3.7 million in fiscal 2004) and these costs are projected to rise 24.3% to $4.6 million in fiscal 2005 (Bohlayer 2004). This situation presented these students with an environmentally important problem that had important (and immediate) economic implications.

The students took a broad view of electrical consumption. Starting with the fuel source for generation (electricity doesn’t start at the switch), they then looked to the attitudes about energy conservation on campus and the amount of electricity being consumed (and wasted) by lights and computers. This information gave rise to their suggestions. What follows is the result of a semester of work on this topic.

The students have worked on their own. I provided only limited guidance and help as requested. They deserve the credit for their success.

I. THE INS AND OUTS OF ELECTRICAL ENERGY SOURCES

Electricity can be produced from many different fuel sources, both conventional and "green." Conventional methods include coal, nuclear, natural gas, and hydroelectric power. In Maryland, approximately 53% of our energy is generated from coal, 33% from nuclear, 8% from natural gas and 2% from hydroelectric power (Reliant Energy undated). All of these sources have both positive and negative attributes associated with their retrieval and use; however, improved practices assist in making them more efficient. "Green" power sources are environmentally friendly alternatives to conventional fuels. Renewable resources, such as wind, sunlight, and biomass, can be used to generate energy and produce relatively little pollution. Technological developments in wind power, solar power and bioenergy are making these resources increasingly viable in regional, national, and global markets.

Conventional Power Sources

Hydroelectric Power

***Basics*:** Hydroelectric power, or hydropower, is a renewable energy source that relies on water cycles. The first record of using water to assist in manpower was in 200 B.C. when the first water wheel was built (Crawford et al. 2004). However, it was not until 1882 that water was used to generate electricity (Crawford et al. 2004). Currently, 24% of the world's electricity is generated by hydropower (Bonsor 2004). This energy source provides over one billion people with more than 650,000 megawatts of power, equivalent to the power provided by 3.6 million barrels of oil (Bonsor 2004). Hydropower can be a very efficient way to generate electricity. Ninety percent of the energy provided by flowing water can be converted into electricity for about $0.85 per kWh (WVIC 2004). This is 50% of the cost of nuclear power and 25% of the cost of natural gas power (WVIC 2004).

Retrieval and Use: Once the gates of a hydropower dam are opened, water is released from the reservoir and flows into a pipe that leads to a turbine (Bonsor 2004). The force of the water turns blades within the turbine, which forces the water up a shaft into a generator (Bonsor 2004). Within the generator, magnets turn concurrently with turbine blades (Bonsor 2004). The magnets pass by copper coils that move electrons to create an alternating current (Bonsor 2004). This is transformed into a high voltage current and sent through a series of power lines to distribute the electricity (Bonsor 2004).

The fate of the water after exiting the turbine is dependent on the type of hydroelectric power plant. Conventional power plants carry water through a pipe or a series of pipes, which discharge downstream (Bonsor 2004). Pumped-storage power plants use water from an upper reservoir to generate electricity and then release it into a lower reservoir (Bonsor 2004). During off-peak consumption hours, the water is pumped back into the upper reservoir via a reversible turbine (Bonsor 2004).

Environmental Considerations: Though considered a "green," environmentally friendly renewable resource, hydropower has several ecological consequences. The dams required to harness hydroelectricity have many impacts, including armoring, downstream erosion, alteration of local hydrology due to operating rules, and the loss of biodiversity (Roberge 2004).

Armoring, the process of removing the smaller stream sediment particles from the ecosystem leaving only larger cobbles and boulders, occurs due to fast moving waters released from dams (Roberge 2004). Floods created by dams do not occur in small, repeated frequencies as in natural processes, but instead in extremely forceful, uncommon patterns (Cave 1998). As a result, those organisms that inhabit small intricate habitats are no longer able to survive in the river (Cave 1998).

Additionally, species which are adapted to living in flowing waters and cool temperatures may not be able to adapt to the changes brought about by a dam (Smith and Smith 2001). The temperature of the dammed river tends to behave much like that of a lake; the water located in the upper layers remains warm, while lower layers stay cold (Cave 1998). Macroinvertebrates, such as stoneflies, may need warmer temperatures to begin metamorphosis (Cave 1998). Cooler waters may delay important life stages (Cave 1998). If a predator is dependant on a macroinvertebrate during a particular stage in its life, the development of the predator could be affected.

Downstream erosion is also a major environmental concern. Suspended sediment from rivers is deposited in slow moving waters behind dams, allowing water that flows through dams to be clean and clear (IDSNET 2002). As this clear water moves downstream it picks up new sediments (IDSNET 2002). The swiftness of moving water ensures that riverbeds located downstream of dams will be drastically eroded in a short period (IDSNET 2002). Following the construction of the Hoover Dam, the riverbed downstream was eroded by at least four meters in nine years (IRN 2004). This can result in further impacts, including increased crop irrigation due to lower water tables, depletion of fish habitat and spawning areas, and decreased habitat for other invertebrates (IRN 2004).

One of the most influential aspects of hydroelectric power is the operators. Hydrologists determine the consistency of flooding, water velocity, and water levels throughout the year, creating an alteration of local hydrology (Roberge 2004). For example, during the spring and winter, the dams are opened more often because of increased rainfall; a consequence attributed to the reduced need to conserve water (Roberge 2004). During summer and fall months, gates tend to remain closed in order to conserve water throughout the dryer seasons (Roberge 2004). Additionally, daily fluctuations in energy demand are common because of varying temperatures during the day (Roberge 2004). Generally, many people turn on their air conditioners during the day because of warmer temperatures, therefore using more electricity (Roberge 2004). Operators compensate for this increase in demand by releasing more water from the dam's reservoir (Roberge 2004). During cooler, overnight temperatures, the public generally turns off their air conditioners; therefore, less water is needed to move through dams (Roberge 2004).

Among all other impacts, perhaps the most important is the loss of biodiversity. Though augmented by armoring, downstream erosion, and alteration of local hydrology, the decline of various stream species is increased by other dam-related factors. These include fragmentation of habitats, isolation of species, and prevention of migration (IDSNET 2002). Fish migration is possibly one of the largest natural processes impacted by hydropower (Cave 1998). In order to complete their life cycles, some fish, such as salmon, require passage up and down the river (Cave 1998). Large dams prevent this movement, therefore potentially stopping the reproduction of an entire species (Cave 1998). If fish do manage to cross the dam, it is unlikely any of their offspring will manage to make it over the dam and through the motorized, revolving turbines, or survive in the high level of nitrogen located in the waters just below the dam (Cave 1998).

While hydropower is much better for the environment than some other sources of energy, it is not as environmentally friendly as it may seem. As demonstrated, dams can have a dramatic impact on the functioning riverbeds, species, and ecosystems.

Policy Implications: New public policy developments are concentrated on electricity deregulation. Increased competition could jeopardize the health of rivers as utility companies work to cut costs in order to stay viable in the market (ENN 2001). This could reduce efforts to mitigate the adverse environmental impacts of hydropower (ENN 2001). In 2002, Congress reauthorized the National Dam Safety Program (ASCE 2003a). This program provides funds to state dam safety agencies to procure equipment, implement new technology, and inspect more frequently (ASCE 2003a). It also provides funds for continuing education for dam safety engineers and funds technological research (ASCE 2003a).

Research is being done on how to mitigate adverse effects on the environment (DOE 2004a). Scientists from The United States Department of Energy (DOE) have been studying fish habitat, fish survival in turbines, water quality downstream of dams, and the response of fish to physical stresses such as hydraulic shear and pressure changes (DOE 2004a). Advanced turbine research has produced improvements to some existing turbines, as well as an innovative turbine runner with a helical screw shape, patterned after centrifugal pumps (DOE 2004a). Due to lack of funding, most of the efforts at the DOE are concentrated on advanced turbine research (DOE 2004a). Biological design criteria based upon laboratory tests of fish stress responses have also been developed (DOE 2004a). Future DOE research projects include computational fluid dynamics modeling and biological testing to quantify turbulence and strike effects on fish (DOE 2004a).

The most important future need is regular maintenance and technological upgrades of current plants (ASCE 2003a). There are over $1 billion in maintenance and upgrading backlogs for hydropower plants (ASCE 2003a). While over 90% of the nation's approximately 100,000 dams are state-regulated, over half of these dams are privately owned (ASCE 2003b). Unfortunately funding (state or private) is erratic, severely inhibiting efforts to rehabilitate dams (ASCE 2003b). Deterioration of dams and hydropower plants causes them to be more susceptible to failure and increases possible negative environmental impacts (ASCE 2003b). Continued downstream urbanization coupled with aging dams and hydropower plants requires that dams are fully funded and staffed in order to prevent possible catastrophic events (ASCE 2003b).

Future Directions: The future of hydropower lies in the creation of new technologies, public policy and grassroots activism. The DOE and The United States Army Corps of Engineers are researching new technologies to reduce the impacts on wildlife, plants and hydrological systems (ASCE 2003a). In addition, there is a growing movement to remove dams that are no longer in use by working at local, state, and national levels to educate the public and do restoration work (Am Rivers 2004).

New technologies may make hydropower a safer and less invasive source of renewable energy. By the year 2010, the DOE is hoping to upgrade aging equipment, retrofit hydropower plants at existing (but unused) dams, and to produce hydropower at sites without the use of dams (DOE 2004a). In addition to upgrading of older equipment, testing is being conducted on large turbines, new tools are being created to improve water use efficiency, and best practices for environmental mitigation are being compiled (DOE 2004a).

If hydropower plants were maintained and kept up-to-date a powerful change in electricity generation could occur (ASCE 2003a). Increased competition due to deregulation in conjunction with advanced environmentally friendly technologies, such as microturbines, fuel cells, and photovoltaics, could give utility companies the ability to generate their own electricity instead of buying it and then redistributing it (ASCE 2003a).

Coal

Basics: Coal is an extremely plentiful and inexpensive form of fuel, often used for generating electricity. Approximately 52% of the electricity in the United States is generated by coal (EIA 2004c). The average family of four would use 3,375 lbs of coal per year to heat an electric water heater, 560 lbs to run an electric stove top, and 256 lbs of coal for a television; totaling over two tons of coal per year (EIA 2004c). Coal consumption in the United States is expected to rise to about 1,500 million tons in 2025 (EIA 2004d). Globally, usage will increase over the next twenty years to meet growing energy demands (Keay 2002).

Retrieval and Use: Two methods are used to extract coal. The first method, underground mining, involves sinking a horizontal and vertical shaft into the ground. Miners then travel through the shaft or tunnel to dig for coal (Energy Quest 2002). The second method, strip mining, starts with removal of the overlaying soil and vegetation in an area, followed by blasting and removal of the bedrock (Energy Quest 2002). Cranes at the top of the stripped mountain are used to take out the coal (Energy Quest 2002). When mining is complete, the layers of topsoil are replaced (Energy Quest 2002). Strip mining provides 60% of the coal used in the United States, while the remaining 40% comes from underground mines (UCS 2001). The process of producing electricity from coal is relatively simple. Coal is burned to heat water, which produces steam that turns a turbine, which produces electricity (Energy Quest 2002).

Environmental Considerations: Coal is damaging to the environment when it is mined, transported, stored and burned (UCS 2001). For instance, in order to produce steam, coal fired power plants draw in massive amounts of water from surrounding tributaries (UCS 2001). This results in water quality degradation and often destroys many fish and fish eggs (UCS 2001). In addition, coal storage can contaminate groundwater and surface water with metals, sulfuric acid and other contaminants (UCS 2001). Water used to clean the smoke stacks is strongly acidic, and can contribute to acid rain as well as potentially seeping into the groundwater table (UCS 2001).

Burning coal also has detrimental effects on the air quality. The average coal plant releases 3.7 million tons of carbon dioxide annually (UCS 2001). A typical 100 mega-watt coal burning power plant releases approximately 25 lbs of mercury each year (Greenpeace 2001). Coal plants also produce high amounts of sulfur dioxide, which can cause respiratory problems in humans, damage plants, and it is one of the leading causes of haze and acid rain (UCS 2001). In order to combat sulfur dioxide, scrubbers have been installed in some power plants (UCS 2001). Scrubbers are instruments designed to clean sulfur from the combustion gases before they are emitted, and for the past twenty years these instruments have been required to be installed on new coal fired plants (UCS 2001). Using this single device, power plants have been able to reduce sulfur dioxide emissions by as much as 95% (UCS 2001). If scrubbers were installed on older plants, the results would be similar (Burnett 2001).

Pollution may be substantially reduced if the coal industry employs new technologies designed to reduce emissions of sulfur dioxide, nitrogen oxides, carbon dioxide and particulate matter (Keay 2002). The Schwarze Pumpe Power Station in Germany is a model for the use of new technologies to lower harmful emissions (Keay 2002). The station has decreased emissions of sulfur dioxide by 91% nitrogen oxides by 61% and particulates by over 98% (Keay 2002). In addition, carbon dioxide levels have dropped by 31% and overall efficiency has improved by 41% (Keay 2002). The plant also requires one third less coal than older plants to generate the same amount of electricity, thus conserving natural resources (Keay 2002).

Policy Implications: The DOE has developed a Clean Coal Power Initiative that uses a process called integrated gasification combined-cycle (IGCC), in which coal is converted into a gaseous state and then combusted in a combined-cycle gas turbine (Burnett 2001, WCI 2002). This process has allowed power plants to reduce sulfur dioxide emissions by 98%, nitrogen oxide emissions by 90% and particulate matter to a level that cannot be traced; also, efficiency is improved by almost 40% (Burnett 2001). In addition, this initiative includes a research program with the objective of developing new technologies that will turn pollutants into safe, commercially valuable products, and limit the emissions of greenhouse gases (WCI 2002).

The Clean Power Act has been proposed in the Senate, and would decrease mercury emissions by 90% by 2008 (Novak 2004). The main goal of this legislation is to lower air pollution from coal burning power plants by requiring coal power plants to reduce emissions of nitrogen oxide, sulfur dioxide, carbon dioxide, and mercury in a manner which is fair, cost efficient and technically feasible (Novak 2004). Economically, jobs associated with the coal industry would be eliminated as other forms of energy production are emphasized (Novak 2004).

President Bush's Clear Skies Initiative calls for a reduction in nitrogen oxide, sulfur dioxide and mercury by 2010 with further reductions by 2018 (WCI 2002). Using a market based approach, the plan calls for a cut, by 2018, in sulfur dioxide emissions by 73%, nitrogen oxide emissions by 67% and mercury emissions by 69% (WCI 2002).

Future Directions: Although environmental issues concerning the use of coal for electricity will continue, the fact that coal is cheap and plentiful will drive its usage well into the 21^{st} century (Burnett 2001). It will no doubt play a major role in supplying not only electricity to the United States, but to the rest of the world as well (Burnett 2001). The technological improvements that are being developed have the potential to reduce negative environmental effects, and ensure that coal will continue to be used in electricity generation (Burnett 2001).

Nuclear Power

Basics: In 2003, nuclear power plants produced 20% of the electricity generated in the United States (NRC 2003a, EIA 2004a). Worldwide, the United States ranks 19^{th} in generating electricity using nuclear power (IAEA 2004a). Lithuania and France lead all other countries, with each obtaining close to 80% of their electricity from nuclear power (IAEA 2004a). Worldwide, there are 440 nuclear power plants in operation, and 25 additional plants currently under construction (IAEA 2004a).

The first commercial nuclear power plant in the United States became operational in 1957 as result of the Atomic Energy Act of 1954, which permitted private sector production of nuclear energy (EIA 2000). The number of commercial nuclear power plants increased through the 1960s, and from 1971 to 1974, 131 new nuclear units were ordered in the United States (EIA 2000). However, rising costs and public concern resulted in no new reactor orders after 1978 (EIA 2000). To counteract this, nuclear power plants increased their ability to operate at full capacity, from 63% power in 1980 to 87% power in 1998 (EIA 2000).

Today there are 104 operational nuclear power plants in the United States, and roughly 78% of those are located east of the Mississippi River (NRC 2003a, NRC 2003b). Maryland has two electricity-generating nuclear power plants, both of which are located at Calvert Cliffs in Calvert County (NRC 2003c). Calvert Cliffs Nuclear Power Plant, Inc. (CCNPPI), a subsidiary of Constellation Energy, owns and operates both of these facilities (NRC 2003c). The first of the two plants began producing electricity in 1975; the second plant began operating in 1976 (IAEA 2004a). These two facilities are capable of producing a combined 1,735 megawatts of electrical power (Constellation Energy 2004).

Retrieval and Use: The most common fuel that is used in a nuclear reactor is uranium (UCS 2003). Uranium, like all radioactive elements, gradually decays and loses its radioactivity. The time it takes for half of a radioactive substance to decay is called a half-life. The most common form of uranium, uranium-238, has a half-life of 4.5 billion years (UCS 2003). Uranium-235, which is most commonly used for energy production, has a half-life of 713 million years (UCS 2003). As uranium decays in nature, it turns into lead (UCS 2003).

The process of mining uranium is similar to coal mining, with both open pit and underground mines (UCS 2003). The amount of uranium concentrate used in the United States was two million pounds in 2003; however, this number is declining each year (EIA 2004b). In order to be used in a nuclear reactor, uranium must be transformed from an ore to solid ceramic fuel pellets and finally to rods (NEI 2004a). This processing involves several steps: mining and milling, conversion, enrichment, and fabrication (NEI 2004a).

First, uranium is mined and transported to a conventional mill where the ore is turned into uranium oxide or yellowcake and packaged (NEI 2004a). In the next step, yellowcake is shipped to a conversion plant where it is converted chemically to uranium hexafluoride (NEI 2004a). Uranium can be enriched by two different methods: gaseous diffusion and centrifuging (NEI 2004a). Gaseous diffusion, the method most commonly used in the United States, allows gaseous uranium hexafluoride to pass through a barrier that separates the isotopes of uranium by weight (NEI 2004a). The second method also separates the isotopes by weight, but in this method centrifugal force is used (NEI 2004a). In the fabrication process, the enriched uranium is converted into uranium dioxide powder and pressed into fuel pellets (NEI 2004a). At this point the fuel is ready to be used in the reactors (NEI 2004a).

Nuclear power plants generate electricity through the process of fission, which involves splitting the atoms of heavy elements such as uranium or plutonium into lighter elements. In this reaction heat is released, which in turn is converted into electricity (NRC 2003d, Hostetter 2002). Nuclear power generation produces massive amounts of energy from relatively small quantities of fuel (Hostetter 2002). Once fuel has been added to a reactor, the nuclear power plant can continue to run approximately one year without additional fuel (Hostetter 2002).

There are two types of light water reactors: boiling water reactors and pressurized water reactors (NRC 2003a). All existing commercial reactors are light water reactors (Wardell 2001). Light water reactors use water as a coolant to remove heat produced from a reactor core during nuclear fission (NRC 2003d). Water is also used as a moderator to reduce the speed of neutrons produced in nuclear fission in order to allow for a controlled sustained chain reaction (NRC 2003d).

In order for fission to occur inside a light water reactor, uranium concentrate is needed (NEI 2004a). This uranium is generally formed into cylindrical pellets, which are arranged into fourteen-foot-long metal rods (NEI 2004a). The rods are bundled together and hundreds of bundled rods are lowered into a pressure vessel, which is usually made of steel (NEI 2004a). Inside the pressure vessel, uranium atoms give off neutrons, some of which crash into other uranium atoms, splitting them, generating heat, and freeing more atom-splitting neutrons (Wardell 2001). The heat from this reaction heats water which drives a steam turbine, forcing generators to spin and produce electricity (FEPC 2004).

Continuing fission beyond this point causes the system to overheat, causing an extremely hazardous situation. Control rods, which absorb neutrons, are used to prevent overheating and control excessive fission (Hostetter 2002). The rods are consistently raised and lowered to regulate the rate of reaction (Hostetter 2002).

In typical boiling water reactors, a single loop directly delivers steam from a pressure vessel to the turbine and returns water to a reactor core to cool it (NEI 2004a). The same water loop serves as a steam source for turbines (NEI 2004a). However, in pressure water reactors, the primary water loop transmits heat through the tube walls to the surrounding water of the secondary cooling system to generate steam, and the secondary loop delivers steam to the turbines. Even though there are differences between boiling water reactors and pressure water reactors, the overall system, which produces steam to rotate turbines, is the same (FEPC 2004). In the United States, sixty-nine of the104 reactors are classified as pressure water reactors and thirty-five are boiling water reactors (EIA 2004b, IAEA 2004b).

Environmental Considerations: Nuclear energy is the world's largest source of emission-free energy (NEI 2004c). Nuclear power plants produce no controlled air pollutants, such as sulfur, particulates and greenhouse gases (NEI 2004c). However, nuclear energy is not without its environmental consequences. Problems include the process of mining uranium and the disposal of used radioactive fuel. Uranium mining produces environmental impacts similar to coal mining, with the added hazard that uranium mine tailings are radioactive (UCS 2003). Groundwater can be polluted not only from the heavy metals present in mine waste, but also from the traces of radioactive uranium that remain in the waste (UCS 2003).

Combined, all of the nuclear power plants in the United States produce about 2,000 metric tons of used fuel annually (NEI 2004b). Nuclear by-products are contained in large steel-lined pools at the nuclear plants where they are produced (UCS 2003). As these pools fill up, fuel rods are stored in large steel and concrete casks (UCS 2003). The Department of Energy has been studying storage sites for long-term burial of the waste, especially at Yucca Mountain in Nevada (UCS 2003). However, transporting the waste to Nevada poses a serious short-term hazard and storing it safely at Yucca Mountain for thousands of years is a long-term danger (UCS 2003). Reprocessing and recycling of waste is another alternative, but is not currently cost-effective in the United States, although it is practiced in other countries (NEI 2004b).

In addition to spent fuel, the reactors contain radioactive waste that must be disposed of after they are shut down (UCS 2003). Reactors can either be disassembled immediately or can be kept in storage for a number of years to give the radiation some time to diminish (UCS 2003).

Most of the reactor is considered “low level waste” and does not require high-safety storage (UCS 2003). Currently, only two sites accept low-level waste: Barnwell in South Carolina and Hanford in Washington (UCS 2003). Estimated decommissioning costs range from $133 million to $303 million per reactor, but so far no large reactors have been decommissioned (UCS 2003). A number of reactors are in storage waiting to be decommissioned at a future time (UCS 2003).

The Chernobyl disaster was the only accident in the history of commercial nuclear power where radiation-related fatalities occurred (WNA 2004). The accident destroyed the Chernobyl-4 reactor and killed thirty people, including twenty-eight from direct radiation exposure (WNA 2004). Additionally, there were 134 cases of acute radiation poisoning, but all the victims eventually recovered (WNA 2004). During the immediate impact, it is estimated that all of the xenon gas, about half of the iodine and cesium, and at least 5% of the remaining radioactive material in the Chernobyl-4 reactor core was released (WNA 2004). No one off-site suffered from acute radiation effects (WNA 2004). However, large areas of Belarus, Ukraine, and Russia were contaminated in varying degrees (WNA 2004). Most of the released material was deposited close by as dust and debris, but the lighter material was carried by wind over Ukraine, Belarus, Russia and to some extent over Scandinavia and Europe (WNA 2004).

Late in 1995, the World Health Organization linked nearly 700 cases of thyroid cancer among children and adolescents to the Chernobyl accident, and among these, some 10 deaths are attributed to radiation (WNA 2004). So far, no increase in leukemia is discernible, but this is expected to be evident in the next few years along with a greater, though not statistically recognizable, increase in the incidence of other cancers (WNA 2004). There has been no substantiated increase, attributable to Chernobyl, in congenital abnormalities, adverse pregnancy outcomes or any other radiation-induced disease in the general population either in the contaminated areas or further abroad (WNA 2004).

Policy Implications: The American public's concern about nuclear power was at its highest when the nation's most significant nuclear accident occurred at the Three Mile Island facility in March 1979 (EIA 2000). Since then, public opinion seems to have changed regarding the use of nuclear power (NEI 2003). A recent survey conducted for the Nuclear Energy Institute found that 64% of Americans favor the use of nuclear power to generate electricity, although only half of those surveyed favor construction of new nuclear power plants (NEI 2003). Despite this split in public opinion over the construction of new nuclear power plants, a consortium of nuclear plant operators and manufacturers may apply for a license to construct a new nuclear power plant at a yet undetermined location (Wald 2004). The last year in which a new commercial nuclear power plant became operational in the United States was 1996 (IAEA 2004a).

The Nuclear Regulatory Commission (NRC) is the federal agency responsible for regulating the operation of all commercial nuclear reactors in the United States (NRC 2003a). The NRC oversees the licensing process for all nuclear power plants, including the application for new licenses and the renewal, transfer, and amendment of existing licenses (NRC 2004). The NRC also oversees safety at commercial nuclear facilities through inspection, evaluation, and enforcement of operating regulations (NRC 2004).

Future Directions: Currently, manufacturers are working on new designs of nuclear plants and trying to sell them abroad, particularly to rapidly growing economies in Asia (UCS 2003). The plants have passive safety features that may be less prone to operator error, and have standardized plans to reduce costs (UCS 2003). These companies are hoping to sell their plants in the United States, although due to high capital costs few utility managers have responded (UCS 2003).

Natural Gas

Basics: The first use of natural gas was around 500 BCE in China, where it was used to distill seawater (API 2004d). Beyond its limited use in China, natural gas was not used as a fuel until the early 1800's. In 1816, Baltimore was the first city in the United States to use natural gas to light street lamps (API 2004d). Several other small cities also began to use natural gas for lighting shortly thereafter (API 2004d). The advent of electric lights made natural gas no longer necessary for lighting; however, after World War II, the use of natural gas for cooking became widespread (API 2004d).

In the United States, natural gas is used to generate 14% of the electricity used annually (DOE 2003a). This figure is expected to grow, because 87% of new electric-generating capacity is natural gas fired (API 2004c). The United States is the second largest producer of natural gas worldwide (DOE 2003a). Currently, the cost for natural gas is roughly $7 per one million British thermal units (Btu) (API 2004a). In 2002, the United States consumed 22.5 trillion cubic feet of natural gas; 83% of this was produced in the United States (API 2004b). The majority of the rest is imported from Canada (API 2004b).

Retrieval and Use: Natural gas is formed from buried plants and animals that are exposed to intense heat and pressure over thousands of years (EPA 2004). To extract natural gas, large wells are drilled deep into the earth's surface (EPA 2004). It then must be treated at gas plants to remove impurities, such as hydrogen sulfide, moisture, carbon dioxide and helium (EPA 2004). The gas is transported via transcontinental pipelines to local utilities (EPA 2004). There, the pressure is reduced and the gas is odorized so that any leaks can be identified before being piped to gas burning power plants (EPA 2004).

There are two methods in which the natural gas is converted into electricity (EPA 2004). The most common practice is to burn the natural gas in a boiler to produce steam to generate electricity (EPA 2004). A more efficient method to produce electricity involves burning gas in a combined cycle combustion turbine (EPA 2004). This process burns the natural gas in a combustion turbine and then uses the hot combustion turbine exhaust to create steam to drive a steam turbine (EPA 2004). This method achieves a much higher efficiency by using the same fuel source twice.

One percent of the United States' imported natural gas is in its liquefied form (API 2004b, DOE 2004b). Liquefied natural gas is natural gas that is cooled to -260° F, which causes the gas to condense and form a liquid. Liquid is more compact and easier to ship (DOE 2004b). There are four storage and vaporization terminals for liquid natural gas in the United States, one of which is located south of Baltimore in Calvert County (DOE 2004b).

Nationwide there are roughly 350,000 active natural gas wells (DOE 2003a). Sixty-five percent of the natural gas recovered from these wells was produced by 7,000 small independent businesses (DOE 2003a). Twenty-six percent of the natural gas produced in the United States comes from Texas and another 25% comes from offshore in the Gulf of Mexico (DOE 2003a). Natural gas is transported from its source to consumers by way of interstate pipelines (DOE 2003a). During the summer when natural gas consumption is low, gas is stored underground in natural storage facilities, most of which are located on the East Coast (DOE 2004b).

Environmental Considerations: Natural gas is increasingly being used as a source of electricity (NGSA 2004). Natural gas is efficient, has low emissions and it is competitively priced on the market (NGSA 2004). It is the cleanest of all fossil fuels (NGSA 2004). Mostly comprised of methane, the products of natural gas combustion are mostly carbon dioxide and water vapor

(NGSA 2004). The combustion of natural gas produces much less carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen oxide, and particulate matter than other popular fossil fuels such as coal and oil (NGSA 2004). Using natural gas as an alternative fossil fuel can help reduce harmful pollutants in our environment.

Environmental effects associated with the burning of fossil fuels include smog and acid rain, which are a result of a chemical reaction of carbon monoxide, nitrogen oxides, particulate matter and heat from the sun (UCS 2004). Particulate matter released by the combustion of natural gas is 90% lower than oil and 99% lower than coal (NGSA 2004a). Natural gas emits 80% less nitrogen oxides and sulfur dioxides than coal or oil (NGSA 2004). Switching to natural gas from coal or oil during the summer could reduce smog and ozone-causing emissions by as much as 50% in the northeast (NGSA 2004).

Policy Implications: The Intergovernmental Panel on Climate Change predicts that over the next one hundred years, the average temperature will rise from 2.4 to 10.4 degrees Fahrenheit due to greenhouse gases (NGSA 2004). Carbon dioxide accounted for approximately 81% of greenhouse gasses emitted in the United States in 2000 (NGSA 2004). Carbon dioxide is an important factor in global warming, and the combustion of natural gas emits 30% less carbon dioxide than oil, and about 45% less than coal (NGSA 2004).

Drilling for natural gas is overseen by the Regional Bureau of Land Management (BLM) (API 2004c). Drilling for gas is tightly regulated on federal lands by environmental laws and litigation from environmental groups, which can often slow or stop a potential mining operation (API 2004c). Finally, a moratorium on natural gas development along the east and west coasts prevents any natural gas development until 2012 (API 2004c).

Future Directions: Over the last ten years consumption of natural gas has grown at a rate of 35% (DOE 2003a). In the next twenty years the demand for natural gas is expected to grow by 50% (DOE 2003a). In fact, roughly 70% of new single homes built in 2001 utilize natural gas for heat (DOE 2003a). Use of natural gas to power vehicles is also expected to increase in the near future; currently there are approximately 100,000 vehicles in the United States powered by natural gas (DOE 2003a). By 2025, liquefied natural gas is estimated to account for nearly 17% of natural gas consumption in the United States (DOE 2004b).

Due to recent technology, natural gas wells can be drilled in previously inaccessible areas such as two miles deep in water and the arctic (DOE 2003a). There is a large amount of natural gas in the Rocky Mountains, offshore, and in Alaska, which has an estimated 18% of the untouched natural gas in the United States (API 2004a, API 2004c). In Alaska much of the natural gas remains inaccessible and transportation poses a major obstacle (API 2004c).

In the future, natural gas may be used to turn seawater into potable water by creating hydrates (lattices of ice surrounding bubbles of gas such as methane and ethane) in seawater (Wolman 2004). In theory, hydrates are produced by releasing natural gas deep in the ocean. As the water freezes impurities would be forced out into the surrounding seawater. The hydrate would then float to the surface and melt where the water, now effectively distilled, would be collected for consumption and the natural gas would be collected and reused.

Another application of natural gas in the near future would be to power fuel cells (NGSA 2004). A natural gas powered fuel cell would work much the same as the hydrogen fuel cell. The main difference being that a hydrogen fuel cell produces water as a by-product while a natural gas fuel cell produces some carbon dioxide in addition to water (NGSA 2004).

Demand for natural gas is becoming so high that it risks outpacing supply. If utilities are to keep up with demand, infrastructure will need to be improved to assure an adequate supply (DOE 2003a).

“Green” Sources of Power

Alternative fuel types, or “green” power, are an ever-increasing aspect of the energy industry market. Public attitudes in favor of green power are shifting the energy industry toward cleaner, more environmentally conscious ways of producing energy (Zahorsky 2004). Alternative fuels have become more popular as sources of energy because they have the potential to stimulate local economies, reduce greenhouse gasses, and lower dependence on foreign oil (Cotton et al. 2004). The primary sources of green power are solar, wind, and biomass. Burgeoning technologies in these areas are already contributing to local and national economies and being incorporated by utility companies.

Wind Power

Basics: Humans first became interested in harnessing the power of wind approximately 2200 years ago when the first windmill was constructed to assist in food production and the drainage of lakes for water consumption (EERE 2004a). The Danish first used wind turbines in 1890 to produce energy, and in the 1940’s the United States developed a turbine known as “Grandpa’s Knob” in Vermont during World War II (EERE 2004a). During a time when resources were scarce, this turbine supplied power to a utility network for months until resources were again plentiful (EERE 2004a). After World War II, the use of wind energy diminished and did not re-emerge until the energy crisis of the 1970’s, at which time wind farms gained a foothold in both the United States and Europe (EERE 2004a). Since then, the use of wind power has steadily increased and is now one of the fastest growing and cleanest sources of renewable energy (EERE 2004a).

Wind results from solar heating of air masses on the earth's surface. When heated air rises, cooler air moves in to take its place, creating wind. Since air has mass, its movement is a form of kinetic energy that can, in part, be converted into mechanical or electrical energy (EERE 2004b). Windmills are the mechanism for harnessing wind to do mechanical work, such as pumping water. Energy systems using wind to generate electricity are called turbines and are becoming more widely used to supply electricity to residential, commercial, and industrial sites (AWEA 2004a).

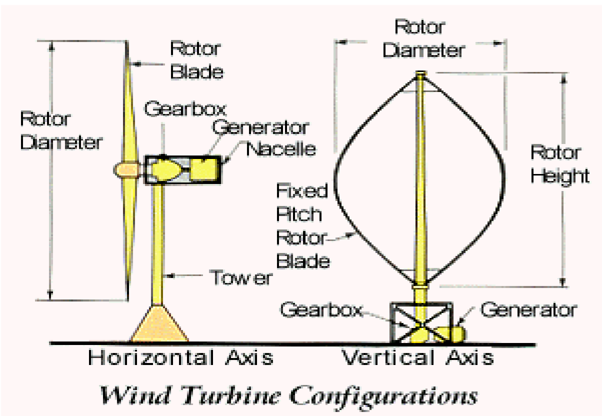


Figure 1 Horizontal-axis turbines are comprised of a rotor or blades, drive train, generator, tower, and electronic equipment (AWEA 2004a).

In today's wind energy market, most systems used by utilities are composed of horizontal-axis or propeller-style turbines, which are manufactured in a range of sizes and power capacities (EERE 2004b). Vertical-axis, or egg-beater, style turbines are less common, but share the same mechanisms for wind energy conversion (AWEA 2004a). The components include a rotor or blades which convert wind force into rotational shaft force, a drive train and generator, a tower supporting these structures, and necessary electronic equipment (Fig. 1) (AWEA 2004a). The amount of energy produced by a turbine depends on the diameter of its rotors as well as wind speed. For example, a turbine with a diameter of 71 meters has the capacity to produce nearly 124 times the power of a 10-meter diameter turbine (AWEA 2004a). Turbines used for land-based utilities and in offshore wind harvesting systems can have diameters as large as 110 meters (AWEA 2004a). Most often, turbines are not referred to by their diameter, but by their power rating, which generally ranges from 250 watts to 1.8 megawatts depending on size (AWEA 2004a).

The average American household uses 10,000 kilowatt-hours of energy per year, roughly the amount of power that can be generated annually by a 10 kilowatt (kW) turbine under average wind speed conditions of 12 miles per hour (AWEA 2004a). Under the same wind conditions, a 1.8 megawatt (MW) turbine generates enough power to support more than 500 households annually (AWEA 2004a). “Utility-scale” turbines, used for industrial output, usually have power ratings between 700 kW and 1.8 MW. A wind energy facility with 10, 1.8 MW turbines could produce up to 18 MW, or enough to theoretically power 4,300 to 5,400 households (AWEA 2004a). In reality, variant wind speeds cause fluctuations in power production, and as a result, wind energy utilities are currently paired with other energy sources to provide more consistent utility service (AWEA 2004a).

Economic Perspectives: Proponents of wind power tout this renewable energy source as positively contributing to the economy by providing jobs, generating nonpolluting fuel, and being virtually resistant to inflation because it is free and ubiquitous (AWEA 2004a). Currently, more than 2,000 people are directly employed in the wind industry, which is poised to contribute significant manufacturing jobs to the economy as production of wind energy components and utilities gain momentum (AWEA 2004a). “Wind farms” also show promise in revitalizing rural communities where turbines share land with crops and cattle and provide income from local utilities (AWEA 2004a). Creating a wind energy system on residential property can provide three important economic benefits. First, energy demand on the property is satisfied without reliance on a utility company. Second, any excess energy that is produced can be bought by utilities. Lastly, tax credits and government incentives lessen overall costs (Windustry 2004). It is not necessary to privately own turbines to benefit from wind energy. The least risky way to invest in wind energy is by leasing one's land to a wind harvesting company (Windustry 2004).

Social Perspectives: Wind power generally garners popular support, with 80% of people polled in favor of it and 5% against it (AWEA 2004a). Surveys show that social attitudes are favorable toward wind power and wind farms because this energy source is believed to be clean, safe, and ubiquitous (Simon 1996). Pollution and hazardous wastes generated from conventional energy sources lead to numerous health issues, including asthma, low birth weights, and cancer (AWEA 2004a). It is estimated that air pollution leads to the premature death of 50,000 Americans annually (AWEA 2004a). Displacing conventional fuel sources, particularly fossil fuels, with wind power could directly lead to reductions in pollution-related illnesses and emergency room visits, and thus lower health care costs (AWEA 2004a).

Public polls generally indicate the public is largely in favor of local wind farms and, with an increase in computer simulations and design awareness, wind farms should be able to satisfy any aesthetic concerns (AWEA 2004a). Early turbine designs had the stigma of being noisy, but newer technology and better placement has noticeably reduced noise issues (AWEA 2004a). Setting turbines at an appropriate distance from residences not only reduces potential noise, but also avoids unwanted "shadow flicker," or flickering of sunlight through rotating blades (AWEA 2004a). The AWEA (2004a) also notes that those concerned about wind farms decreasing tourism need not worry, and that in fact wind farms have been shown to have no effect on tourist attitudes and are even pictured on postcards.

Social issues surrounding the development of wind energy facilities, however, are far from simple. The United States Army Corps of Engineers has put forth an environmental impact statement that is supportive of Cape Wind Associate's plans to develop an extensive off-shore wind farm on the Nantucket coast (Leaning 2004). Many interested parties are in favor of alternative fuels, but are skeptical or fully opposed to this plan. Opponents, such as the Alliance to Protect Nantucket Sound, are concerned about aesthetic impacts and the degree to which bird life would be affected (Leaning 2004).

Environmental Perspectives: Wind energy is widely accepted as a “green” source of power because it produces no hazardous by-products and does not deplete natural resources. Today’s conventional power plants are known to emit detrimental quantities of particulate matter into the environment (CATF 2004). In comparison, the manufacturing of wind energy components contributes an insignificant amount of pollutants to the air (AWEA 2004a). At current rates, generating 20% of the national energy budget with wind would be equivalent to displacing all the radioactive waste from nuclear power or a third of the emissions from coal power plants in the United States (AWEA 2004a).

The two primary environmental impacts of wind power are erosion and wildlife deaths (AWEA 2004a). Erosion of soils due to installing turbines can be a significant problem in desert habitats and along ridgelines (AWEA 2004a). Erosion control methods for these types of natural areas have become standardized and used by other developments, such as ski resorts (AWEA 2004a). Reports of bats and birds being killed by turbine blades have caused alarm among those concerned about wildlife and species decline (AWEA 2004a). Occurrences of large numbers of such deaths are often considered site-specific, and avian deaths by turbines are not likely to exceed 1% of human-related avian mortality (AWEA 2004a). A Danish study showed that suspended power lines actually cause more avian deaths than turbines (DWIA 2003). The wind energy industry is working to address this issue and avoiding placement of wind farms in areas frequented by endangered bird and bat species (AWEA 2004a). In 2003 at a wind plant in West Virginia, an inordinately large number of bats were killed, which has lead to further investigations of impacts on bat populations (AWEA 2004a). Additional concerns include habitat fragmentation due to access roads and utility line right-of-ways (AWEA 2004a).

Wind turbines of various sizes can be constructed where there is ample wind supply and open land, and often these areas can be simultaneously used for agriculture and ranching (AWEA 1999). To generate one MW of energy with turbines, sixty acres of open, relatively flat land is needed, but only 5% of this land is needed for development of turbines; therefore, 95% of the land is potentially free for compatible uses (AWEA 2004a).

Current Perspectives: Currently, the United States has 8,000 megawatts of wind energy in place (DOE 2004c). Recently, wind energy use has shown some decline due to deregulation of the energy industry; however, wind energy can still have an important place within the national energy industry (DOE 2004c). The relative cost of wind power at a typical productive wind site has decreased from approximately $0.35 per kWh in 1980 to approximately $0.05 per kWh currently, and is projected to drop to an even lower rate (Fig. 2) (DOE 2004c). The DOE ranks each state according to its average wind speed and amount of available land that can be developed for harvesting wind energy (EERE 2004b). In Maryland, 0.02% of the land has potential for wind energy development. If this amount of land were used for wind power, Maryland could generate approximately 700,000-megawatt hours, an amount equal to 2% of the total electric consumption of the state (EERE 2004c). The Savage Mountain Wind Energy Project in Garrett and Allegany Counties is

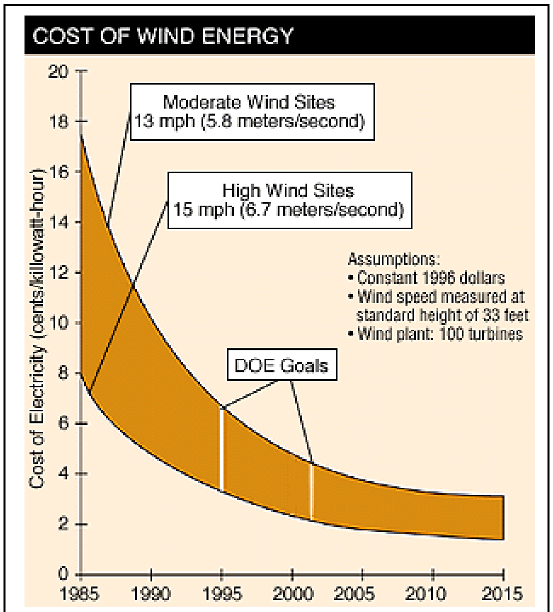


Figure 2 This graph illustrates the current and projected costs of development and use of wind energy technology (DOE 2004).

one of two prospective wind power initiatives being considered in the state (AWEA 2004b). This and other efforts to increase the use of wind power in the region will likely benefit from progressive policies set forth by the United States DOE.

Future Perspectives: In 2003, the United States DOE set forth a six-year wind energy plan which aimed to promote renewable energy development and viability primarily through bettering technologies, reducing costs, and increasing the attractiveness of green power in the energy marketplace (DOE 2003b). For example, in 2010 the DOE plans to aid sixteen states in the installation of at least 100 MW of wind turbines, and in 2012, the DOE plans to establish guidelines that would prime wind energy for competition in the national energy market (DOE 2003b). The DOE has established a goal of 100 gigawatts (GW) of wind energy to be used in the United States by the year 2020 (DOE 2003b). Implementation of the DOE's plan could displace approximately three quadrillion Btus per year of primary energy, which in turn could displace an annual 65 million metric tons of carbon emissions (DOE 2003b).

New technologies for wind power are on the horizon. Improvements to turbine efficiency and output will allow for low speed winds to generate the same amount of power as current turbines harvest from high-speed winds (DOE 2003b). This technology would allow more states with lower average wind speeds to adopt wind energy systems. The DOE's plan also focuses on distributed wind technology, which would allow smaller wind turbines to be constructed in areas where there is not enough land to construct a large scale wind farm (DOE 2003). The rising costs of other types of energy compounded with the environmental and human health costs of non-renewable energy types make the development of energy sources such as wind imperative in the near future.

Solar Energy

Basics: Solar energy is a renewable energy source that uses sunlight to produce electricity. Energy from the sun provides the equivalent of 10,000 times the current global energy demand while creating little to no air pollutants (CAT undated). In 1999, renewable energy sources accounted for only 13% of the global energy demand, with solar energy only accounting for a small fraction of that percentage (Solarbuzz 2004). Currently, even after rapid growth of solar energy use, it only accounts for less then 1% of global primary energy demand (Solarbuzz 2004).

In 1839 a French scientist discovered the possibility of solar power when he noticed that light increased the current of a simple battery (CAT undated). Thirty-four years later, it was discovered that selenium was light sensitive and had the ability to conduct electricity (CAT undated). These two discoveries sparked the research that led to the first selenium-based solar cell (CAT undated). However, solar energy did not get much recognition until the 1950s when Bell Laboratories developed the silicon-based solar cell, which had low efficiency and was expensive to produce (CAT undated). In 1991, a more efficient system was developed by Ron Swenson who built and introduced his solar car at the Denver Grand Prix (Ecotopia 2004).

Solar-thermal and photovoltaic (PV) technologies are the two basic ways to convert solar energy to electricity (EPA 2004). Solar-thermal technologies concentrate the sun's rays with reflective or absorbent devices to heat a liquid, creating vapor that is then used to turn a generator and create electricity (EPA 2004). PV systems consist of semi-conducting cells that release energy when struck by sunlight (EPA 2004). The leading commercial semi-conductive material is crystalline silicon, which is based on silicon, the predominant semi-conductor material used in electronics and computer industries (Azom 2004). The atomic properties of semi-conductors allow for the release of an electron into a current flow, or "conduction band" (Quinn 1997). Electron release occurs when the sunlight strikes the silicon PV cell with 1.1

electron volts. The electrons are then able to enter into the conduction band and become part of an electrical current to power electrical appliances (Quinn 1997).

Environmental Perspectives: The use of solar energy itself has minimal environmental impacts, yet issues have arisen regarding manufacturing, installation and disposal processes. For example, PV cells can be made with arsenic, cadmium and silicon, and should be considered hazardous materials and be treated accordingly (UCS 2004). However, with proper handling, solar energy use has few environmental impacts (UCS 2004). Assuming proper techniques are employed producing electricity with PV cells emits no pollution, produces no greenhouse gases and uses no finite fossil fuel resources (Azom 2004).

Some risks arise during manufacturing, disposal or recycling of PV components. The most significant health risks are confined to those who directly interact with the components in manufacturing plants and disposal areas (EPRI 2003). Inhalation of dust particles containing various heavy metals and toxins could cause lung disease and other respiratory illnesses (Azom 2004). Several risks associated with the chemicals used in PV cell production include: ingestion of gases and other toxins during manufacturing spills, the unlikely occurrence of an explosion during installation, and the leaching of trace metals from modules (EPRI 2003). The nature of the heavily sealed cells prevents significant amounts of toxins from reaching the environment (EPRI 2003). Biomonitoring of personal protective equipment with gas detection systems reduces exposure to toxins (NCPV 2004).

Current Perspectives: Regardless of its obstacles and disadvantages, solar technology has become a more efficient and accessible energy source (SolarQuest 2004, ElectroRoof 2004). PV panels are becoming less expensive, and are increasingly used in conjunction with or in place of conventional building materials. Roofing materials, for example, can now be replaced by PV panels, which allow buildings to generate their own electricity (EERE 2004d). In the developing world, PV technology is already commercially viable because it can compete with the higher installation costs of other technologies (CAT undated).

Future Perspectives: Several solar techniques are showing considerable promise. One of these techniques uses dye-sensitized solar cells to generate a voltage which is more efficient and cost effective than other materials (EERE 2004d). However, problems with creating seals and transfer modules have restricted the evolution of this type of cell and future research is required (ACS 2003). Organic compounds, such as polymers and perylenes, have shown great potential, but inorganic cells are commercially more cost efficient (Salomon 2001). Polymers have lower fabrication costs than traditional cells, less toxic manufacturing techniques and offer the possibility of lightweight and flexible panels (Salomon 2001). Like polymers, perylenes can be used as semi-conducting molecules, and can be derived from common automobile paint pigments, making them inexpensive to produce and easy to contain and use (Salomon 2001).

Another burgeoning PV technology is the photoelectron chemical cell, which produces hydrogen from water in the presence of sunlight (EERE 2004d). Like the polymer system, its design limits efficiency; the amount of usable hydrogen produced is relatively low (NEMO 2002). Research and development of hybrid cells are ongoing, but currently lack the technology to be efficient and cost effective (NEMO 2002).

Bioenergy/Biomass

Basics: With the discovery of fire, humans were able to harness and manipulate heat. Today, the concept of using organic matter to produce energy is termed bioenergy. Bioenergy refers to the energy stored within organic matter such as wood, paper, corn stalks, algae, and even manure (Carless 1993). These organic waste products are collectively called biomass. Today, the use of bioenergy goes beyond simply using combustion to produce heat. Not only can biomass be used to produce electricity, but it can also be used to produce liquid or solid fuels and chemicals (Carless 1993, DOE 2004d).

Biomass crops are usually harvested, dried, and then shipped to their destination where they are converted into energy (Borowitz 1999). Various technologies are used to convert biomass into energy, including combustion, thermochemical conversion, and biochemical conversion (Carless 1993). The primary by-product of many of these technologies can be either gas, liquid, or solid fuel (Carless 1993). Of these technologies, the one that is most commonly used to produce electricity is combustion (ORNL undated).

Any type of biomass is suitable for combustion, as long as it contains less than 60% moisture (Carless 1993). Currently, in the United States, power plants that use direct combustion have a capacity of up to ten GW (DOE 2004f). Co-firing is another form of biomass combustion that involves the burning of biomass along with fossil fuels in power plants (DOE 2000, DOE 2004f). Co-firing reduces dependency on fossil fuels and harmful emissions of nitrogen oxides and sulfur dioxides (DOE 2000). The burning of biomass with coal is one of the least expensive renewable energy options (DOE 2004f).

A more contemporary technology that can be used to produce electricity is termed gasification, a type of thermochemical conversion (Carless 1993, ORNL undated). This method involves a partial combustion of biomass in a low oxygen environment in order to produce a mixture of gasses, which can then be used as fuel for driving a gas turbine (Carless 1993, DOE 2004f). Gasification has several advantages over combustion of biomass. First, gasification can take advantage of a wider range of fuels (ORNL undated). Instead of using wood and wood residues, the most common fuel for biomass combustion in the United States, gasification can use other organic by-products, such as rice hulls (ORNL undated). Second, the heat produced by gasification can then be used to turn a secondary turbine, thus harvesting larger proportions of energy (ORNL undated). Third, the gas produced in this process can power a fuel cell or be burned in combination with natural gas (ORNL undated). Finally, gasification may be able to help improve efficiency and cost competitiveness at smaller scale plants (ORNL undated).

Economic Perspectives: There are many angles from which the costs and benefits of bioenergy can be examined. For instance, manufacturing companies could reduce disposal costs by converting some of their waste products (wood chips, e.g.) to energy, which could then be used on site (Carless 1993). Conventional power facilities could increase market-based competitiveness and reduce costs by incorporating biomass into their fuel mixture (DOE 2004h). Since alternative fuel is a growing market and encouraged by government incentives, plants that reduce their emissions using biomass could sell emissions credits (DOE 2004h).

Costs could increase if power plants are required to ship biomass fuel from its source to the plant (Carless 1993). In California, for example, it is not cost effective to transport wood residues further than 100 miles (Carless 1993). Bulkiness and rapid decomposition pose problems for storing biomass (Carless 1993). It would be necessary to find ways to slow the decomposition process so that biomass resources could be adequately stored (Borowitz 1999). The consumer cost of the electricity produced by biomass depends on many factors, such as type of biomass used, transport of components, and method of energy extraction. Estimates range from $0.03 to $0.07 per kWh (Carless 1993, ORNL undated).

Bio-power plants can be built more quickly and less expensively than larger fossil fuel plants, which is advantageous for several reasons (Carless 1993). For one, conventional power plants are no longer considered suitable for meeting the United States' energy demands (DOE 2004g). In rural communities, small biopower facilities can employ local residents, use local crops, and produce clean energy (DOE 2004g). Building biomass plants could result in a reduced need for fossil fuels, which in turn could mean greater energy independence for countries which do not have fossil fuel reserves (Carless 1993). In addition, a reduction in pollution and greenhouse gas emissions could benefit public health and the environment (DOE 2004i).

There is no one type of biomass that is most appropriate for energy production. Depending on the climate and amount of land available, different types of biomass are going to be available on the local level. For example, Brazil relies heavily on alcohol made from sugar cane to produce fuel for transportation (Borowitz 1999). In the United States, it would be more practical to consider corn stalks as a source of biomass. However, additional steps are needed to convert corn to ethanol due to the physiological structure of the crop (Borowitz 1999).

Environmental Perspectives*:* There are many environmental benefits associated with bioenergy. Unlike fossil fuels, bioenergy is carbon dioxide-neutral (Carless 1993). The carbon that is lost to combustion during the conversion of biomass to energy was recently removed from the atmosphere and converted into organic matter through photosynthesis, resulting in a zero net input of carbon dioxide into the atmosphere (Carless 1993). In addition, when burned, biomass releases fewer toxic chemicals than do fossil fuels (Borowitz 1999). Lower emissions of carbon dioxide and toxins promote better air quality. Since the materials for bioenergy are usually waste materials, this form of energy also benefits the environment by reducing landfill volume (Carless 1993). The burning of manure could also reduce the environmental and economic problems associated with waste disposal at large animal facilities (ORNL undated). Additionally, biomass crops require less fertilization and one-tenth of the herbicides and pesticides of agricultural crops (ORNL undated). Biomass crops also have the potential to act as stream buffers, and thus could be used to prevent erosion and absorb excess nutrients often associated with traditional agricultural practices (ORNL undated).

Although there are many benefits associated with bioenergy, there is also cause for concern. It is possible that farmers will not plant and harvest biomass in a sustainable way, thus depleting land and forest resources (Carless 1993). Some are concerned that old growth forests and fragile wetland ecosystems will be vulnerable to biomass harvesting (Carless 1993).

***Current Perspectives*:** Worldwide, the use of biomass for energy varies greatly. In countries such as Denmark and Sweden, biomass accounts for as much as 10% of energy production (Borowitz 1999). In many developing countries, the proportion is much higher; for instance, India produces 56% of its energy using biomass (Borowitz 1999). Before coal and oil became readily available in the United States, biomass was the primary source of energy (Carless 1993). Today, however, biomass accounts for only 4% of energy production in the United States (Borowitz 1999).

Between 2000 and 2003, biomass was the leading source of alternative energy in the United States (DOE 2004e). The most commonly used biomass fuels are agricultural and forestry by-products, particularly from paper mills (DOE 2004e). Other materials can be used as well, such as herbaceous and woody plant crops, aquatic crops, municipal wastes, and animal wastes (DOE 2004e). The United States Department of Energy (DOE) is responsible for the development of technologies that will allow biomass to become a more readily used resource (DOE 2004i). The DOE Biomass Program focuses not only on the production of electricity, but also on the use of biomass to create fuels and chemicals (DOE 2004i). Their goals are to increase the presence of biorefineries and to reduce dependence on foreign oil (DOE 2004i).

Future Perspectives: Bioenergy has great potential. In the United States, production of bioenergy is based on direct combustion (DOE 2004f). New analytical and evaluation techniques, as well as increased genetic manipulation of crops is allowing for better fuels to be grown on poorer land (DOE 2004d). This has the potential to decrease costs and to improve environmental quality (DOE 2004d). The ideal bioenergy crop would be photosynthetically and water efficient, able to grow with little or no fertilizer, and disease and pest resistant (Borowitz 1999). Bioenergy holds great promise for producing clean, economical, renewable energy. Although biomass is a renewable resource, the degree to which it is sustainable will depend on the methods implemented by farmers (Carless 1993).

II STATE OF THE CAMPUS

The Energy Usage Survey

Introduction:

In order to reduce Towson University's energy consumption, it is important to know the general habits and behaviors of the college community. Therefore, an electrical conservation survey was designed that would obtain information about student, faculty, and staff behaviors and attitudes. The Institutional Review Board for the Protection of Human Participants at Towson University approved the survey for use on the Towson campus.

In addition to demographic data, such as age, status on campus (faculty, staff, part-time student, etc.) and current housing situation, the participants were asked to rate, using a qualitative ranking scale (i.e. usually, often, sometimes, rarely, never), their behavior on and off campus. Some of the statements respondents were asked to react to were: (6) I stop and turn the lights out in a classroom when I observe that the room is not being used; (7) I am bothered when I see lights left on that are not being used; and (15) I am or have been responsible for paying some or all of my electrical bill. In addition, there were several open-ended questions. The survey instrument is presented in Appendix I. After an initial field test, the survey was administered in October 2004.

The survey:

- Assessed individual interest and activities regarding electrical conservation among members of the Towson community.
- Assessed individual beliefs about other people's interest and activities regarding electrical conservation.
- Probed community ideas about methods to conserve electrical energy on campus.

Materials and Methods

An attempt was made to survey all members of the community in proportion to their distribution on the Towson campus. The composition of the University is 84% students, 6% faculty, and 10% staff (TU 2000). Convenience sampling was used. Members of the class went to places on campus where they were likely to meet different members of the community. Sampling sites included the library, student union, and campus pathways as well as faculty and staff offices. Surveyors requested that individuals complete the questionnaire. A total of 490 surveys were completed and analyzed (71% students, 12% faculty, 14% staff and 3% unknown status).

Responses were numerically coded and the data was entered into Statistical Program for the Social Sciences (SPSS). A cross tabulation analysis was used to examine relationships between status (i.e., faculty, student, etc.) of the respondents and their responses. The responses of each status group were then compared. A mean test was also run to find the average answer per age group or campus housing status. Associations were found between different age groups or campus housing status regarding beliefs and behaviors on electrical usage at Towson. The open-ended answers were reviewed for trends in responses and similar answers were grouped together for analysis. The grouping system for open ended questions was as follows:

Question 16 – ***Are there places on campus that are too dark or too well lit? Where***?

1) No answer
2) Don't know
3) Lighting fine
4) Pathways/Outside too dark
5) Classrooms too well lit
6) Garages too dark
7) Dorm hallways too well lit
8) Other
9) Offices too dark
10) Other hallways too dark

Question 17– *How could the campus reduce its use of electricity?*

1) No answer
2) Don't know
3) Signs/Awareness/Education
4) Timers/Sensors/Technology
5) Turn off lights/ computers
6) Decrease lighting
7) Regulating heat/AC
8) Other

Question 18 – *What do you think might make other people more willing to conserve electricity on campus?*

1) No answer
2) Don't know
3) Signs/ Awareness/ Education
4) Raise tuition
5) Lower tuition
6) Increase Fees
7) Pay own bills
8) Other

Question 19 – *Why might someone not turn off lights, computers or appliances?*

1) No answer
2) Don't know
3) Lazy/ Too busy/ Don't care
4) Safety/ Security
5) Not aware/Don't think/ Habit
6) Don't pay bill
7) Told not to
8) Other
9) Other people about to use it
10) Wear & Tear

Question 20 – *What is your best guess (in dollars) of how much the University pays per year in electrical bills?*

1) No answer
2) Up to $100,000
3) 100,001-500,000
4) 501,000-1,000,000
5) 1,000,001 plus

Results

Data are reported as a percentage of respondents. Results from the survey suggest that Towson community members are relatively indifferent to energy usage on campus. Over 62% "never" or "rarely" turn off lights in classrooms when no one is using them (Fig. 3), while just 22% stated they do so "often," or "always." In addition, approximately 54% "never" or "rarely," shut down campus computers when done using them (Fig.4), while just over 20% answered they did so "often" or "always."

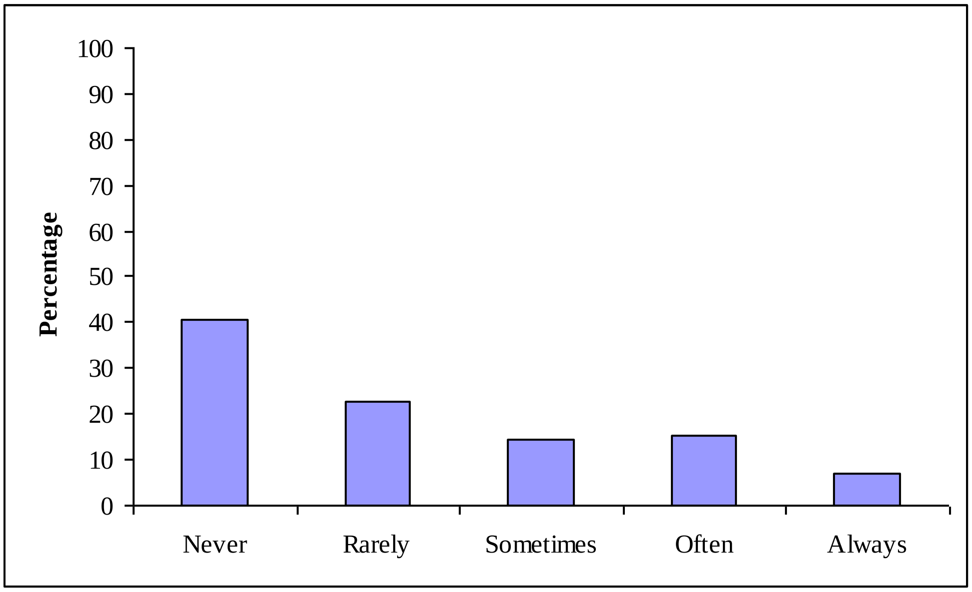


Figure 3 The responses of survey participants to statement 6 -"I stop and turn the lights out in a classroom when I observe that the room is not being used" are presented above.

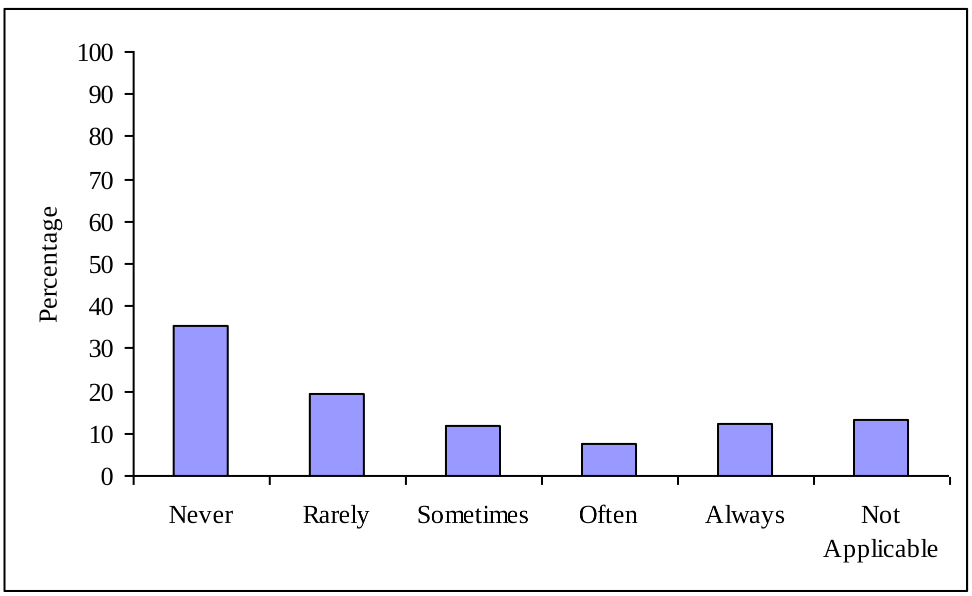


Figure 4 The responses of survey participants to statement 10 – "When I am done using a computer in a computer lab or in the library, I shut it down" are presented above.

Interestingly, respondents do care about energy usage in their own homes. Over 88% of respondents answered that they "always" or "often" turn off lights when they are not at use at home (Fig. 5) and over 55% answered that they "always" or "often" turn off their home personal computers when they are finished using them (Fig. 6).

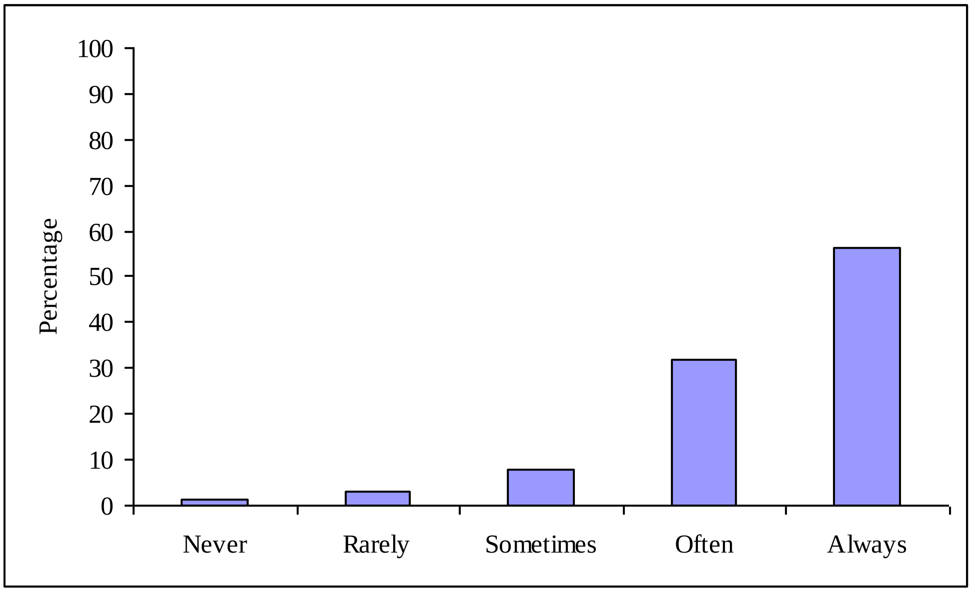


Figure 5 The responses of survey participants to statement 12 – "At home, I turn off lights when they are not being used" are presented above.

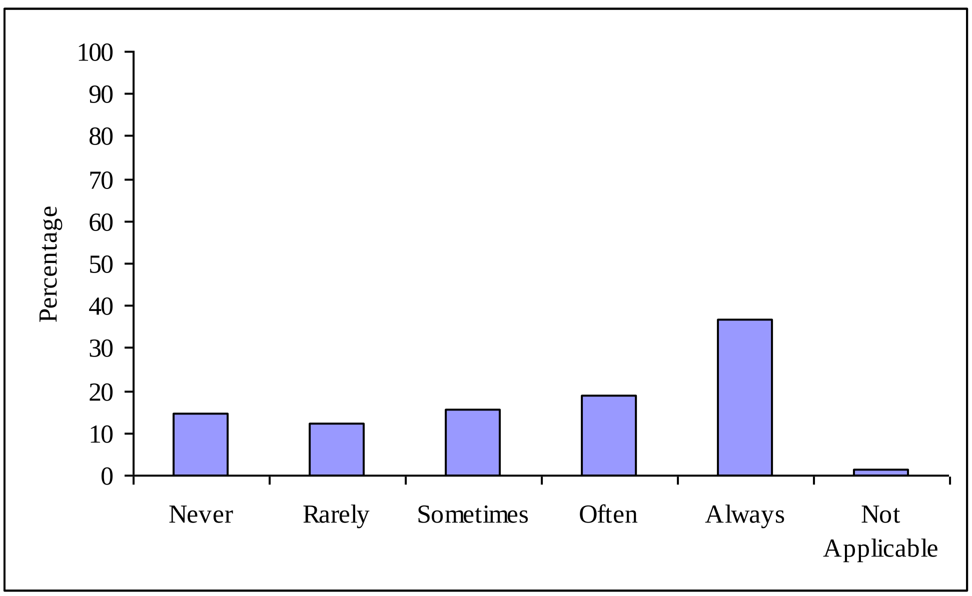


Figure 6 The responses of survey participants to statement 11 –"When I am done using my personal computer at home, I shut it down" are presented above.

The above answers suggest that while respondents make an effort to use less energy in their homes, they are indifferent to energy usage on campus. Responses concerning household electricity consumption imply there may be a need for educational programs on campus. Over

51% of the respondents “agree” or “strongly agree” that signs requesting that switches be turned off are effective (Fig. 7). Moreover, over 60% of the respondents answered that they “often” or “always” turn off switches in response to such signs (Fig. 8), suggesting that signs may be an effective way to encourage the community to turn off lights or shut down computers.

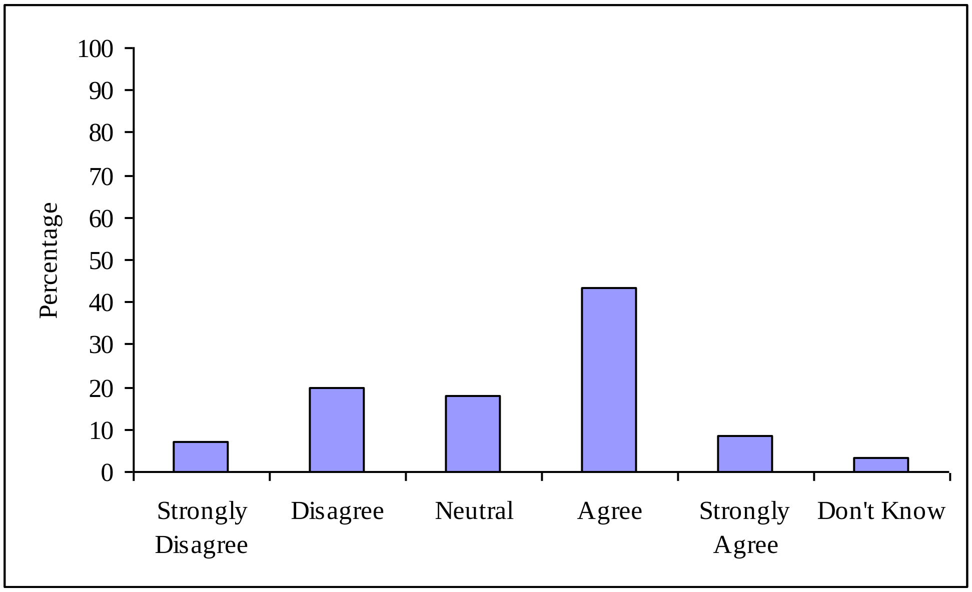


Figure 7 The responses of survey participants to statement 5 – “Signs by switches reminding people to ‘turn [something] off’ are effective” are presented above.

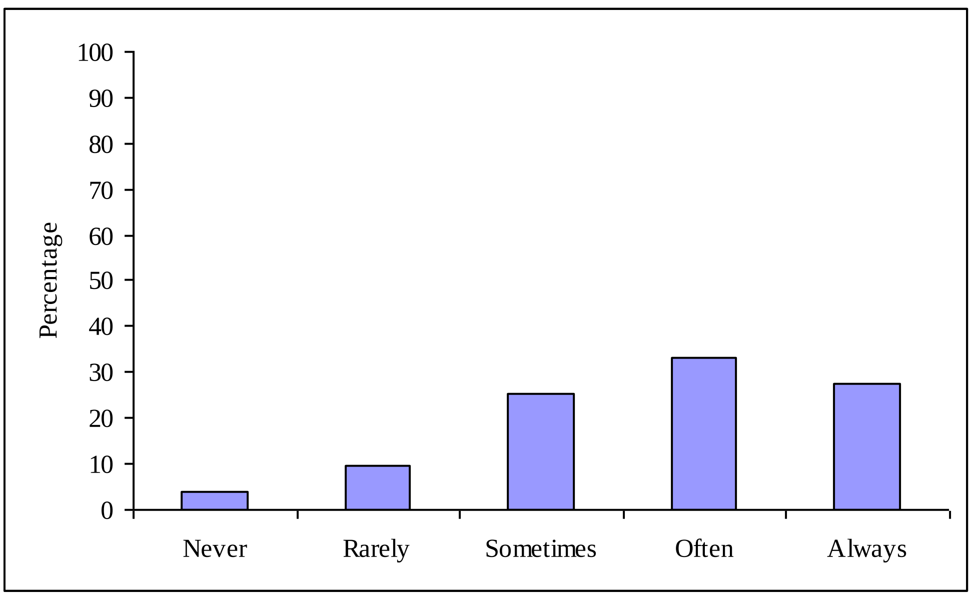


Figure 8 The responses of survey participants to statement 8 – “When I see signs by switches saying to “turn [something] off,” I do so” are presented above.

The data suggests that education and increasing awareness about the role of energy usage on campus would be an effective means of influencing energy conservation behavior on campus. Over 44% of the respondents did not know whether or not the cost of electricity had declined over the past five years (Fig. 9), reflecting a general lack of knowledge about energy cost, efficiency, and usage.

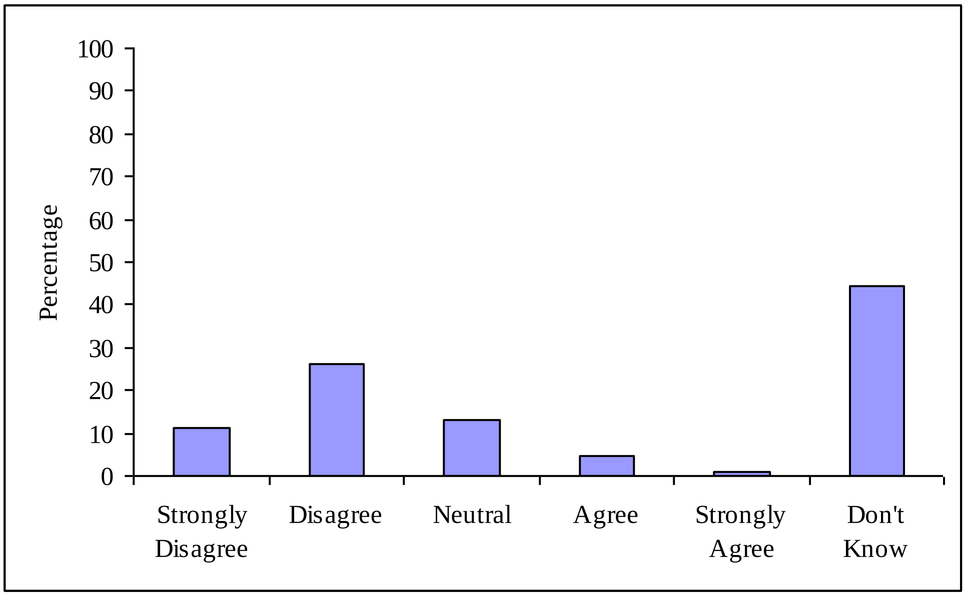


Figure 9 The responses of survey participants to statement 4 – "The cost of electricity (taking inflation into account) has gone down over the last 5 years" are presented above.

A large portion of those surveyed stated that the level of lighting on campus is fine (Table 1). Still a quarter of the faculty and students answered that campus pathways are too dark and a quarter of the students answered that classrooms are too well lit. This clearly suggests areas where lighting levels can be lowered and where they need to be improved.

Table 1. The responses of survey participants to question 16- "Are there places on campus that are too dark or too well lit? Where?" are presented below.

	Unidentified	Staff	Faculty	Students
No Answer	10.0%	11.8%	15.8%	25.9%
Don't Know	10.0%	19.1%	24.6%	23.9%
Lighting is Fine	10.0%	7.4%	3.5%	23.9%
Pathways are too dark	20.0%	7.4%	7.0%	3.4%
Classrooms are too bright	0%	0%	3.5%	2.3%
Garages are too dark	0%	4.4%	1.8%	0.6%
Dorm hallways are too bright	0%	1.5%	3.5%	1.1%

Every group surveyed felt that implementing education or awareness programs would be the best way to promote energy conservation (Table 2). The majority of respondents in each group also said the campus could employ new electrical technologies as well as turn off lights and computers when they are not in use to reduce campus consumption of electricity (Table 3).

Table 2. The responses of survey participants to question 18- "What do you think would make other people more willing to conserve electricity on campus?" are presented below.

	Unidentified	Staff	Faculty	Students
No Answer	40.0%	44.1%	45.6%	33.0%
Don't Know	0%	0%	3.5%	8.0%
Signs/ Awareness Programs/ Education	0%	2.9%	7.0%	10.2%
Tuition Increases	0%	7.4%	5.3%	4.5%
Tuition Decreases	0%	5.9%	7.0%	5.7%
Allotment Fees	10.0%	4.4%	5.3%	6.0%
Individual Usage Bills	0%	7.4%	8.8%	13.1%

Table 3. The responses of survey participants to question 17- "How could the campus reduce its use of electricity?" are presented below.

	Unidentified	Staff	Faculty	Student
No Answer	30.0%	26.5%	12.3%	13.9%
Don't Know	10.0%	4.4%	8.8%	11.9%
Signs/Awareness/Programs/ Education	10,0%	10.3%	1.8%	10.8%
New Technology	No answer	14.7%	35.1%	18.2%
Turning off lights and computers	10.0%	30.9%	15.8%	31.5%
Decrease Lighting Used	10.0%	1.5%	3.5%	6.0%
Increased Regulation of Heat/AC	10.0%	5.9%	10.5%	2.3%
Other	20%	4.4%	12.3%	5.4%

When asked why they think someone might not turn off lights, computers or other appliances, most of the respondents stated that people are too lazy or too busy (Table 4). Other respondents suggested that people do not turn off computers because they know others will be using them or because the Office of Technology Services (OTS) requires they be left on for computer updates, suggesting that there may be widespread confusion about whether on-campus computers should be left on or off.

Table 4. The responses of survey participants to question 19- "Why might someone not turn off lights, computers or appliances?" are presented below.

	Unidentified	Staff	Student	Faculty
No Answer	30.0%	26.5%	36.8%	45.5%
Don't Know	0%	5.9%	7.0%	9.0%
Lazy or Too Busy	20.0%	17.6%	12.3%	16.8%
Safety or Security	10.0%	5.9%	5.3%	2.8%
Not Aware/ Don't Think/ Habit	10.0%	5.9%	14.0%	4.0%
Not Responsible for Bill	0%	2.9%	1.8%	5.7%
Instructed Not To Turn Off	10.0%	5.9%	10.5%	13.6%
Other	0%	4.4%	3.5%	1.4%

Those responsible for electric bills also tended to be bothered when they see lights on in an unused room (Table 5). In addition, those who say they try to reduce electrical consumption responded that they do not usually see their peers do the same (Table 6). (Raw data and additional results can be found in Appendix II.)

Table 5. The responses of survey participants to statement 15- "I am or have been responsible for paying some or all of my electrical bill" compared to statement 7- "I am bothered when I see lights left on that are not being used" are presented below.

	Statement 7 Responses	Never	Rarely	Sometimes	Often	Always
Statement 15 Responses						
Never		5.6%	9.2%	10.7%	6.1%	2.1%
Rarely		1.0%	1.9%	2.1%	2.7%	0.6%
Sometimes		0.6%	1.9%	3.6%	1.3%	1.3%
Often		0.6%	2.3%	4.6%	1.7%	1.5%
Always		2.5%	4.4%	12.3%	10.7%	8.8%

Table 6. The responses of survey participants to statement 14- "I take actions to reduce electrical use" compared to statement 13- "I see my peers taking action to reduce electrical use" are presented below.

	Statement 14 Responses	Never	Rarely	Sometimes	Often	Always
Statement 13 Responses						
Never		2.5%	1.9%	4.2%	2.7%	1.7%
Rarely		0%	8.0%	17.0%	13.8%	3.6%
Sometimes		0%	1.7%	13.2%	15.7%	4.0%
Often		0%	0%	1.9%	3.4%	1.9%
Always		0%	0.2%	0.4%	0.8%	1.5%

Conclusions and Suggestions

The survey results suggest it is important to educate people and increase awareness among members of the Towson University community about the amount of energy usage on campus, its impact on their environment and its impact on their daily lives. The survey established that the members of the Towson community may not be aware of the amount of money spent on electricity and therefore are less likely to be involved in actions to reduce electric consumption. The survey suggests that signs or incentives that encourage people to take an action to turn off the lights and computers would be effective in reducing energy usage on campus.

The survey results should be considered when deciding upon methods of reducing electrical waste. Technology is only one part of the solution. For technology to be effective, community members must feel they have a stake in the process and be actively involved in making changes. A model protocol that combines education and technology could help Towson University successfully reduce campus electrical consumption.

Campus Audit of Electrical Usage

Introduction

Towson University's forty-five buildings are situated on a 328-acre campus, and are used by more than 21,000 people (Sellers 2004, TU 2000). The university spends millions of dollars each year to provide electrical power to the buildings on campus for necessities such as lighting, power, heating, and cooling. The university spent $3.7 million for approximately 61.9 million kWh of electricity in fiscal year 2004, and electrical use on campus is expected to increase by 3% for fiscal year 2005 with an anticipated increase in costs of about 25% (McKee 2004).

In an effort to determine the amount of electrical energy wasted on campus, an audit was conducted to quantify waste associated with lighting and computers. The following sections detail the equipment, procedures, and results associated with this audit.

Materials and Methods

Light Usage: The main goal of the light usage portion of the audit was to determine how much electricity was being wasted due to lights being left on in areas that were unoccupied. The sensors used for this audit were IT-200 InteliTimer® Pro Loggers, manufactured and provided by Watt Stopper, Inc., of Santa Clara, CA. Each sensor contained a light and motion detector, and recorded the lighting and occupancy status within the monitored area. Each data record collected by the sensor was placed in one of four possible lighting and occupancy usage categories, as shown in Table 7.

Table 7. The lighting/occupancy usage categories are presented below.

Category	Description
On + Occupied	Lights on; area occupied
On + Vacant	Lights on; area vacant
Off + Occupied	Lights off; area occupied
Off + Vacant	Lights off; area vacant

Only six sensors were available for this study, so a limited number of locations on campus could be sampled. After examining all buildings on campus, four buildings representing different usage categories were selected for the light usage audit: Glen Tower B (residential), Cook Library (general use), Enrollment Services (administrative), and Smith Hall (academic).

Since the audit had to be completed within one semester, it was determined that light usage in each of the selected buildings would be monitored for a period of one week. Therefore, with six available sensors, up to six locations in each building could be monitored during the sampling period. Sampling locations in each of the buildings were chosen based on factors such as how accessible the location was and how representative it was of other rooms in the building. Additionally, rooms or areas that were often lit when unoccupied were chosen. The sampling locations, their room/area classifications, and sampling periods are shown in Table 8.

Table 8. Shown are sampling locations, area classifications, and sampling periods for light/occupancy sensors.

Sampling Location	Area Classification	Sampling Period
Glen Tower B: Room 1009	Dormitory room	9/28/04 - 10/05/04
*Glen Tower B:*10th floor study area	Study area	9/28/04 - 10/05/04
*Glen Tower B:*5th floor study area	Study area	9/28/04 - 10/05/04
Glen Tower B: Basement laundry area	Laundry area	9/28/04 - 10/05/04
Glen Tower B: Bathroom (public)	Bathroom	9/28/04 - 10/05/04
Cook Library: 4th floor stacks	Stacks	10/05/04 - 10/12/04
Cook Library: 5th floor staff lounge	Lounge	10/05/04 - 10/12/04
Cook Library: Room 525	Lounge	10/05/04 - 10/12/04
Cook Library: Room 312	Office	11/16/04 - 11/23/04
Cook Library: 2nd floor bathroom	Bathroom	10/05/04 - 10/12/04
Cook Library: Room 35	Computer lab	10/05/04 - 10/12/04
Enrollment Services: Room 336	Customer service area	10/12/04 - 10/19/04
Enrollment Services: Room 107	Classroom	10/12/04 - 10/19/04
Enrollment Services: Room 202	Office	10/12/04 - 10/19/04
Enrollment Services: Room 304	Bathroom	10/12/04 - 10/19/04
Enrollment Services: Room 108	Computer lab	10/12/04 - 10/19/04
Smith Hall: Room 279	Classroom	10/19/04 - 10/26/04
Smith Hall: 3rd floor bathroom	Bathroom	10/19/04 - 10/26/04
Smith Hall: Room 317	Lab	10/19/04 - 10/26/04
Smith Hall: Room 348	Office	10/19/04 - 10/26/04
Smith Hall: Room 359	Lecture hall	10/19/04 - 10/26/04
Smith Hall: 3rd floor hallway	Hallway	10/19/04 - 10/26/04

The sensors were mounted on the ceiling as close as possible to the lights being monitored. If the room chosen had windows, care was taken to ensure that the sensor was only registering artificial light and not sunlight. If it was not possible to prevent sunlight from affecting the sensor, the light detector's sensitivity could be adjusted so that it would only register artificial light. To ensure the accuracy of the occupancy status of the monitored area, the sensors were placed so that the motion sensor was pointed towards the part of the room that was most likely to be in use. Care was also taken to position the sensors away from doors so that motion or light from the hallway would not be picked up.

After each sampling period, the information collected by the sensors was downloaded to a computer via a serial connection using ITProSoft version 2.10 software (The Watt Stopper, Inc., Santa Clara, CA). The data were then used to analyze lighting per occupancy for each sensor location.

In order to accurately estimate power used in sampled buildings based on the six rooms sampled, students counted the number of light fixtures and bulbs in as many rooms as possible in each of the buildings included in the audit. Room number, room use classification, number of fixtures, number of lights per fixture, type of bulb, and general comments were recorded. In the event that the type of bulb could not be identified, it was assumed that the bulb was the lowest wattage available for the particular fixture in order to give the most conservative estimate of power usage.

Computer Usage: The main goal of the computer usage portion of the audit was to determine how much electricity is wasted due to computers and monitors being left on when not in use. According to the University's Property Records Department, 414 desktop computers are located in Smith Hall. Two hundred and eighty-five of these computers are used by faculty. The remainder are located in the building's computer labs and teaching labs.

A survey was conducted to determine how computers and monitors are managed by faculty during off-peak hours. Specifically, faculty in Smith Hall were asked if they turned off equipment at the end of the day. In addition, a visual inspection of computer usage in the building's computer labs was conducted. Power consumption of a typical desktop computer and monitor was measured using a PL-100 Plug Load Analyzer (manufactured and provided by Watt Stopper, Inc.).

Results

Light Usage: The classification, size, and 2003 actual electrical consumption for Glen Tower B, Cook Library, Enrollment Services, and Smith Hall based on university electric bills are shown in Table 9 (McKee 2004).

Table 9. The classification, square footage, and 2003 electrical consumption for the selected buildings are presented below.

Building	Classification	Square Footage	2003 Electrical Consumption (kWh)
Glen Tower B	Residential	100,622	2,304,900
Cook Library	Multi-Purpose	180,356	3,169,790
Enrollment Services	Administrative	63,750	1,839,400
Smith Hall	Academic	220,254	4,301,700

Each sensor analysis included a summary of lighting per occupancy usage category that identified the number of hours in each of the four usage categories for the sampling period (Table 7). Since the goal of this audit was to estimate the amount of electrical energy wasted on campus due to lights being left on when areas are unoccupied, the only item of interest in the reports was the information on the *On + Vacant* usage category. Table 10 contains this information for each of the sampled locations.

Table 10. The percentage of sampling period for the *On + Vacant* usage category for each sampling location is presented below.

Sampling Location	*On + Vacant* (% of sampling period)
Glen Tower B:	
Room 1009	12.7
10th floor study area	24.1
5th floor study area	64.5
Basement laundry area	48.0
Bathroom (public)	19.7
Cook Library:	
4th floor stacks	50.0
5th floor staff lounge	0.1
Room 525	4.0
Room 312	13.9
2nd floor bathroom	64.8
Room 35	30.8
Enrollment Services:	
Room 336	76.6
Room 107	1.8
Room 202	3.3
Room 304	32.9
Room 108	4.7
Smith Hall:	
Room 279	1.9
3rd floor bathroom	54.6
Room 317	7.6
Room 348	11.2
Room 359	12.5
3rd floor hallway	21.3

The number of light fixtures and bulbs in each building were organized by room purpose (Appendices III-VI). The approximate power consumption was then calculated for each of the monitored areas/rooms when the lights were in use, based on the number and type of fixture. It should be noted that the power consumption attributed to the ballast of each light fixture was not included in these calculations.

Light usage patterns where sensors were deployed were considered typical for all rooms of that type within each building. For example, light usage patterns in all bathrooms in Smith

Hall were assumed to be the same as in the sampled bathroom. If a particular room classification was not sampled, that room type was not included in the analysis. The estimate of the amount of energy wasted per year is summarized in Table 11.

Table 11. Presented below is the estimated energy wasted per year due to lights being on while areas are unoccupied, where wasted energy per year equals the number of hours *On + Vacant* per year multiplied by the power consumption of lights in all rooms/ areas of that classification. *On + Vacant* hours are calculated by multiplying the percentage *On + Vacant* during the sampling period by the approximate number of hours in a year (8,760). The percentage of waste attributed to each room type in each building is also included in parenthesis.

Room/Area Classification	*On + Vacant*(% of sampling period)	*On + Vacant* (hours per year)	Power Consumption (W)	Wasted Energy Per Year (kWh) (%)
Glen Tower B:				
Dormitory rooms	12.7	1,113	13,184	14,667 (36.7)
Study areas	44.3	3,881	5,376	20,863 (52.2)
Laundry area	48.0	4,205	1,024	4,306 (10.8)
Bathrooms (public)	19.7	1,726	64	110 (0.3)
Subtotal:				39,946 (100.0)
Cook Library:				
Stacks	50.0	4,380	135,968	595,540 (89.0)
Lounges	2.1	184	1,408	259 (0.0)
Offices	13.9	1,218	28,544	34,756 (5.2)
Bathrooms	64.8	5,676	2,208	12,534 (1.9)
Computer labs	30.8	2,698	9,696	26,161 (3.9)
Subtotal:				669,249 (100.0)
Enrollment Services:				
Customer service areas	76.6	6,710	3,200	21,473 (57.4)
Classrooms	1.8	158	5,376	848 (2.3)
Offices	3.3	289	35,264	10,194 (27.2)
Bathrooms	32.9	2,882	1,152	3,320 (8.9)
Computer labs	4.7	412	3,840	1,581 (4.2)
Subtotal:				37,415 (100.0)
Smith Hall:				
Classrooms	1.9	166	13,312	2,216 (1.1)
Bathrooms	54.6	4,783	4,536	21,696 (10.4)
Labs	7.6	666	103,168	68,685 (33.0)
Offices	11.2	981	47,360	46,466 (22.3)
Lecture halls	12.5	1,095	15,488	16,959 (8.2)
Hallways	21.3	1,866	27,840	51,946 (25.0)
Subtotal:				207,968 (100.0)
Total				954,579

Computer Usage: Approximately 60 faculty responded to the e-mail survey. Faculty survey responses indicated that 53.3 % of the computers and 61.7 % of the monitors were left on overnight. These data appear to be consistent with the campus-wide survey, which found that 55% of the students and faculty surveyed never or rarely shut down computers when they are finished. Assuming that all faculty in Smith Hall practice similar off-peak computer management to those responding to the survey, it is estimated that of the 285 faculty computer systems, 152 computers and 109 monitors are left on when not in use. A visual inspection of computer labs in Smith Hall showed that 96.9% (125) of the computers and 99.2% (128) of the monitors were left on when not in use.

The power consumption of a typical computer and monitor were measured at forty-eight watts (W) and seventy-one W, respectively. The estimated amount of electrical energy wasted (Table 12) was determined by using these values, assuming that 66.9% (277) of the computers and 73.4% (304) of the monitors in Smith Hall are left on when not in use.

Table 12. Presented below is the estimated energy wasted per year due to computers and monitors being left on while not in use in Smith Hall, where wasted energy per year equals the number of system components left on while not in use multiplied by the number of hours per year the system components are not in use (6,680 hours) multiplied by the power consumption of the system component. Not in use hours are based on 2,080 hours of use during an 8,760-hour year.

System Component	Percentage On While Not In Use	Power Consumption (W)	Wasted Energy Per Year (kWh)
Computer	66.9 (277)	48	88,817
Monitor	73.4 (304)	71	144,181
Total			232,998

Conclusion

A total estimate of 954,579 kWh of electricity is wasted each year by not turning off lights in the four buildings studied. Based on a price of $0.07 per kWh, this waste is estimated to cost the school more than $66,800 per year.

A total estimate of 232,998 kWh of electricity is wasted each year by not turning off computers and monitors in Smith Hall. Based on a price of $0.07 per kWh, this waste is estimated to cost the school more than $16,300 per year.

Two factors must be kept in mind when interpreting the data collected during this audit. First, the audit included only four buildings for the light usage audit (less than 10% of the buildings on campus) and only one building for the computer usage audit. Electrical waste seen in these buildings may or may not be typical of waste in other campus buildings. Second, this audit only considered light and computer usage. While it is not within the scope of this study, there may be a number of other sources of electrical waste on campus, such as heating, cooling, and the use of personal appliances. However, these data do seem to suggest that Towson University could save considerably by establishing a protocol for turning off lights and computers.

IDEAS FOR THE FUTURE

<u>Computer Power Management</u>

University computers and monitors use more electricity than all other forms of office equipment combined (Energy Star 2004c). Instead of paying utility bills for computers that are kept on all day and night, it makes sense that schools and universities should only have to pay for the time they are in use (Energy Star 2004c).

Monitors

During periods of inactivity, computer monitors can go into a low-power sleep mode (Ryan undated). This does not interfere with downloading or network connections and performance is not sacrificed (Ryan undated). When a user touches the keyboard or mouse, the monitor is quickly "awakened," returning the computer to full power and capacity (Ryan undated). This low-power sleep mode is standard on all new computers sold today (Energy Star 2004a).

Making sure this feature is employed across a large institution poses a challenge. There have been programs developed to implement power management across networks, including one distributed through the EPA called EZ Save (Energy Star 2004b). EZ Save is a free download which polls each monitor on a network to determine its power management settings, generate a report of that information, and then set up power management on those monitors (Energy Star 2004b). The program does not require special hardware or network processes (Energy Star 2004b). There is no need for client installation since users can retain their screen saver settings, and the program even includes a savings calculator (Energy Star 2004b).

Personal Computers: Verdiem

Another solution for enabling power management across an institution is offered by EPA Energy Star business partner, Verdiem, which has developed the Surveyor Network Energy Manager (Surveyor). Surveyor is an easy-to-use software utility that reduces energy waste and reduces operating costs without impacting PC users (Verdiem 2004a). Surveyor measures, manages, and minimizes the energy consumed by a network's PCs through one centralized interface (Verdiem 2004a). It provides Information Technology departments with a powerful way to automate energy-efficient "best practices" throughout their networks, while it adds new control and flexibility to traditional PC power management (Verdiem 2004a). Universities that are currently using Surveyor include City University of New York, Linfield College, and Mt. Hood Community College (Verdiem 2004b).

The main benefit of Surveyor is the ability to customize the program to meet an institution's specifications (Verdiem 2004a). Features of Surveyor that are not included in EZ Save are ongoing compliance by performing daily checks, custom profiles for each computer with the ability to group these profiles together, collection of data for energy analysis, and unlimited technical support (Verdiem 2004a). As is evident by the results of the energy survey conducted here, an unclear PC shutdown policy at Towson has left faculty and students confused whether to leave on or turn off computers around campus. With Surveyor, scheduled shutdowns can be performed but can also be aborted or overwritten if certain applications are running (Verdiem 2004a).

The list price for Surveyor is based on the number of PCs at the institution. For each computer there is an initial fee of $20 and as well as a fee of $2 for every year of maintenance and technical support (Wise 2004). This investment is returned by energy savings within twelve to eighteen months (Verdiem 2004a). Verdiem also offers a performance guarantee that provides a full refund of license and maintenance fees if Surveyor has not achieved a minimum energy savings of 120 kWh per PC per year (Wise 2004).

Verdiem: A Viable Option for Towson?

An audit of computers and monitors was conducted to find out if implementing power management would make a significant difference in cutting Towson University's kWh consumed per year (Table 13).

Table 13. There are 414 computers in use in Smith Hall, a science building which houses classrooms, offices and research laboratories. The kWh used and potential savings from installing a power management system are presented below.

Current computers and monitors situation	Amount of kWh used for computers and monitors
Per unit kWh consumption	1042
Total consumption all units	431,388
Estimated power wasted based on data collected.	232,998
Potential savings with power management	198,390

Fees for installing Surveyor on PCs in Smith Hall would be $9,108 for the first year but will amortize in about 7.9 months at $0.07 per kWh (Table 14). (Calculations can be found in Appendix VII).

Table 14. Presented below are current usage figures and potential savings at two different billing rates with power management enabled on computers and monitors in Smith Hall.

	Cost of Electricity at $0.07 per kWh	Cost of Electricity at $0.10 per kWh
Per unit before power management (PM)	$72.94	$104.20
414 units in Smith Hall before PM	$30,197.16	$43,138.80
Potential savings with PM	$13,887.30	$19,839.00
Startup & maintenance cost of Verdiem	$8280 + $828	$8280 + $828
Savings after year one	$4,779.30	$10,731.00
Savings after year two	$13,059.30	$19,011.00

When implementing power management, some behavioral changes may be required of the computer user. Updates or patches could take up to five minutes after a PC has been turned on (Wolfson 2004). This delay is just enough time to grab another cup of coffee or take books out of a backpack. Regardless, Verdiem's Surveyor is a valid option that could offer energy savings at Towson University and should be given serious consideration.

Flat Screen Monitors

Another way to reduce energy costs would be to phase-out the older cathode ray tube (CRT) monitors that are in use at Towson. Flat screen or liquid crystal display (LCD) monitors use only one-third of the power required for a CRT with the same screen area (Arsenal PC 2004). Data from the PL-100 Plug Load Analyzer showed that LCD monitors use about twenty-six W compared to seventy-one W used by CRT monitors. This converts into a savings of forty-five W, or $28 per year for each monitor at $0.07 per kWh. (Calculations are found in Appendix VIII.)

The environmental benefits of LCD monitors include more energy efficient manufacturing as well as reduced disposal problems because they contain fewer hazardous and solid waste materials than CRT monitors (PNNL 2003). The flat screen monitors save desk space, have better resolution, have neither glare nor flickering, and do not have the electromagnetic fields of CRT monitors (PNNL 2003).

The most expensive part of an LCD monitor is the backlight, which is composed of one or more tiny fluorescent tubes (Arsenal PC 2004). LCD backlights typically have 50,000 hours until brightness is one-half of the original brightness, which is the industry standard measure for product life (Arsenal PC 2004). In contrast, CRT backlights usually have between 10,000 and 20,000 hours until they reach one-half of their original brightness (Arsenal PC 2004). Consequently, CRT monitors last about five years while LCD monitors last up to thirteen years (PNNL 2003).

Depending on the size and number of features that come with it, a typical LCD monitor could cost anywhere from $200 to $1,500 (Dell PC 2004). LCD monitors that Towson might purchase would probably have an average cost of about $300 (Dell PC 2004). The cost of a CRT monitor averages about $140 (Dell PC 2004). This $160 difference in price would be returned to Towson through energy savings after six years. The life of the LCD monitor would also last for about another six years after this point. Assuming energy costs stay constant, the flat screen monitor will almost pay for itself with the energy it has saved over its lifespan.

LCD monitors would initially work best in offices around campus. The screens tend to scratch very easily; hence a screen protector would need to be applied to the monitor in order to introduce them into student computer labs. Computer hardware upgrades such as advanced video and accelerator cards for better resolution might also need to be taken into consideration.

Occupancy Sensors

Occupancy sensors control lighting by detecting the occupancy status of an area (Lightsearch.com 2000). There are two types of occupancy sensors: infrared and ultrasonic (Lightsearch.com 2000). Infrared sensors detect infrared radiation emitted by humans, while ultrasonic sensors detect changes in reflected ultrasonic waves (Lightsearch.com 2000). Based upon the analysis of the light usage audit (Appendices III-VI), rooms found to be lit while unoccupied for over 20% of the time may be prime candidates for occupancy sensors (Table 15).

Table 15. Presented below are rooms/areas which were lit and unoccupied for more than 20% of the time while monitored during the light usage audit.

Building	Room/Area Classifications
Glen Tower B	Study areas, laundry area
Cook Library	Stacks, bathrooms, computer labs
Enrollment Services	Customer service areas, bathrooms
Smith Hall	Bathrooms, hallways

Although a wide variety of occupancy sensors are available, only information for models manufactured by Watt Stopper, Inc. (Santa Clara, CA) were used. From the available product literature, models that were most suited for each of the applications were selected (Table 16).

Table 16. Presented below are proposed occupancy sensor models, price per unit, number of units required, and total cost of sensor installation. Occupancy sensors are from Watt Stopper, Inc, Santa Clara, CA. The price per unit includes the sensor cost, power pack, miscellaneous electrical supplies, and two hours of installation labor (Bohlayer 2004).

Room/Area Classification	Proposed Occupancy Sensor Model	Price per Unit(Installed)	Number of Units Required	Total Cost of Sensor Installation
Tower B:				
Study Areas	W500A	$194.65	14	$2,725.10
Laundry Area	W500A	$194.65	1	$194.65
Cook Library:				
Stacks	W1000A	$207.25	80	$16,580.00
Bathrooms	W500A	$194.65	14	$2,725.10
Computer Labs	CX-100	$201.00	3	$603.00
Enrollment Services:				
Customer Service Areas	W1000A	$207.25	4	$829.00
Bathrooms	W500A	$194.65	9	$1,751.85
Smith Hall:				
Bathrooms	W500A	$194.65	12	$2,335.80
Hallways	CX-100	$201.00	25	$5,025.00

Assuming sensors would eliminate situations where rooms are lit and unoccupied, energy savings would be equal to the amount of energy wasted without the use of sensors (Table 17).

Table 17. Presented below is the cost-benefit analysis for the installation of occupancy sensors in selected locations. Projected yearly cost savings are based on a rate of $0.07 per kWh. *Years required to recoup installation cost* is calculated by dividing the *sensor installation cost* by the *projected yearly cost savings*.

Room/Area Classification	Projected Yearly Energy Savings (kWh)	Projected Yearly Cost Savings	Sensor Installation Cost	Years Required to Recoup Installation Cost
Tower B: Study Areas	20,863	$1,460	$2,725	1.9
Tower B: Laundry Area	4,306	$301	$195	0.6
Cook Library: Stacks	595,540	$41,688	$16,580	0.4
Cook Library: Bathroom	12,534	$877	$2,725	3.1
Cook Library: Computer Labs	26,161	$1,831	$603	0.3
Enrollment Services: Customer Service Areas	21,473	$1,503	$829	0.6
Enrollment Services: Bathrooms	3,320	$232	$1,752	7.5
Smith Hall: Bathrooms	21,696	$1,519	$2,336	1.5
Smith Hall: Hallways	51,946	$3,636	$5,025	1.4

Reduced Energy Lighting Technologies

Easylite

One means of saving energy is with a computer controlled fluorescent light dimming system manufactured by Easylite. The Easylite system reduces the cost of lighting from storage to office and educational purposes and is capable of reducing energy consumption and increasing system control. Similar technologies do not allow dimming of fluorescent lights; they simply turn the lights on or off (Fisher 2004). Turning fluorescent lights on and off on an irregular basis affects the longevity of bulbs (Fisher 2004). Dimming fluorescent light bulbs could possibly extend the life of the bulb (Fisher 2004).

The Easylite system is controlled from one main computer that can handle up to 64,000 fluorescent light fixtures, or 265 individual dimming ballasts (Fisher 2004). Instead of "de-lamping," which does not reduce electricity costs, Easylite simply lowers the light output (Fisher 2004). Easylite dims output to a lower level, causing the light to draw less power and wattage (Fisher 2004). There are nine components of the system (Fisher 2004):

- Building Demand Meter – Maintains the scheduled building demand levels
- Easy Talk Lighting Control Software – A Windows-based computer system used to control schedules and light intensity
- Address-a-Lite – The Digital Addressable Interface Unit
- Dimming Ballast – Controls the power of the fluorescent tubes, allowing them to be dimmed or to reduce the power flowing into the tubes
- Link-Easy – An interface module that provides flexibility to incorporate control strategies
- Daylight Harvester – An indirect ceiling mounted sensor which detects the level of ambient light in the room and adjusts the light output to the desired level

- Wall Mounted Dimmer/Occupancy Sensor – Allows the user to have more control over the system
- Power Link – A twenty-Amp line voltage relay used to control non–Easylite fixtures
- DC Analog Control Loop – Ballast powered and utilizes "plug and play technology" with low voltage cable

Based on the information gathered from the campus audit, the potential for reduced electricity consumption from this type of technology is possible. If the light output is reduced to 50% then power consumption is decreased by 50% (Fisher 2004). One major benefit of the Easylite system is that it does not use any major line voltage to any components. Therefore, all power is provided from the ballast itself (Fisher 2004). This, in conjunction with the plug and play technology, makes the system safer and easier to install (Fisher 2004).

The cost of deploying the Easylite System in new buildings ranges from $0.65 to $1.25 per square foot, which varies depending on what additional components are installed (Fisher 2004). Retrofitting a building is slightly higher ($0.75 to $1.75). The Easylite system is also compatible with existing lighting components, possibly reducing costs further (Fisher 2004).

LED Lighting Technologies

Light emitting diode (LED) technology has been used for indicator lights on electronics since the 1960s (Lumileds undated). LEDs have an extended life of ten to twenty years, and are ecologically safe (Lumileds undated). Recently, however, LEDs have begun to be used for everyday lighting applications (Lumileds undated). LED replacements for incandescent bulbs are now available on the market and cost about $20 each (Super-Bright LED bulb 2003). These bulbs have a regular screw-in base, and consist of a cluster of LED bulbs (Super-Bright LED bulb 2003). This light draws approximately 2.3 W and provides a brightness of 11,000 Lux (Super-Bright LED bulb 2003).

There are also LED ceiling drop lights designed to replace in-ceiling fluorescent fixtures (TheLEDlight.com undated). These drop lights are capable of producing a light output of 130 W while drawing 360mA/hr and retail for $840.00 per unit (TheLEDlight.com undated). In addition to these, there are a wide variety of replacement LED bulbs styles (TheLEDlight.com undated). LEDs bulbs can last up to twenty-five years depending upon the quality of the bulb (Resculite.com 2004). While this form of lighting is quite expensive, they draw only one-third to one-tenth of the power drawn from conventional lighting sources (TheLEDlight.com undated, Super-Bright LED bulb 2003).

LED lights are well suited for applications in exit signs. Despite the fact that they are low wattage, exit signs consume a large amount of electricity simply because they are on twenty-four hours a day. LED exit signs last 100% longer than incandescent exit signs (EPA 2001). In the late 1990s, Towson replaced many exit signs in many of the academic buildings with LED exit signs (see Table 18) (Bohlayer 2004). Exit signs were counted in Hawkins Hall, Psychology, Towson Center, Stephens Annex, Van Bokkelen Hall, University Union, Cook Library, Media Center, Stephens Hall, Smith Hall, Linthicum Hall, 7800 York Road, and the Administration Building during the fall 2004 semester. These buildings contain 411 exit signs, and of these 264 of them use LED technology. The remaining 147 exit signs use incandescent light bulbs. Replacing the remaining exit signs with LED exit signs will result in additional savings for Towson University.

Table 18. Presented below is a count of exit signs in selected Towson academic buildings.

BUILDING	LED	NON-LED	TOTAL
Hawkins Hall	32	0	32
Psychology	25	0	25
Towson Center	7	43	50
Stephens Annex	0	13	13
Van Bokkelen Hall	0	20	20
University Union	0	35	35
Cook Library	43	0	43
Media Center	10	1	11
Stephens Hall	1	18	19
Smith Hall	82	1	83
Linthicum Hall	0	16	16

LED retrofit kits are available for as little as $10.95 (4exits.com 2003). These kits include two bulbs and come with adapters that fit any size light bulb base to easily replace any incandescent bulbs (4exits.com 2003). These LED retrofit kits usually consume between 1.5 and 2.0 watts per bulb (4exits.com 2003, Resculite.com 2004). A regular incandescent bulb uses anywhere between 3.0 and 13.0 watts per bulb (4exits.com 2003, Resculite.com 2004). Retrofitting existing exit signs with LED bulbs would save about $24 per sign per year (EPA 2001). At a cost of $10.95 per retrofit kit, the LED's would pay for themselves within the first year.

Educational Suggestions

Based on survey data, it appears the Towson University community will be receptive to educational programs that encourage energy conservation. Educating students, faculty and staff about energy conservation is beneficial for two reasons. First, it will encourage conservation on the Towson campus. Second, it will encourage conservation in the larger community if the conservation measures taught at Towson are applied to life outside of school. In both cases there exists the possibility of not only monetary savings but also environmental benefits. According to the survey data, students are more likely to have poor energy conservation habits then faculty and staff, and because of this the bulk of educational programs should be directed towards students.

One method to incorporate conservation education at Towson is to place an annual article in the Towerlight, the campus newspaper. A brief article could outline sources of locally available electricity and the environmental damage and health risks associated with these sources. It could also emphasize the rising cost of electricity and offer simple ways to save through energy efficient light bulbs and wise computer use. The article could also describe what Towson has done so far to conserve energy and how much energy and money the university has saved as a result of these efforts.

It became apparent, through the survey data, that some community members are uncertain when they should shut off computers and lights. Towson University can save energy by sending a clear message regarding when it is appropriate to shut off the lights or computers in a room. This message could be sent out through the Daily Digest or the Towerlight. In addition, readable signs could be posted outside of classrooms or near light switches instructing people to turn off the lights or computers.

Another possibility to educate the campus is to distribute manuals or informational brochures on campus. This brochure would be brief and contain energy saving information and suggestions that are applicable both on and off campus. For instance, the brochure could offer information about energy efficient products such as lights, mini-fridges, and computers. This brochure could address common energy myths and misconceptions.

The university could also take a more active role by setting up booths or giving out information at events such as TigerFest and freshman orientation. If students are introduced to campus life with conservation in mind, they will have more opportunity to apply that information over the course of their school career. Distributing information at annual events such as

TigerFest will reinforce the energy conservation message. At these events it may be possible to catch students' attention by handing out bumper stickers and other paraphernalia with catchy phrases on them such as "Lights Out for a Brighter Future!"

Another way to reinforce the conservation message would be to air informative but entertaining commercials or programs on Towson's television and radio station. For instance, a program might involve students answering energy related trivia, and awarding a prize to the winner. It might even be possible to get students involved in conservation through activities such as dorm-based contests, in which the dorm that conserves the most electricity is awarded a prize. Students might even be engaged by periodic energy saving seminars.

Lastly, Towson University could work closely with the campus club, Students for Environmental Awareness, to support activities on campus that encourage energy conservation. Members could be encouraged to introduce innovated conservation measures, or could hold an annual contest for the most effective conservation idea (SEA 2004).

Energy Conservation Efforts by Other Universities

Conservation is not only good for the environment; it also has the potential to save large sums of money. This is especially significant for large institutions such as universities, whose electricity costs include the powering of many academic, administrative, and residential buildings. In its efforts to conserve electricity Towson University is a part of the ranks of conservation minded universities across the country.

Many universities have saved money and funded energy saving projects by negotiating with energy providers. In 1994, an energy audit was conducted for the University of Washington campus, which resulted in an agreement with the school's primary electricity provider to implement energy conservation measures (The University of Washington 2003). The agreement ensured financial incentives for saving energy in construction design and systems, and promised energy conservation methods in existing buildings (The University of Washington 2003). As a result, the school has saved about 47.7 million kWh per year and $1.7 million in electricity costs (The University of Washington 2003).

At Northern Illinois University cost-saving tools called "performance contracts" have been developed (Northern Illinois University 2004). These allow the university to pay for energy-saving improvements using the resulting savings (Northern Illinois University 2004). These contracts to install more efficient lighting in some buildings could save up to $2.8 million per year (Northern Illinois University 2004). In addition, Northern Illinois University has taken advantage of the recently deregulated market for electricity (Northern Illinois University 2004). Negotiating their own contracts and remaining flexible allows them to make the most of local rates, riders, and supply grids (Northern Illinois University 2004). The university receives a cash incentive in exchange for agreeing to make emergency reductions in power consumption during peak demand times (Northern Illinois University 2004).

Other universities, such as the University of New Brunswick in Canada have taken steps to conserve energy by modifying lighting schemes (University of New Brunswick 2000). This university replaced discolored lenses and installed new reflectors, which made light fixtures more efficient and allowed the university to decrease the number of lamps necessary to achieve an adequate light level (University of New Brunswick 2000).

The State University of New York at Buffalo (SUNY-Buffalo) has had an energy conservation program since the late 1970s (SUNY undated a). This program results in annual savings of approximately $9 million, and includes conservation projects, campus energy policies, a campus awareness program, and green building designs (SUNY undated a). SUNY-Buffalo's guidelines for efficient lighting recommend using white paint to maximize light reflection, using task lighting (such as small table top lights) when overhead florescent lights are excessive, adjusting window blinds to maximize the use of sunlight, and turning off lights whenever they're not needed (SUNY undated b). SUNY-Buffalo found that as many as 50% of corridor lights could be removed while still maintaining adequate light levels (SUNY 1996).

The University of Washington has promoted and developed ways to conserve electricity for close to a decade (The University of Washington 2003). In January 2001, the University of Washington created the Conservation Project Development Team at Facilities Services to implement several energy and water reduction measures (Roseth 2002). The energy audit reported that thirty-eight campus buildings had lights that were not in effective use, and de-activated them (The University of Washington 2003). This resulted in an energy consumption reduction of 4,290,445 kWh per year, which translates to $214,500 in savings (The University of Washington 2003). Other implementations and programs include the cutting back lighting by 25% during operation of Husky Stadium, adjusting library lighting shutdown hours, and publishing and distribution of "Guidelines to Follow" for the University of Washington Medical Center staff and faculty (The University of Washington 2003).

Many other universities have taken steps to conserve energy by more efficiently managing computer equipment. Universities such as Pennsylvania State University and Tulane University have tackled this issue by joining the Million Monitor Drive (Energy Star 2004b). The Million Monitor Drive is an Energy Star campaign to activate monitor power management on at least one million computer monitors (Energy Star 2004b). Joining requires pledging to activate power management on all monitors, organization-wide (Energy Star 2004b).

SUNY-Buffalo also began a Green Computing Campaign, which published a Green Computing Guide (SUNY 1996). The guide contains many energy saving suggestions, dispels myths associated with computer use, and gives recommendations on making computer-related purchases (SUNY 1996). This guide was freely distributed around the campus (SUNY 1996).

Tulane University participates in a dorm room project promoted by Energy Star (Energy Star 2004d). The purpose of the Energy Star dorm room is to demonstrate how much money can be saved by using Energy Star products, and to educate others about purchasing those products (Energy Star 2004d). Tulane students who participate win the use of two compact fluorescent desk lamps, one compact fluorescent halogen lamp, one flat screen monitor, one computer tower, one all-in-one flat screen monitor/computer combo, two alarm clocks, one stereo system, and several compact fluorescent light bulbs for one year (Tulane 2004). In exchange, Tulane students are expected to open their room to tours, be available for publicity pictures, and implement at least one energy efficiency idea on campus (Tulane 2004).

Tulane students calculated that using Energy Star lighting and equipment would save about $130 for one dorm room over the course of the school year (Energy Star 2004d). The savings that would occur if every one of Tulane's 1,708 dorm rooms used Energy Star products would be over $200,000 (Energy Star 2004d). Setting up and promoting a similar dorm room could encourage the use of Energy Star products on the Towson University campus.

At the University of Vermont, refrigerators are the largest energy-using appliances in residence halls (The University of Vermont 2004). In response, the university is selling energy efficient mini-fridges to students (The University of Vermont 2004). In addition, vending machines that do not contain perishable food items are now equipped with motion sensors that cause them to power down after fifteen minutes of inactivity (The University of Vermont 2004). In extended periods of inactivity, the machines will power back up to keep items cool (The University of Vermont 2004). Vending machines are huge consumers of electricity (Tufts

University undated). A typical beverage vending machine uses 3500 kWh per year, compared to a residential refrigerator, which uses 450-800 kWh per year (Tufts University undated).

The University of Washington is using this type of technology as well, called vending misers (The University of Washington 2003). Each of the 200 campus cold-drink machines has been retrofitted with these devices (Roseth 2002). These devices allows the machine to "go to sleep" when the area around the machine is unoccupied (Roseth 2002). After fifteen minutes if the motion sensor does not sense anyone, the vending miser will shut the machine off and powers back up when someone walks by (Tufts University undated). Vending misers do not influence the internal thermostat or the compressor (Tufts University undated). Initial tests show that energy savings could be up to 50%. (Roseth 2002).

It is possible to use energy conservation as an educational tool. In January 2001, Pennsylvania State University installed a solar rooftop system on the roof of the Main Building of Penn State Delaware County (PSU 2001). This system will not only produce energy, but will be monitored through the Internet (PSU 2001). This information can be incorporated into relevant courses and will allow students to examine relationships between energy, the sun, and the environment (PSU 2001).

Technologies of the Future

Hybrid Lighting Technologies

In the future, hybrid lighting may be of interest to Towson University. Hybrid lighting is a system in which sunlight is piped into a building via fiber optic cables and is used as a source of light along with fluorescent lighting. Currently the Oak Ridge National Laboratory is developing hybrid lighting (Minkel 2004). Rotating forty-six inch mirrored dishes are used to focus light into fiber optic cables which run to the interior of the building where light fixtures emit a mixture of sunlight and fluorescent light (Minkel 2004). These fibers are made of a silicone gel that transfers light far more efficiently than other commonly used fibers (Minkel 2004). Once inside, the sunlight is diffused through an acrylic light-diffusing rod; the light fixture also contains two fluorescent bulbs which are attached to a photosensitive dimmer (Minkel 2004).

When the light provided by the sun lessens, the sensor then raises the amount of light being put out by the fluorescent lights. At noon a hybrid light will illuminate 500 square feet for every square yard of collecting dish (Minkel 2004). Energy efficient fluorescent lights put out ninety lumens per bulb; on a sunny day a hybrid light puts out more than 180 lumens per fixture, not including any output from the fluorescent bulbs (Minkel 2004). Some new modifications to the prototype system include the use of photovoltaic cells to convert the infrared light collected into electricity (ORNL 2002). The use of this system for interior lighting can cut electric use by lights by 50% (Minkel 2004).

Hybrid lights are expected to cost around $4,000 per installed dish (Minkel 2004). Currently the price for a system of this type makes its use impractical. For a building the size of Smith Hall it would cost roughly $1.7 million to retrofit the building with this type of lighting, while roughly $110,000 would be saved in lighting costs each year. At this rate it would take sixteen years for the hybrid lights to pay for themselves. While this type of system would not currently be cost effective, it may become a viable option in the future as production increases and the price decreases.

CONCLUSION

We undertook this project with the full cooperation of Facilities Management, an office at Towson University aware of the importance of being environmentally and economically responsible. In the late 1990s, Facilities Management updated the lighting fixtures in all academic buildings except for residence halls, Enrollment Services and Towson Center (Bohlayer 2004). The ballasts were changed from magnetic to more efficient electric and light bulbs were changed from T12 to the more efficient T8 (Bohlayer 2004). In addition, Facilities Management has made it a priority to replace obsolete equipment with more efficient technology (Bohlayer 2004). Roofs have been replaced using better materials at Towson Center (1998), Media Center (2003), Dowell Health (2004) and Cook Library (2004) (Bohlayer 2004). Between1995-1997, higher efficiency chillers and boilers were installed in the power plant (Bohlayer 2004). The continuing mission to manage costs is reflected in the ongoing discussions among the Towson Four (TU, St. Joseph Medical Center, Greater Baltimore Medical Center and Sheppard Pratt Hospital) to consider building an electrical generation plant run by natural gas to supply the needs of the institutions (Bohlayer 2004).

We hope that our work this semester will support the University in our conservation efforts.

References

4 exits.com. 2003. LED Retro Fit Kits. (2004; http://4exits.com/cgi-bin/miva?Merchant2/merchant.mv+Screen=PROD&Store_Code=4&Product_Code=RFLED&Category_Code=RF).

[ACS] American Chemical Society. 2003. Physical Chemical Principles of Photovoltaic Conversion with Nanoparticulate, Mesoporus Dye-sensitized Solar Cells. (12 December 2003;http://www.nrel.gov/ncpv/thin_film/pdfs/review_of_dye_cells_by_bisquert_and_cahen_weizmann2004.pdf).

[Am Rivers] American Rivers. 2004. “Our ‘Rivers Unplugged’ Campaign.” (2 November 2004; http://www.amrivers.org).

[API] American Petroleum Institute. 2004a. FYI on Natural Gas. (26 October 2004; http://www.naturalgasfacts.org/factsheets/FYI_NaturalGas2.pdf).

[API] American Petroleum Institute. 2004b. Natural Gas. (14 September 2004; http://www.naturalgasfacts.org/factsheets/quick_facts.html).

[API] American Petroleum Institute. 2004c. Natural Gas Supply: An Overview. (14 September 2004; http://www.naturalgasfacts.org/factsheets/overview.html).

[API] American Petroleum Institute. 2004d. Natural Gas, Then and Now. (26 October 2004; http://naturalgasfacts.org/factsheets/thenandnow.html).

Arsenal PC. 2004. LCD vs. CRT. (14 November 2004; http://www.arsenalpc.com/Items.asp?CatID=62).

[ASCE] American Society for Civil Engineers, 2003a. “Report Card for America’s Infrastructure 2003 Progress Report. Factsheet: Energy.” (2 November 2004; http://www.asce.org/reportcard/index.cfm?reaction =factsheet&page=12).

[ASCE] American Society for Civil Engineers, 2003b. “Report Card for America’s Infrastructure 2003 Progress Report. Factsheet: Dams” (2 November 2004; http://www.asce.org/reportcard/index.cfm?reaction =factsheet&page=8).

[AWEA] American Wind Energy Association. 1999. President Clinton Signs Wind Energy Tax Credit Extension into Law. 9November 2004; http://www.awea.org/news/news991217ptc.html).

[AWEA] American Wind Energy Association. 2004a. Wind Web Tutorial. (November 2004; http://www.awea.org/faq/).

[AWEA] The American Wind Energy Association. 2004b. Maryland Wind Energy Development. (8 August 2004; http://www.awea.org/projects/maryland.html).

Azom, 2004. Cadmium Telluride: As a Photovoltaic Material; Energy Payback from Photovoltaic Systems. (2004; http://www.azom.com/details.asp?ArticleID=1164#_Background).

Bohlayer, Dennis. 2004. Personal communication. (Mr. Bohlayer is the Director of Operations and Maintenance for Towson University).

Bonsor, Kevin. 2004, How Hydropower Plants Work. (6 October 2004; http://science.howstuffworks.com/hydropower-plant.htm).

Borowitz, Sidney. 1999. Farewell Fossil Fuels: Reviewing America's Energy Policy. New York: Plenum Press.

Burnett, H. Sterling and Jason Meyer, 2001. Coal Will Power America's Future. (21 October 2004; www.ncpa.org/edo/sb/2001/sb091001.html).

Carless, Jennifer. 1993. Renewable Energy. New York: Walker and Company.

[CAT] Center for Alternative Technology. Undated. A Shining Example. (10 October 2004; http://www.cat.org.uk/information/solarage.tmpl).

[CATF] Clean Air Task Force. 2004. (2004; http://www.catf.us/publications/reports/Power_Plant_Emissions_June_2004.php).

Cave, Christi, 1998. The Ecology of Dams. (28 October 2004; http://chamisa.freeshell.org/dam.htm#return1)

Constellation Energy. 2004. Constellation generation group fact sheet. (30 October 2004; www.constellation.com/files/factsheet_generation.pdf).

Cotton, Robin, Boyle, S., and Carey-Wood, J. 2004. Devon County Council, Economy and Regeneration Service. A Renewable Energy Guide for Devon 2004. (November 2004; http://www.devon.gov.uk/renewable_energy_guide.pdf).

Crawford, Nathan *et al.*, 2004. Water Power: Dams and Hydropower. (9 October 2004; http://drake.marin.k12.ca.us/stuwork/rockwater/Upload%20this%20doc--dams%20and%20hydropower%20report/index.html).

Dell PC. 2004. Software and Peripherals Monitors. (2 December 2004; http://accessories.us.dell.com/sna/category.aspx?c=us&category_id=4009&cs=2238&l=en&s=eep).

[DOE] United States Department of Energy. 2000. Biomass Cofiring Program. (3 October 2004; http://www.netl.doe.gov/publications/factsheets/program/prog015.pdf).

[DOE] Department of Energy, Office of Fossil Energy. 2003a. Natural Gas Fundamentals from Resource to Market. (14 September 2004; http://fossil.energy.gov/programs/oilgas/ publications/naturalgas_general/gas_fundamentals.pdf).

[DOE] United States Department of Energy. 2003b. Wind Energy Program Multi Year Technical Plan for 2004-2010. (November 2003; http://www.nrel.gov/wind_meetings/2003_imp_meeting/pdfs/mytp_nov_2003.pdf).

[DOE] The United States Department of Energy, 2004a. Wind and Hydropower Technology Program. (20 October 2004; http://www.eere.energy.gov/windandhydro/hydro_mvg.html).

[DOE] Department of Energy, Office of Fossil Energy. 2004b. Gas Storage and Liquefied Natural Gas R&D. (14 September 2004; http://fossil.energy.gov/programs/oilgas/storage/index.html).

[DOE] United States Department of Energy. 2004c. Technologies: Wind. (21July2004; http://www.eere.energy.gov/state_energy/technology_overview.cfm?techid=2).

[DOE] The United States Department of Energy. 2004d. Biomass Resources. (27 September 2004; http://www.eere.energy.gov/RE/bio_resources.html).

[DOE] United States Department of Energy. 2004e. Biomass Today. (20 October 2004; http://www.eere.energy.gov/biomass/biomass_today.html).

[DOE] The United States Department of Energy. 2004f. Biopower. (3 October 2004; http://www.eere.energy.gov/RE/bio_biopower.html).

[DOE] The United States Department of Energy. 2004g. Economic Growth. (13 October 2004; http://www.eere.energy.gov/biomass/economic_growth.html).

[DOE] The United States Department of Energy. 2004h. Electrical Power Generation. (20 October 2004; http://www.eere.energy.gov/biomass/electrical_power.html).

[DOE] The United States Department of Energy. 2004i. Program. (20 October 2004; http://www.eere.energy.gov/biomass/).

[DWIA] Danish Wind Industry Association. 2003. Birds and Wind Turbines. (November 2004; http://www.windpower.org/en/tour/env/birds.htm).

Earth Science Australia, 2004. Coal and Gas Hydrate Resources. (22 October 2004; http://earthsci.org/teacher/basicgeol/coal/coal.html).

Ecotopia. 2004. Solar and Electric Vehicles. (16 April 2004; http://www.ecotopia.com/st/solarcar.htm).

[EERE] Energy Efficiency and Renewable Energy. DOE. 2004a. History of Wind Energy. (2 March 2004; http://www.eere.energy.gov/windandhydro/wind_history.html).

[EERE] Energy Efficiency and Renewable Energy. DOE. 2004b. Wind and Hydropower Technologies. (November 2004; http://www.eere.energy.gov/windandhydro/wind_basics.html).

[EERE] Energy, Energy Efficiency and Renewable Energy. DOE. 2004c. Maryland Wind Resources. (21 July 2004; http://www.awea.org/projects/maryland.html).

[EERE] Energy Efficiency and Renewable Energy. DOE. 2004d. Solar Energy Topics. (21 July 2004; http://www.eere.energy.gov/RE/solar.html)

[EIA] Energy Information Administration. 2000. The changing structure of the electric power industry: an update. (30 October 2004; http://tonto.eia.doe.gov/FTPROOT/electricity/056200.pdf).

[EIA] Energy Information Administration. 2004a. Nuclear quick facts. (1 November 2004; www.eia.doe.gov/neic/quickfacts/quicknuclear.htm).

[EIA] Energy Information Administration. 2004b. U.S. Nuclear Reactors. (21 October 21 2004; http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/reactsum.html).

[EIA] Energy Information Administration. 2004c. 2003 Coal Report. (6 October 2004; http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html).

[EIA] Energy Information Administration. 2004d. International Energy Outlook. (21 October 2004; http://www.eia.doe.gov/oiaf/ieo/coal.html).

ElectroRoof. 2004. (2004; http://www.electroroof.com).

Energy Quest. 2002. Energy Story- Chapter 8: Fossil Fuels – Coal, Oil and Natural Gas. (28 October 2004; http://www.energyquest.ca.gov/story/chapter08.html).

Energy Star. 2004a. Energy Star Teaches Universities and Schools to Save Energy and Money. (15 October 2004; http://www.energystar.gov/ia/products/power_mgt/University_Case_Studies.doc).

Energy Star. 2004b. Million Monitor Drive. (15 October 2004; http://208.254.22.7/index.cfm?c=pm_mmd.pr_pm_mmd).

Energy Star. 2004c. Easy Save Software. (15 October 2004; http://www.energystar.gov/index.cfm?c=power_mgt.pr_pm_easy_save).

Energy Star. 2004d. Creating an Energy Star Showcase Dorm Room. (15 October 2004; http://208.254.22.7/index.cfm?c=higher_ed.bus_dormroom).

[ENN] Environmental News Network, 11 January 2001. The future of hydropower could mean bad news for U.S. rivers. (4 November 2004; http://archives.cnn.com/2001/NATURE/01/11/hydropower.enn/).

[EPA] U.S. Environmental Protection Agency. 2001. HOT TIPS: CONTROL THE CHILL AND REDUCE OFFICE ENERGY BILLS. Tip # 2. (2004; http://www.epa.gov/smallbiz/archive/mahot.html).

[EPA] U.S. Environmental Protection Agency. 2004. Electricity from Natural Gas. (20 October 2004; http://www.epa.gov/cleanenergy/natgas.htm).

[EPRI] EPRI Journal online. 2003. Potential Health, Environmental Impacts of Photovoltaic Cells Assessed. (25 November 2003; http://www.epri.com/journal/details.asp?doctype=discovery&id=730).

[FEPC] Federation of Electric Power Companies of Japan. 2004. (21 October 2004; http://www.fepc.or.jp/menu/nuclear.html).

Greenpeace. August, 2001. Coal-Fired Power Plants and the Menace of Mercury Emissions. A Greenpeace Southeast Asia Report. (2004; www.greenpeacesoutheastasia.org).

Hostetter Martha. 2002. The Reference Shelf: Energy Policy. U.S.A: the H.W. Wilson Company.

[IAEA] International Atomic Energy Agency. 2004a. Power reactor information system. (30 October 2004; www.iaea.org/programmes/a2/index.html).

[IAEA] International Atomic Energy Agency. 2004b. (20 October 20, 2004; http://www.iaea.org/).

[IDSNET] International Development Studies Network, 2002. Environmental Impacts. (19 October 2004; http://www.idsnet.org/Resources/Dams/Development/impact-enviro.html).

Incandecent Replacement Bulbs. 2004. (2004; http://www.elights.com/ledexsinlam.html).

[IRN] International Rivers Network, 2004. The Environmental Impact of Large Dams. (28 October 2004; http://www.irn.org/index.asp?id=/basics/impacts.html).

Instrumentation System and Automation, 2004. Hot New Jet Fuel Source: Coal. (28 October 2004; http://www.isa.org/InTechTemplate.cfm?Section= InTech& template=/ContentManagement/ContentDisplay.cfm&ContentID=34626).

Jamsky, R.J., 2002. Coal: A Long-Term Energy Alternative. Air University Review. (22 October 2004; http://www.airpower.maxwell.af.mil/airchronicles/aureview/1980/nov-dec/jamsky.html).

Keay, Malcolm, 2002. Coal and Sustainable Development- Reducing the Environmental Footprint. (21 October 2004; http://www.wci-coal.com/uploads/DryCargo.pdf).

Leaning, John. 2004. Draft Report Favorable to Wind Farm. Cape Cod Times. (8 November 2004; http://www.capecodonline.com/special/windfarm/draftreport8.htm).

Lightsearch.com. 2000. Light guide: occupant sensors. (20 November 2004; www.lightsearch.com/resources/lightguides/sensors.html).

[LSA] Latent Semantic Analysis, 2003. What is Coal? (29 October 2004; http://lsa.colorado.edu/essence/texts/coal.htm).

Lumileds. Undated. The 10 myths about LED's and the Luxeon Difference. (October 2004; http://www.lumileds.com/pdfs/10Myths1.PDF).

McKee, Leroy. Energy coordinator, Towson University, Towson, MD. Personal communication, September 9, 2004.

Fisher Mike, Executive Vice President of Easylite, Towson University, Towson, MD. Interview, November 2004.

Minkel JR. 2004. Let the Sun Shine In. (15 November 2004; http://www.discover.com/issues/jul-04/features/let-the-sun-shine-in/).

[NCPV] National Center for Photovoltaics. DOE. 2004. Frequently Asked Questions about Photovoltaics (PV). (2004; http://www.nrel.gov/ncpv/pvmenu.cgi?site+ncpv&idx=3&body=faq.html).

[NEI] Nuclear Energy Institute. 2003. Perspective on public opinion. (30 October 2004; www.nei.org/documents/PublicOpinion_04-06.pdf).

[NEI] Nuclear Energy Institute. 2004a. (20 October 2004; http://www.nei.org/index.asp?catnum=1&catid=1).

[NEI] Nuclear Energy Institute. 2004b. High Level "Nuclear Waste" is Really Nuclear Fuel. (10 October 2004; http://www.nei.org/doc.asp?catnum=2&catid=62).

[NEI] Nuclear Energy Institute. 2004c. Nuclear Facts. (10 October 2004; http://www.nei.org/doc.asp?catnum=2&catid=106).

[NEMO] Nanostructured Electrodes of Metal Oxides Group. Uppsala University. 2002. Photoelectrochemical Production of Hydrogen. (2004; http://www.fki.uu.se/research/nano/textfile2/hydrogen3.html).

[NGSA] Natural Gas Supply Association. 2004. Natural Gas and the Environment. (13 September 2004; http://www.naturalgas.org/environment/naturalgas.asp).

Northern Illinois University. 2004. Energy Conservation Efforts Save NIU $10 Million (27 October 2004; http://www.niu.edu/PubAffairs/RELEASES/2004/april/energy.shtml).

Novak, Robert, 2004. Kerry and Coal. (26 April 2004; http://www.townhall.com/columnists/robertnovak/rn20040426.shtml).

[NRC] U.S. Nuclear Regulatory Commission. 2003a. Power reactors. (30 October 2004; www.nrc.gov/reactors/power.html).

[NRC] U.S. Nuclear Regulatory Commission. 2003b. Map of power reactor sites. (30 October 2004; www.nrc.gov/reactors/operating/map-power-reactors.html).

[NRC] U.S. Nuclear Regulatory Commission. 2003c. List of power reactor units. (30 October 2004; www.nrc.gov/reactors/operating/list-power-reactor-units.html).

[NRC] U.S. Nuclear Regulatory Commission. 2003d. (20 October 2004; http://www.nrc.gov/reactors.html).

[NRC] US Nuclear Regulatory Commission. 2004. Operating Reactors. (30 October 2004; www.nrc.gov/reactors/operating.html).

[ORNL] Oak Ridge National Laboratory. Undated. Biomass Frequently Asked Questions. (10 October 2004; http://bioenergy.ornl.gov/faqs/index.html).

[ORNL] Oak Ridge National Laboratory. 2002. Technical Overview. (15 November 2004; http://www.ornl.gov/sci/hybridlighting/techoverview1.htm).

Patin, Stanislav, 2004. Natural Gas in the Marine Environment. (9 September 2004; http://www.offshore-environment.com/naturalgas.html).

[PNNL] Pacific Northwest National Laboratory. 2003. January 2003 Energy Tips. (19 October 2004; http://www.pnl.gov/conserve-energy/tips/jan03.stm).

[PSU] Pennsylvania State University. 2001. New at Penn State. (27 October 2004; http://www.psu.edu/ur/archives/intercom_2001/Jan25/new.html).

Quinn, Randy. 1997. Sunlight Brightens Our Energy Future. The World & I 13: 3: 156-63.

Reculite.com. 2004. LED Retro Fit Kits. (2004; http://resculite.com/Merchant2/merchant.mvc?Screen=PROD&Store_Code=RI&Product_Code=RETKITR&Category_Code=AC).

Roberge, Martin., Professor, Department of Geography and Environmental Planning, Towson University, Towson, MD. lecture, March 12, 2004.

Roseth, Bob. 2002. UW Efforts to Conserve Pay Off. (27 October 2004; http://depts.washington.edu/uweek/archives/2002.02.FEB_07/news_b.html).

Ryan, Steve. Undated. Savings-Wise, World's Smartest Universities Are Also World's "Sleepiest." (15 October 2004; http://www.energystar.gov/ia/products/power_mgt/pm_tulane_university.doc).

Salomon, Ashley. 2001. Perylene/Polymer Composite Solar Cells. (17 August 2001; http://www.nrel.gov/docs/gen/fy01/NN0046.pdf).

Sellers, Kevin. 2004. Fall 2004 enrollment statistics. (14 November 2004; www.towson.edu).

Simon, Anne Marie. 1996. The British Wind Energy Association. A Summary of Research. (November 2004; http://www.bwea.com/ref/surveys-90-96.html).

Smith R, Smith T. 2001. Ecology and Field Biology. San Francisco, CA: Addison Wesley Longman, Inc.

Solarbuzz. 2004. Solar Cell Technologies. (14 October 2004; http://www.solarbuzz.com/).

SolarQuest. 2004. (2004; http://www.solarquest.com/).

[SUNY] The State University of New York at Buffalo. 1996. State University of New York at Buffalo Comprehensive Energy and Resource Management Profile #124. (27 October 2004; http://wings.buffalo.edu/ubgreen/documents/programs/ energyconservation/compreport.pdf).

[SUNYa] The State University of New York at Buffalo. Undated a. Energy Conservation. (27 October 2004; http://wings.buffalo.edu/ubgreen/content/programs/energyconservation/main.htm).

[SUNYb] The State University of New York at Buffalo. Undated b. Energy Conservation. (27 October 2004; http://wings.buffalo.edu/ubgreen/content/programs/ energyconservation/goodlighting.html).

Super-Bright LED bulb. 2003. Super Bright Edison Base Bulb. (15 November 2004; http://www.hightechlighting.com/index.php/cPath/50_158).

[SEA] Students for Environmental Awareness. 2004. Home Page. (17 November 2004; http://tiger.towson.edu/users/apacel1/).

TheLEDlight.com. Undated. Ceiling Drop Light. (2 October 2004.; http://www.theledlight.com/120-VAC-LEDbulbs.html).

The State of Queensland Department of Energy, 2004. Coal as a Primary Energy Source for Electricity Generation. (22 October 2004; http://www.energy.qld.gov.au/infosite/coal.html).

The University of Vermont. 2004. Energy Efficiency Projects at UVM. (27 October 2004; http://www.uvm.edu/~energy/?Page=Energy%20Efficiency%20Projects.html).

The University of Washington. 2003. Energy and Water Reduction Measures. (27 October 2004; http://www.washington.edu/admin/facserv/conserve-measures.html).

[TU] Towson University. 2000. About TU. (14 November 2004; www.towson.edu/tu/aboutlinks/did.you.know.html).

Tufts University. Undated. Vending Misers: Facts and Issues. (27 October 2004; http://www.tufts.edu/tie/tci/excel%20and%20word/Vending%20Miser%20Handout.doc).

[Tulane] Tulane University. 2004. Contest Rules. (15 October 2004; http://green.tulane.edu/energysmart/ContestRules.html).

[UCS] Union of Concerned Scientists. 2001. (15 October 2004; http://www.ucsusa.org/CoalvsWind/c01.html).

[UCS] Union of Concerned Scientists. 2003. How Nuclear Power Works. (1 November 2004; http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=85).

[UCS] Union of Concerned Scientists. 2004. Clean Energy. (15 October 2004; http://www.ucsusa.org/clean_energy/health_and_environment/).

University of New Brunswick. 2000. University of New Brunswick Fredericton Campus: Energy Conservation – A Long Term Commitment (27 October 2004; http://oee.nrcan.gc.ca/publications/infosource/pub/ici/eii/pdf/m27-01-1364E.pdf).

Verdiem. 2004a. Surveyor vs. EZ Save: a Head-to-Head Comparison. email, November 3, 2004.

Verdiem. 2004b. Verdiem Customers. (14 November 2004; http://virtual.pnw.com/customers/college.asp).

Wald, ML. 2004. Seven companies band together in hopes of building nation's first nuclear plant in decades. New York Times. A14.

Wardell Charles. 2001. Nuclear Energy Comes Full Circle. POPULAR SCIENCE.

Windustry. 2004. Wind Energy Economics. (November 2004; http://www.windustry.com/basics/05-economics.htm).

Wise, Charlie. 2004. Personal Communication. (Mr. Wise is an Account Manager for Verdium)

[WNA] World Nuclear Association. 2004. Information and Issue Briefs: Chernobyl Accident. (1 November 2004; http://world-nuclear.org/info/chernobyl/inf07.htm).

Wolfson J., Director, Environmental Science and Studies Programs, Towson University, Towson, MD. 2004. Information From OTS. email, November 11, 2004.

Wolman David. 2004. Hydrates, Hydrates Everywhere. (30 November 2004; http://www.discover.com/issues/oct-04/features/hydrates-hydrates-everywhere/).

[WVIC] Wisconsin Valley Improvement Company. 2004. Facts About Hydropower. (9 October 2004; http://www.wvic.com/hydro-facts.htm).

[WCI] World Coal Institute. March 2002. Sustainable Entrepreneurship, the Way Forward for the Coal Industry. Ecoal: the Newsletter of the World Coal Institute 41.

Zahorsky, Darrell. 2004. Hottest Small Business Trends for 2003. About.com. (November 2004; http://sbinformation.about.com/cs/bestpractices/a/aa122202a.htm).

APPENDIX 1

THE ENERGY USAGE SURVEY

The Environmental Sciences and Studies Senior Seminar class is examining the use of electrical energy on the Towson campus. Answers are completely confidential and will not be reported individually. Please fill out only one survey and return to the person who gave it to you.

Please give your best response to each question so that we can collect the most accurate information possible.

==

1. What is your primary status on campus? Circle the best answer

Full-Time Student	9	Administrative Staff	5
Part-Time Student	8	Support Staff	4
Full-Time Faculty	7	[including Aramark & Chartwells]	
Part-Time Faculty	6	Other_______________	0

1a. If you are a student do you live ______off campus or ______on campus.

1b. If you live in a dorm, which dorm ______________?

2. What is your age category? _____15-20; _______21-25; _______26-30; _______31+

Please indicate [X] the response which most accurately reflects your thinking.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
3. The university could save a substantial amount of money by consuming less electricity.	1	2	3	4	5	7
4. The cost of electricity (taking inflation into account) has gone down over the last 5 years.	1	2	3	4	5	7
5. Signs by switches reminding people to 'turn [something] off' are effective.	1	2	3	4	5	7

Comments on questions 3-5:

	Never	Rarely	Some-times	Often	Always
6. I stop and turn the lights out in a classroom when I observe that the room not being used	1	2	3	4	5
7. I am bothered when I see lights left on that are not being used.	1	2	3	4	5
8. When I see signs by switches saying to "turn [something] off," I do so.	1	2	3	4	5
9. When I am the last person to leave a room on campus (classroom, bathroom, etc.) I turn off the lights.	1	2	3	4	5

APPENDIX 1

	Never	Rarely	Some-times	Often	Always	Not Applicable
10. When I am done using a computer in a computer lab or in the library, I shut it down.	1	2	3	4	5	6
11. When I am done using my personal computer at home, I shut it down.	1	2	3	4	5	6
12. At home, I turn off lights when they are not being used.	1	2	3	4	5	
13. I see my peers taking action to reduce electrical use.	1	2	3	4	5	
14. I take actions to reduce electrical use.	1	2	3	4	5	
15. I am or have been responsible for paying some or all of my electrical bill.	1	2	3	4	5	

Comments on questions 6-15:

Please share your ideas/thoughts about the following.

16. Are there places on campus that are too dark or too well lit? Where?

17. How could the campus reduce its use of electricity?

18. What do you think might make other people **more willing** to conserve electricity on campus?

19. Why might someone **not** turn off lights, computers or appliances?

20. What is your best guess (in dollars) of how much the University pays per year in electrical bills?

APPENDIX II

THE ENERGY USAGE SURVEY RESULTS

The number of responses per statement as classified by status of respondent are found in the tables below.

Statement	Status	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
3. The university could save a substantial amount of money by consuming less electricity.	Faculty	1	1	6	29	13	7
	Staff	5	1	6	21	24	11
	Student	6	18	89	137	57	44
	Other	1	0	2	5	1	1
4. The cost of electricity (taking inflation into account) has gone down over the last 5 years.	Faculty	9	19	3	4	1	20
	Staff	23	20	9	2	0	14
	Student	19	88	50	16	3	176
	Other	3	1	1	0	0	0
5. Signs by switches reminding people to 'turn [something] off' are effective.	Faculty	4	13	8	21	7	3
	Staff	4	14	19	25	3	3
	Student	26	66	58	162	30	10
	Other	0	3	3	3	1	0

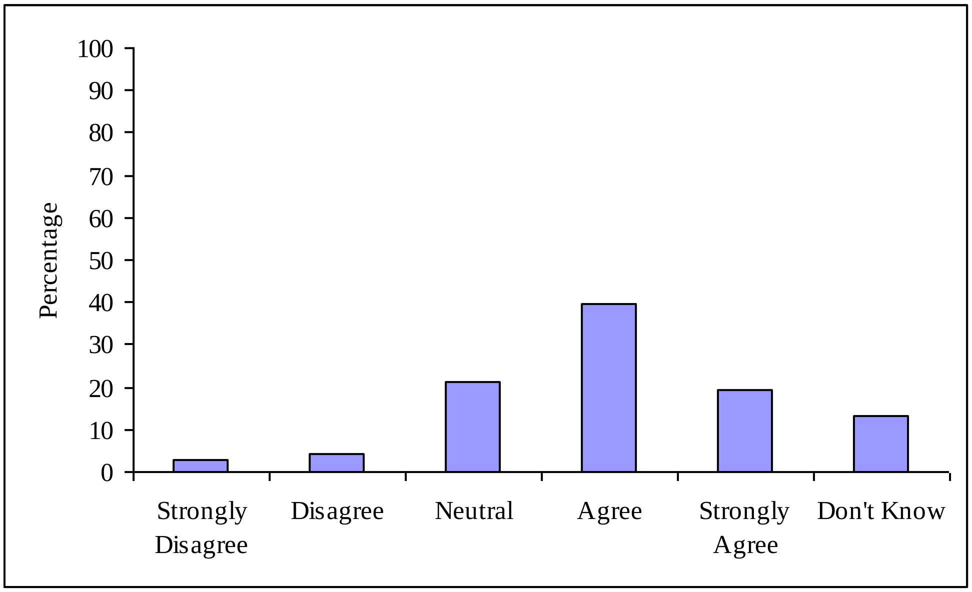
Statement	Status	Never	Rarely	Some times	Often	Always
6. I stop and turn the lights out in a classroom when I observe that the room is not being used	Faculty	8	6	10	23	10
	Staff	11	3	12	22	17
	Student	174	99	47	25	7
	Other	4	2	1	3	0
7. I am bothered when I see lights left on that are not being used.	Faculty	2	5	17	18	15
	Staff	2	4	20	22	20
	Student	45	84	122	71	30
	Other	1	3	2	1	3
8. When I see signs by switches saying to "turn [something] off," I do so.	Faculty	1	5	11	23	17
	Staff	1	7	16	19	25
	Student	18	34	95	117	87
	Other	0	0	2	3	5
9. When I am the last person to leave a room on campus (classroom, bathroom, etc.) I turn off the lights.	Faculty	3	2	9	23	20
	Staff	2	6	11	22	27
	Student	89	83	80	71	28
	Other	2	0	3	2	3

Statement	Status	Never	Rarely	Some times	Often	Always	N/A
10. When I am done using a computer in a computer lab or in the library, I shut it down.	Faculty	16	9	7	4	9	12
	Staff	9	8	7	4	21	19
	Students	145	72	43	28	30	29
	Other	1	4	1	1	0	3
11. When I am done using my personal computer at home, I shut it down.	Faculty	4	6	6	12	27	1
	Staff	4	2	8	9	41	4
	Students	62	49	61	68	106	1
	Other	1	3	0	1	4	1

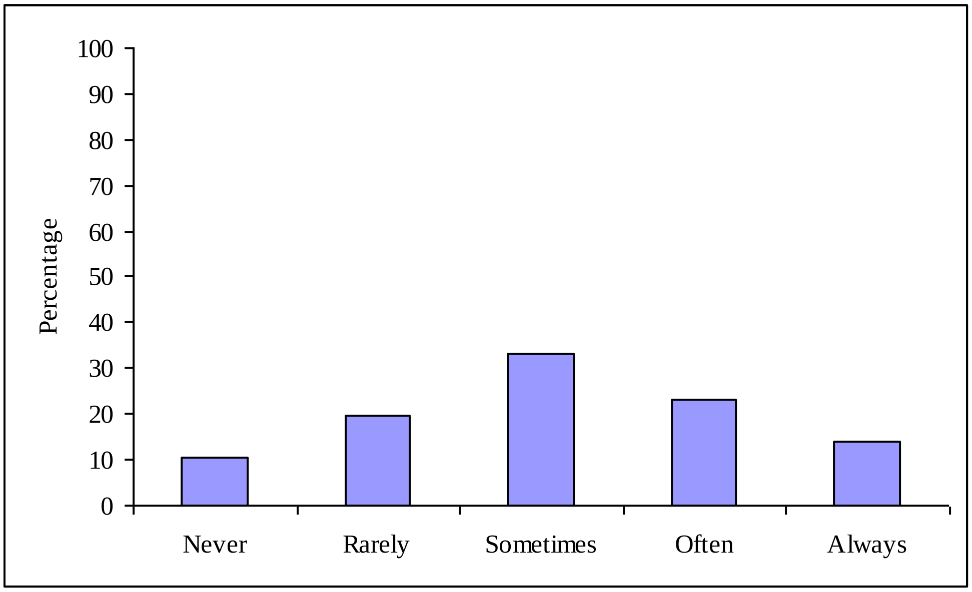
Statement	Status	Never	Rarely	Some times	Often	Always
12. At home, I turn off lights when they are not being used.	Faculty	0	1	3	15	38
	Staff	1	1	4	17	45
	Students	5	11	29	121	181

	Other	0	1	1	1	7
13. I see my peers taking action toreduce electrical use.	Faculty	2	15	25	6	7
	Staff	5	31	25	3	0
	Students	55	151	110	25	6
	Other	1	4	5	0	0
14. I take actions to reduce electrical use.	Faculty	0	1	15	29	12
	Staff	1	2	28	21	16
	Students	12	52	126	120	34
	Other	0	1	5	4	0
15. I am or have been responsible for paying part or all of my electrical bill.	Faculty	1	3	0	5	48
	Staff	3	1	1	9	53
	Students	155	35	40	35	77
	Other	1	1	0	2	6

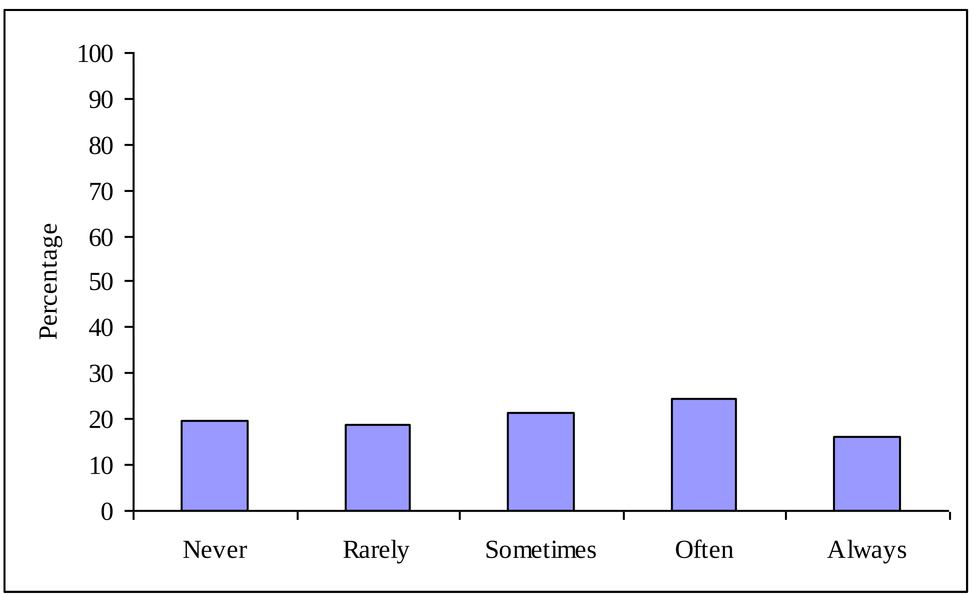
Additional response calculations are found in the figures below.



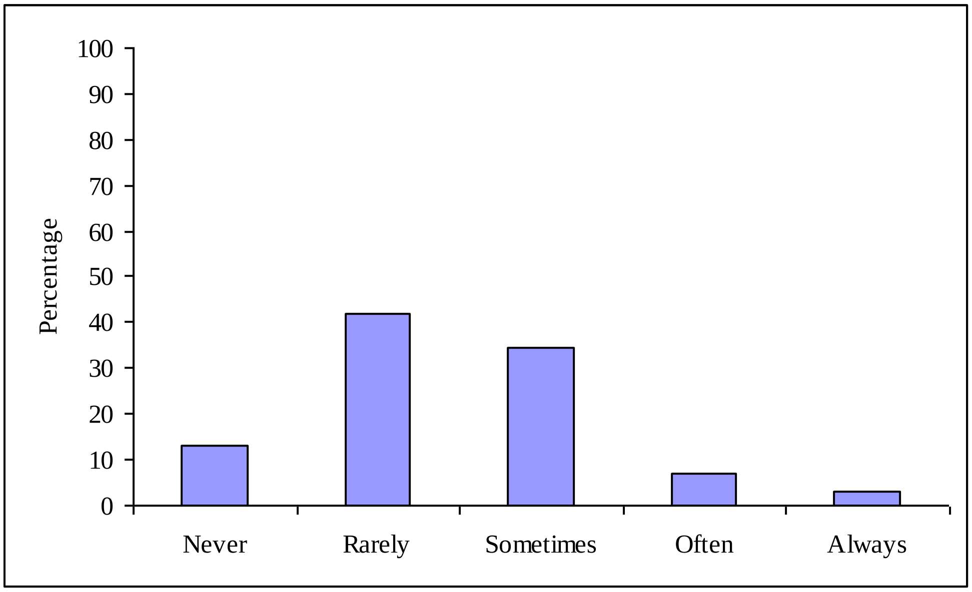
The responses of survey participants to statement 3: “The University could save a substantial amount of money by consuming less electricity.”



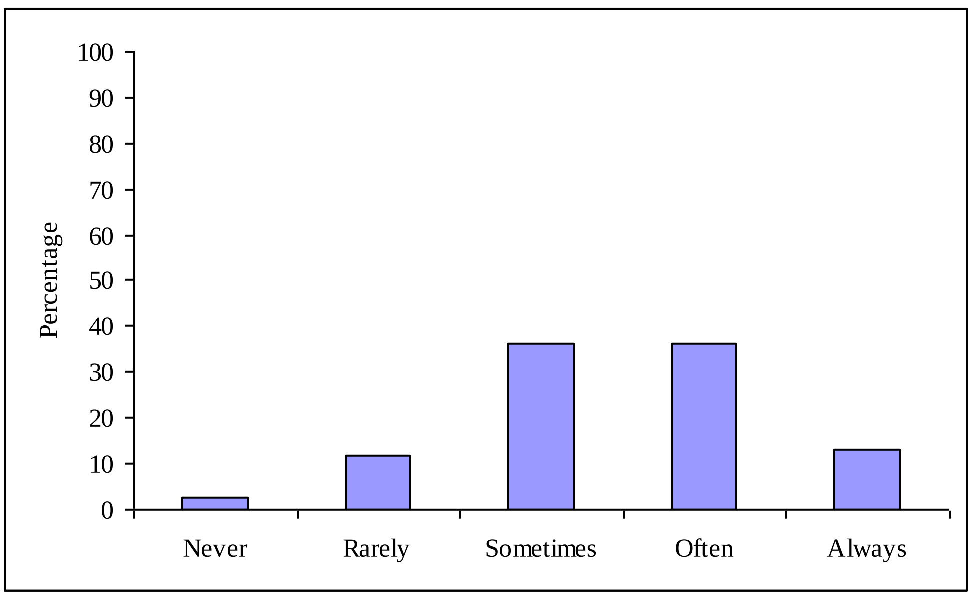
The responses of survey participants to statement 7: "I am bothered when I see lights left on that are not being used."



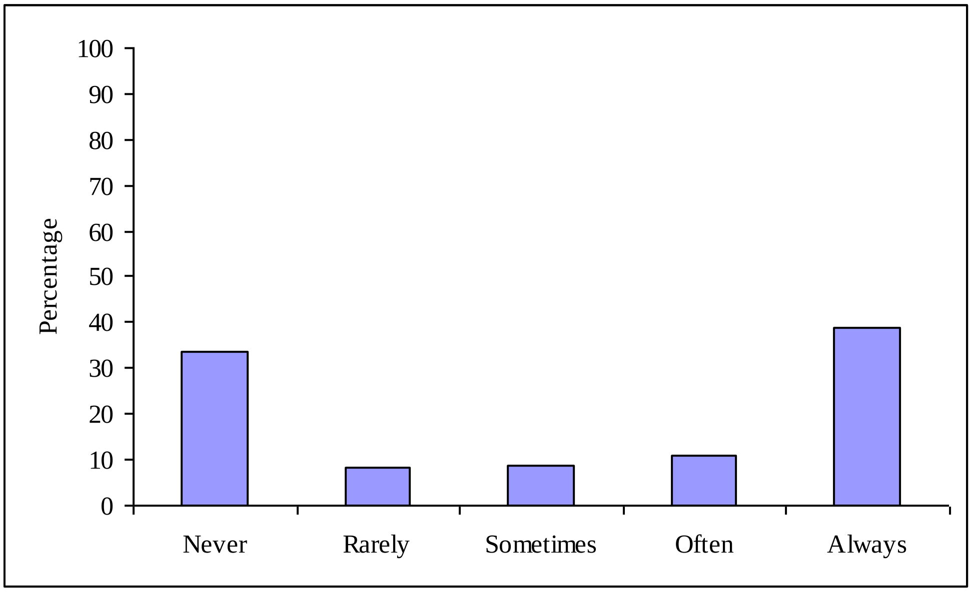
The responses of survey participants to statement 6: "When I am the last person to leave a room on campus (classroom, bathroom, etc.) I turn off the lights."



The responses of survey participants to statement 6: "I see my peers taking action to reduce electrical use."



The responses of survey participants to statement 14: "I take actions to reduce electrical use."



The responses of survey participants to statement 15 "I am or have been responsible for paying some or all of my electrical bill."

Additional response summaries are found in the tables below.

The responses of survey participants to statement 15: "I am or have been responsible for paying some or all of my electrical bill." compared to tatement 7: "I am bothered when I see lights left on that are not being used."

	Statement 7 Responses	Never	Rarely	Sometimes	Often	Always
Statement 15 Responses						
Never		5.6%	9.2%	10.7%	6.1%	2.1%
Rarely		1.0%	1.9%	2.1%	2.7%	.6%
Sometimes		.6%	1.9%	3.6%	1.3%	1.3%
Often		.6%	2.3%	4.6%	1.7%	1.5%
Always		2.5%	4.4%	12.3%	10.7%	8.8%

The responses of survey participants to statement 15: "I am or have been responsible for paying some or all of my electrical bill." compared to statement 8: "When I see signs by switches saying to "turn something off," I do so."

	Statement 8 Responses	Never	Rarely	Sometimes	Often	Always
Statement 15 Responses						
Never		2.1%	3.8%	9.4%	9.2%	9.2%
Rarely		.2%	1.0%	2.5%	3.1%	1.5%
Sometimes		.2%	.8%	2.7%	3.4%	1.5%
Often		.2%	1.0%	2.3%	3.6%	3.6%
Always		1.5%	2.7%	8.2%	13.8%	12.4%

The responses of survey participants to statement 15: "I am or have been responsible for paying some or all of my electrical bill." compared to statement 14: "I take actions to reduce electrical use."

	Question 14 Responses	Never	Rarely	Sometimes	Often	Always
Question 15 Responses						
Never		1.7%	6.7%	14.9%	8.8%	1.5%
Rarely		.2%	1.5%	3.4%	2.7%	.6%
Sometimes		.2%	1.5%	2.1%	3.8%	1.1%
Often		.4%	1.1%	3.8%	4.8%	.6%
Always		.2%	.8%	12.2%	16.0%	9.3%

The responses of survey participants to statement 5: "Signs by switches reminding people to "turn [something] off" are effective." compared to statement 8: "When I see signs by switches saying 'turn [something] off,' I do so."

	Statement 8 Responses	Never	Rarely	Sometimes	Often	Always
Statement 5 Responses						
Disagree		2.2%	5.7%	7.6%	7.1%	3.9%
Neutral		.4%	1.0%	6.6%	6.0%	4.5%
Agree		1.0%	2.5%	10.2%	20.1%	17.9%
Don't Know		.4%	.2%	1.2%	No answer	1.2%

The responses of survey participants to statement 11: "When I am done using my personal computer at home, I shut it down." compared to statement 10: "When I am done using a computer in a computer lab or in the library, I shut it down."

	Statement 11 Responses	Never	Rarely	Sometimes	Often	Always	Not Applicable
Statement 10 Responses							
Never		9.7%	4.3%	4.6%	7.2%	9.5%	n/a
Rarely		1.0%	4.3%	2.7%	5.2%	5.8%	.2%
Sometimes		1.4%	2.1%	3.3%	2.1%	3.1%	.2%
Often		.2%	1.2%	.8%	2.3%	3.1%	n/a
Always		.8%	.2%	1.4%	.2%	9.3%	.4%
Not Applicable		1.4%	.4%	2.7%	1.7%	6.2%	.6%

ENROLLMENT SERVICES LIGHT SURVEY DATA								
Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total tubes**	**Bulb Wattage**	**Power (W)**
Bathroom	1	W114	2	2	T8	4	32	128
Bathroom	1	M115	2	2	T8	4	32	128
Bathroom	1	W121	2	2	T8	4	32	128
Bathroom	1	M122	2	2	T8	4	32	128
Bathroom	2	M263	2	2	T8	4	32	128
Bathroom	2	W249	2	2	T8	4	32	128
Bathroom	3	M303	2	2	T8	4	32	128
Bathroom	3	W329	2	2	T8	4	32	128
Bathroom	3	M335	2	2	T8	4	32	128
Break room	3	307A	3	4	T8	12	32	384
Bursar annex	3	319	8	2	T8	16	32	512
Bursars	3	336	50	2	2U	100	32	3200
Classroom	1	101	12	4	T8	48	32	1536
Classroom	1	103	15	4	T8	60	32	1920
Classroom	1	107	15	4	T8	60	32	1920
Computer lab	1	102	15	4	T8	60	32	1920
Computer lab	1	108	15	4	T8	60	32	1920
Conference	2	209	6	2	2U	12	32	384
Conference	3	306	6	2	2U	12	32	384
Elevator	1	N/A	3	4	T8	12	32	384
Enr. Serv. Center	2	223	20	2	2U	40	32	1280
Hallway	1	105	2	4	T8	8	32	256
Hallway	1	101-8	14	4	T8	56	32	1792
Hallway	2	N/A	104	2	T8	208	32	6656
Hallway	3	N/A	80	2	T8	160	32	5120
Kitchen	3	307	4	2	2U	8	32	256
Lobby	2	N/A	28	4	T8	112	32	3584
Office	1	110A	2	2	2U	4	32	128
Office	1	111A	6	2	T8	12	32	384
Office	2	200	24	4	T8	96	32	3072
Office	2	201	4	2	T8	8	32	256
Office	2	202	4	2	T8	8	32	256
Office	2	203	4	2	T8	8	32	256
Office	2	205	9	2	2U	18	32	576
Office	2	208	12	2	2U	24	32	768
Office	2	208A	4	2	2U	8	32	256
Office	2	208B	4	2	2U	8	32	256
Office	2	208C	4	2	2U	8	32	256
Office	2	208D	4	2	2U	8	32	256
Office	2	208E	4	2	2U	8	32	256
Office	2	210	2	2	2U	4	32	128
Office	2	211	6	2	T8	12	32	384
Office	2	212	2	2	2U	4	32	128
Office	2	213	4	2	T8	8	32	256
Office	2	214	2	2	2U	4	32	128
Office	2	215	2	2	2U	4	32	128
Office	2	216	16	2	T8	32	32	1024

ENROLLMENT SERVICES LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total tubes**	**Bulb Wattage**	**Power (W)**
Office	2	217	2	2	2U	4	32	128
Office	2	218	9	2	T8	18	32	576
Office	2	219	9	2	T8	18	32	576
Office	2	220	2	2	2U	4	32	128
Office	2	221	10	2	2U	20	32	640
Office	2	222	2	2	2U	4	32	128
Office	2	225	2	2	2U	4	32	128
Office	2	227	2	2	2U	4	32	128
Office	2	228	4	2	2U	8	32	256
Office	2	229	2	2	2U	4	32	128
Office	2	230	2	2	2U	4	32	128
Office	2	231	20	2	2U	40	32	1280
Office	2	232	2	2	2U	4	32	128
Office	2	233	2	2	2U	4	32	128
Office	2	234	2	2	2U	4	32	128
Office	2	235	2	2	2U	4	32	128
Office	2	237	2	2	2U	4	32	128
Office	2	239	6	2	T8	12	32	384
Office	2	240	6	2	T8	12	32	384
Office	2	242	6	2	T8	12	32	384
Office	2	244	6	2	T8	12	32	384
Office	2	246	6	2	T8	12	32	384
Office	2	247	6	2	T8	12	32	384
Office	3	301	2	2	T8	4	32	128
Office	3	302	2	2	T8	4	32	128
Office	3	305A	4	2	2U	8	32	256
Office	3	305B	4	2	2U	8	32	256
Office	3	305C	4	2	2U	8	32	256
Office	3	305E	4	2	2U	8	32	256
Office	3	308	3	4	T8	12	32	384
Office	3	309	3	4	T8	12	32	384
Office	3	310A	3	4	T8	12	32	384
Office	3	311	3	4	T8	12	32	384
Office	3	312	3	4	T8	12	32	384
Office	3	313	3	4	T8	12	32	384
Office	3	314	3	4	T8	12	32	384
Office	3	315	6	2	T8	12	32	384
Office	3	316	6	2	T8	12	32	384
Office	3	317	6	2	T8	12	32	384
Office	3	318	6	2	T8	12	32	384
Office	3	321	3	4	T8	12	32	384
Office	3	322	3	4	T8	12	32	384
Office	3	323	3	4	T8	12	32	384
Office	3	324	3	4	T8	12	32	384
Office	3	325	6	2	T8	12	32	384
Office	3	325A	9	2	T8	18	32	576
Office	3	326	6	2	T8	12	32	384

APPENDIX III

ENROLLMENT SERVICES LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total tubes**	**Bulb Wattage**	**Power (W)**
Office	3	327	6	2	T8	12	32	384
Office	3	328	6	2	T8	12	32	384
Office	3	331A	4	2	T8	8	32	256
Office	3	331B	4	2	T8	8	32	256
Office	3	331C	4	2	T8	8	32	256
Office	3	331D	4	2	T8	8	32	256
Office	3	331E	4	2	T8	8	32	256
Office	3	333	2	2	T8	4	32	128
Office	3	334	2	2	T8	4	32	128
Office	3	337A	2	4	T8	8	32	256
Office	3	337B	3	4	T8	12	32	384
Office	3	338	2	2	2U	4	32	128
Office	3	340	2	4	T8	8	32	256
Office	3	342	2	2	T8	4	32	128
Office	1	105A	2	2	2U	4	32	128
Office	1	105B	2	2	2U	4	32	128
Office	1	105C	2	2	2U	4	32	128
Office	1	110	6	2	2U	12	32	384
Office	1	110B	2	2	2U	4	32	128
Office	1	111	12	2	T8	24	32	768
Office	1	111B	6	2	T8	12	32	384
Office - Arts	3	331	19	2	T8	38	32	1216
Office - Dean	2	245	9	2	T8	18	32	576
Office - Dean	2	245A	9	2	T8	18	32	576
Office - Fin. desk	3	339	0	0	0	0	32	0
Office - Financial	3	337	30	2	2U	60	32	1920
Office - Scholarsh.	3	305	12	2	2U	24	32	768
Sewing	1	104	8	2	2U	16	32	512
Sink	2	262	1	1	T8	1	32	32
Slide library	3	332	13	2	2U	26	32	832
St Am Assn	2	204	9	2	2U	18	32	576
Storage	1	110C	1	4	T8	4	32	128
Storage	3	320	1	2	T8	2	32	64
Technology unit	3	310	3	4	T8	12	32	384
Unknown	1	109	4	2	T8	8	32	256
Unknown	1	109A	6	2	T8	12	32	384
Unknown	1	116	4	2	T8	8	32	256
Unknown	1	116A	6	2	T8	12	32	384
Unknown	1	118	8	4	T8	32	32	1024
							TOTAL	**74,656**

APPENDIX IV

SMITH HALL LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Autoclave	4	464	6	4	T8	24	32	768
Bathroom	2	M	3	2	4	6	60	360
Bathroom	2	M	6	2	4	12	32	384
Bathroom	2	W	6	2	4	12	32	384
Bathroom	3	W	6	2	4	12	32	384
Bathroom	3	M	6	2	4	12	32	384
Bathroom	3	W	3	2	4	6	60	360
Bathroom	4	M	3	2	4	6	60	360
Bathroom	4	W	6	2	4	12	32	384
Bathroom	4	M	6	2	4	12	32	384
Bathroom	5	W	6	2	4	12	32	384
Bathroom	5	W	6	2	4	12	32	384
Bathroom	5	M	6	2	4	12	32	384
Chemistry Stock Room	5	528	6	4	4	24	32	768
Classroom	4	446	20	4	T8	80	32	2560
Classroom	4	469	24	4	T8	96	32	3072
Classroom	5	570	8	4	4	32	32	1024
Classroom	5	541	16	4	4	64	32	2048
Classroom	5	508	9	4	4	36	32	1152
Classroom	5	506	9	4	4	36	32	1152
Classroom	5	504	18	4	4	72	32	2304
Cold room	4	466	8	1	T8	8	32	256
Computer Lab	3	354	20	4	T8	80	32	2560
Computer Lab	5	539	4	4	4	16	32	512
Conference	3	340	20	4	T8	80	32	2560
Conference	5	554	12	4	4	48	32	1536
Display	3	N/A	5	2	T8	10	32	320
Display	4	N/A	8	2	T8	16	32	512
Entrance	3	315	4	4	T8	16	32	512
Hallway	1	N/A	40	2	U	80	32	2560
Hallway	2	N/A	90	2	U	180	32	5760
Hallway	3	N/A	90	2	2U	180	32	5760
Hallway	4	N/A	90	2	2U	180	32	5760
Hallway	5	N/A	90	2	2U	180	32	5760
Hallway - Lec	3	N/A	12	4	T8	48	32	1536
Hallway - Ofc	3	N/A	7	2	2U	14	32	448
Hallway-Other	5	566	2	4	4	8	32	256
Herbarium	2	200	15	4	T8	60	32	1920
Lab	2	203	18	4	T8	72	32	2304
Lab	2	209	18	4	T8	72	32	2304
Lab	2	211	18	4	T8	72	32	2304
Lab	2	217	18	4	T8	72	32	2304
Lab	2	221	18	4	T8	72	32	2304
Lab	3	300	14	4	T8	56	32	1792
Lab	3	301	18	4	T8	72	32	2304
Lab	3	307	18	4	T8	72	32	2304
Lab	3	311	18	4	T8	72	32	2304
Lab	3	313	18	4	T8	72	32	2304
Lab	3	317	18	4	T8	72	32	2304

APPENDIX IV

SMITH HALL LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Lab	3	362	9	4	T8	36	32	1152
Lab	3	364	4	4	T8	16	32	512
Lab	3	373	25	4	T8	100	32	3200
Lab	3	374	24	4	T8	96	32	3072
Lab	3	375	30	4	T8	120	32	3840
Lab	3	377	30	4	T8	120	32	3840
Lab	3	379	30	4	T8	120	32	3840
Lab	4	401	18	4	T8	72	32	2304
Lab	4	402	18	4	T8	72	32	2304
Lab	4	403	18	4	T8	72	32	2304
Lab	4	404	18	4	T8	72	32	2304
Lab	4	405	18	4	T8	72	32	2304
Lab	4	406	18	4	T8	72	32	2304
Lab	4	407	18	4	T8	72	32	2304
Lab	4	408	18	4	T8	72	32	2304
Lab	4	409	18	4	T8	72	32	2304
Lab	4	417	6	4	T8	24	32	768
Lab	4	448	20	4	T8	80	32	2560
Lab	4	468	4	4	T8	16	32	512
Lab	4	475	8	4	T8	32	32	1024
Lab	4	485	25	4	T8	100	32	3200
Lab	4	487	11	4	T8	44	32	1408
Lab	4	491	30	4	T8	120	32	3840
Lab	5	589	32	4	4	128	32	4096
Lab	5	587	35	4	4	140	32	4480
Lab	5	591	33	4	4	132	32	4224
Lab	5	509	21	4	4	84	32	2688
Lab	5	507	20	4	4	80	32	2560
Lab	5	505	20	4	4	80	32	2560
Lab	5	501	19	4	4	76	32	2432
Lab - small	5	549	6	4	4	24	32	768
Lab - small	5	505A	4	4	4	16	32	512
Lab - small	5	505A	4	4	4	16	32	512
Lecture	2	264	32	2	2U	64	32	2048
Lecture	2	265	24	4	T8	96	32	3072
Lecture	5	566	30	2	U	60	32	1920
Lecture	5	524	N/A	N/A	N/A	0	32	0
Lecture Hall	3	326	0	0	N/A	0	32	0
Lecture Hall	3	356	32	2	2U	64	32	2048
Lecture Hall	3	359	35	4	T8	140	32	4480
Lecture Hall	4	420	15	4	T8	60	32	1920
Locker Room	1	129A	8	2	4	16	32	512
Locker Room	1	131B	8	2	4	16	32	512
Lounge	2	269	8	4	T8	32	32	1024
Lounge	4	N/A	8	2	2U	16	32	512
Mech Rm	1	102	36	1	60W	36	60	2160
Office	1	122A	6	2	4	12	32	384
Office	1	123	8	2	4	16	32	512
Office	2	205	3	4	T8	12	32	384
Office	2	205A	5	4	T8	20	32	640

APPENDIX IV

SMITH HALL LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Office	2	206	2	4	T8	8	32	256
Office	2	208	6	4	T8	24	32	768
Office	2	212	6	4	T8	24	32	768
Office	2	213	6	4	T8	24	32	768
Office	2	215	6	4	T8	24	32	768
Office	2	215C	6	4	T8	24	32	768
Office	2	223	6	4	T8	24	32	768
Office	2	226	3	4	T8	12	32	384
Office	2	230	6	4	T8	24	32	768
Office	2	232	6	4	T8	24	32	768
Office	2	251	4	4	T8	16	32	512
Office	2	253	4	4	T8	16	32	512
Office	2	258	13	4	T8	52	32	1664
Office	2	263	4	4	T8	16	32	512
Office	2	267	13	4	T8	52	32	1664
Office	3	303A	4	4	T8	16	32	512
Office	3	304	8	4	T8	32	32	1024
Office	3	309A	4	4	T8	16	32	512
Office	3	312A	2	4	T8	8	32	256
Office	3	312C	2	4	T8	8	32	256
Office	3	312D	2	4	T8	8	32	256
Office	3	312E	4	4	T8	16	32	512
Office	3	312H	2	4	T8	8	32	256
Office	3	312I	2	4	T8	8	32	256
Office	3	312J	2	4	T8	8	32	256
Office	3	N/A	4	4	T8	16	32	512
Office	3	319	4	4	T8	16	32	512
Office	3	320	4	4	T8	16	32	512
Office	3	324A	4	4	T8	16	32	512
Office	3	341	11	4	T8	44	32	1408
Office	3	352	6	4	T8	24	32	768
Office	3	357	N/A	N/A	N/A	0	32	0
Office	3	360	9	4	T8	36	32	1152
Office	4	447	4	4	T8	16	32	512
Office	4	465	3	4	T8	12	32	384
Office	4	467	3	4	T8	12	32	384
Office	4	489,A	25	4	T8	100	32	3200
Office	5	589A	6	4	4	24	32	768
Office	5	589B	6	4	4	24	32	768
Office	5	568	6	4	4	24	32	768
Office	5	563	3	4	4	12	32	384
Office	5	567	3	4	4	12	32	384
Office	5	565	3	4	4	12	32	384
Office	5	569	3	4	4	12	32	384
Office	5	571	3	4	4	12	32	384
Office	5	572	3	4	4	12	32	384
Office	5	575	3	4	4	12	32	384
Office	5	577	3	4	4	12	32	384
Office	5	579	3	4	4	12	32	384
Office	5	561	3	4	4	12	32	384

SMITH HALL LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Office	5	559	3	4	4	12	32	384
Office	5	557	3	4	4	12	32	384
Office	5	555	3	4	4	12	32	384
Office	5	553	3	4	4	12	32	384
Office	5	551	3	4	4	12	32	384
Office	5	547	8	4	4	32	32	1024
Office	5	511	6	2	2U	12	32	384
Office	5	514A	2	4	4	8	32	256
Office	5	514B	2	4	4	8	32	256
Office	5	514C	2	4	4	8	32	256
Office	5	514D	2	4	4	8	32	256
Office	5	514E	2	4	4	8	32	256
Office	5	514F	2	4	4	8	32	256
Office	5	514G	2	4	4	8	32	256
Office	5	512	2	4	4	8	32	256
Office	5	502	4	4	4	16	32	512
Office area	4	445	10	2	2U	20	32	640
Office - Dean	3	312B	5	4	T8	20	32	640
Offices	4	412	9	4	T8	36	32	1152
Offices	4	419	18	4	T8	72	32	2304
Offices	4	449-63	24	4	T8	96	32	3072
Other	5	509A	4	4	4	16	32	512
Other	5	503B	4	4	4	16	32	512
Prep	3	309	4	4	T8	16	32	512
Prep	3	372	8	4	T8	32	32	1024
Prep Rm	3	322	15	4	T8	60	32	1920
Prep Rm - Herbarium	2	200A	4	4	T8	16	32	512
Prep Rm - Herbarium	2	200B	2	4	T8	8	32	256
Prep Room	5	509B	4	4	4	16	32	512
Prep Room	5	503A	4	4	4	16	32	512
Receiving	1	132	12	2	4	24	32	768
Shop Rm	1	103	12	1	60W	12	60	720
Snack area	2	238	4	4	T8	16	32	512
Storage	3	303	4	4	T8	16	32	512
Storage	3	308	N/A	N/A	N/A	0	32	0
Storage Rm	1	126	2	1	4	2	32	64
Storage Rm	1	125A	4	2	4	8	32	256
Storage Rm	1	128	7	2	4	14	32	448
Storage Rm	1	125	6	3	4	18	32	576
Storage Rm	1	131C	6	2	4	12	32	384
Storage Rm	1	131	6	2	4	12	32	384
Storage Rm	1	127	6	2	4	12	32	384
Tutor Ctr	5	538	10	2	2U	20	32	640
							TOTAL	**240,568**

APPENDIX V

COOK LIBRARY LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Bathroom	3	304	1	1	2	1	32	32
Bathroom	3	303	1	1	2	1	32	32
Bathroom	4	410C	1	1	2U	1	32	32
Bathroom	4	410G	2	1	4	2	32	64
Bathroom - M	3	324	4	2	4	8	32	256
Bathroom - M	4	402	5	1	4	5	32	160
Bathroom - M	5	501	5	1	4	5	32	160
Bathroom - W	3	323	7	1	4	7	32	224
Bathroom - W	4	403	7	1	4	7	32	224
Bathroom - W	5	503	7	1	4	7	32	224
Bathroom -M	1	47	2	2	4	4	32	128
Bathroom -M	2	N/A	4	2	4	8	32	256
Bathroom- W	1	46	5	1	4	5	32	160
Bathroom -W	2	N/A	4	2	4	8	32	256
Classroom	3	317	20	2	4	40	32	1280
Classroom	5	512	63	1	4	63	32	2016
Classroom	5	513	N/A	N/A	N/A	0	32	0
Classroom	5	526	N/A	N/A	N/A	0	32	0
Conference Room	4	404A	6	3	4	18	32	576
Conference Room	4	411	12	2	4	24	32	768
Conference Room	4	410F	2	4	4	8	32	256
Conference Room	5	524A	4	4	4	16	32	512
Conference Room	5	507	15	6	4	90	32	2880
Custodial	1	37	2	2	4	4	32	128
Custodial	1	48	1	1	4	1	32	32
Custodial	2	206	1	1	4	1	32	32
Custodial	2	204	1	2	4	2	32	64
Custodial	3	316	2	2	4	4	32	128
Custodial	3	305	1	1	4	1	32	32
Custodial	4	402A	1	1	4	1	32	32
Custodial	4	405C	1	2	4	2	32	64
Custodial	4	409	2	2	4	4	32	128
Custodial	5	502	1	1	4	1	32	32
Custodial	5	504	2	2	4	4	32	128
Hall	1	1	7	2	4	14	32	448
Hall	1	2	14	1	4	14	32	448
Hall	1	3	8	1	4	8	32	256
Hall	1	4	30	1	4	30	32	960
Hall	1	5	9	1	4	9	32	288
Hall	1	6	16	1	4	16	32	512
Hall	1	7	8	1	4	8	32	256
Hall	1	8	9	1	4	9	32	288
Hallway	3	N/A	3	1	4	3	32	96
Hallway	3	N/A	4	2	4	8	32	256
Hallway	4	N/A	9	1	4	9	32	288
Hallway	5	N/A	6	2	4	12	32	384

APPENDIX V

COOK LIBRARY LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Lab - Computer	1	35	59	4	4	236	32	7552
Lab - Computer	1	34	10	4	4	40	32	1280
Lab - Computer	4	404B	9	3	4	27	32	864
Lab -Media	2	202A	16	4	4	64	32	2048
Lobby	1	4Z	6	4	4	24	32	768
Lobby	2	200	16	4	4	64	32	2048
Lobby	3	300A	264	1	4	264	32	8448
Lobby	5	500	6	N/A	N/A	N/A	32	0
Lounge	4	400	6	N/A	N/A	N/A	32	0
Lounge - Staff	5	500A	3	4	4	12	32	384
Lounge - Student	5	525	6	4	4	24	32	768
Lounge - Vending	3	N/A	4	2	4	8	32	256
Meeting Room	4	401	3	6	4	18	32	576
Office	1	35A	6	4	4	24	32	768
Office	2	202	8	4	4	32	32	1024
Office	2	202B	6	4	4	24	32	768
Office	2	202C	2	2	4	4	32	128
Office	2	202E	4	4	4	16	32	512
Office	2	202G	4	4	4	16	32	512
Office	2	200C	10	4	4	40	32	1280
Office	3	308	2	4	4	8	32	256
Office	3	310	9	2	4	18	32	576
Office	3	311	3	4	4	12	32	384
Office	3	312	3	2	4	6	32	192
Office	3	314	8	4	4	32	32	1024
Office	3	319	2	4	4	8	32	256
Office	3	320	2	4	4	8	32	256
Office	3	321	4	4	4	16	32	512
Office	3	309	0	0	N/A	0	32	0
Office	4	405	8	3	4	24	32	768
Office	4	405A	1	2	4	2	32	64
Office	4	405B	1	2	4	2	32	64
Office	4	405D	1	2	4	2	32	64
Office	4	405H+I	5	3	4	15	32	480
Office	4	406	2	2	4	4	32	128
Office	4	408G	3	3	4	9	32	288
Office	4	408D	1	2	4	2	32	64
Office	4	408A	1	2	4	2	32	64
Office	4	408	10	4	4	40	32	1280
Office	4	408K	2	4	4	8	32	256
Office	4	408J	2	4	4	8	32	256
Office	4	410	14	2	4	28	32	896
Office	4	410D	3	4	4	12	32	384
Office	4	410K	2	4	4	8	32	256
Office	5	524	6	4	4	24	32	768
Office	5	524B	4	4	4	16	32	512
Office	5	506	4	2	4	8	32	256

APPENDIX V

COOK LIBRARY LIGHT SURVEY DATA								
Room Classification	**Floor ID**	**Room ID**	**Fixtures**	**Tubes per Fixture**	**Type**	**Total Tubes**	**Bulb Wattage**	**Power (W)**
Office - Repair	4	407A-I	25	1	4	25	32	800
Offices	3	329	140	2	4	280	32	8960
Offices	3	306	35	2	4	70	32	2240
Offices	4	405 E-G	5	3	4	15	32	480
Offices	4	408H+I	6	4	4	24	32	768
Reference Desk	3	330	65	1	4	65	32	2080
Stacks	2	210	733	1	4	733	32	23456
Stacks	3	325	227	4	4	908	32	29056
Stacks	4	420	499	2	4	998	32	31936
Stacks	5	509	521	2	4	1042	32	33344
Stacks - Auxillary	3	318	38	4	4	152	32	4864
Stacks - Periodicals	2	208	104	4	4	416	32	13312
Storage	1	42	45	1	4	45	32	1440
Storage	2	202D	19	1	4	19	32	608
Storage	2	202H	2	4	4	8	32	256
Storage	2	209	60	1	4	60	32	1920
Storage	3	307	4	4	4	16	32	512
Storage	3	302	2	2	4	4	32	128
Storage	4	404C	14	2	4	28	32	896
Storage	4	408F	1	2	4	2	32	64
Storage	4	408E	1	2	4	2	32	64
Storage	4	408C	1	2	4	2	32	64
Storage	4	408B	1	2	4	2	32	64
Storage	4	412	4	2	4	8	32	256
Storage	4	410A	2	2	4	4	32	128
Storage	4	410B	1	2	2U	2	32	64
Storage	4	410I	1	2	4	2	32	64
Storage	4	410H	0	0	N/A	0	32	0
Storage	4	410E	0	0	N/A	0	32	0
Storage	5	524C	2	4	4	8	32	256
Storage	5	505	61	2	4	122	32	3904
Study	2	201Z	10	1	4	10	32	320
Study	2	242F-214F	15	30	4	450	32	14400
Study	2	217	4	2	4	8	32	256
Study	2	213Z	12	1	4	12	32	384
Study or Storage	2	201-206	12	24	4	288	32	9216
							TOTAL	**242,624**

TOWER B LIGHT SURVEY DATA

Room Classification	Floor ID	Room ID	Fixtures	Tubes per Fixture	Type	Total Tubes	Bulb Wattage	Power (W)
Dormitory	N/A	all	206	2	2 ft	412	32	13184
Bathrooms	N/A	N/A	2	1	2U	2	32	64
Hallway	B1	N/A	14	2	T8	28	32	896
Hallway	B2	N/A	14	2	T8	28	32	896
Hallway - 1st flr	1	N/A	8	2	2U	16	32	512
Hallways	N/A	all	192	2	T8	384	32	12288
Lounge	B2	N/A	16	2	T8	32	32	1024
Lounge - 1st flr	N/A	N/A	10	2	T8	20	32	640
Lounge - study	B1	N/A	6	2	T8	12	32	384
Lounge - study	1	N/A	6	2	T8	12	32	384
Lounge - study	2	N/A	6	2	T8	12	32	384
Lounge - study	3	N/A	6	2	T8	12	32	384
Lounge - study	4	N/A	6	2	T8	12	32	384
Lounge - study	5	N/A	6	2	T8	12	32	384
Lounge - study	6	N/A	6	2	T8	12	32	384
Lounge - study	7	N/A	6	2	T8	12	32	384
Lounge - study	8	N/A	6	2	T8	12	32	384
Lounge - study	9	N/A	6	2	T8	12	32	384
Lounge - study	10	N/A	6	2	T8	12	32	384
Lounge - study	11	N/A	6	2	T8	12	32	384
Lounge - study	12	N/A	6	2	T8	12	32	384
Lounge - study	13	N/A	6	2	T8	12	32	384
Office - HRL	N/A	N/A	10	2	T8	20	32	640
Stairwells	N/A	all	28	2	T8	56	32	1792
Storage	N/A	N/A	22	2	T8	44	32	1408
Trash chutes	N/A	all	14	1	2U	14	32	448
Trash dumpster	B1	N/A	1	2	T8	2	32	64
Elevator	N/A	N/A	4	2	T8	8	32	256
Exit door area	N/A	N/A	3	2	T8	6	32	192
Front desk	N/A	N/A	3	2	T8	6	32	192
Kitchens	N/A	N/A	2	2	T8	4	32	128
Laundry room	N/A	N/A	16	2	T8	32	32	1024
Lobby	N/A	N/A	12	2	2U	24	32	768
Phone room	N/A	N/A	10	2	T8	20	32	640
Staff Apt	N/A	N/A	16	2	T8	32	32	1024
							TOTAL	**43,456**

APPENDIX VII

CALCULATIONS USING VERDIEM

Calculation of potential cost savings resulting from implementation of a computer power management system in Smith Hall.

119W x 24 hours/day x 365 days/yr =	1,042	kWh per computer and CRT monitor/yr
1042 kWh x 414 computers in Smith =	431,388	kWh used for Smith Hall PCs
kWh wasted-computer/monitor on, not in use	232,998	kWh (audit results)
kWh that could be saved	198,390	kWh
Computer/monitor calculations at $0.07 per kWh		
1042 kWh x $0.07 =	$72.94	cost/computer and monitor/yr
$72.94 x 414 =	$30,197.16	Smith Hall computers and monitors/yr
198390 kWh x $0.07 =	$13,887.30	potential savings
Cost to implement Verdiem		
$20 a computer x 414 computers =	$8,280	
$2 service per year x 414 computers =	$828	
	$8280+ $828 = $9108	
Time it takes to see savings		
$9108/$13887.30 =	0.66years	
0.66 months x 12 =	7.9months	
Savings first year =		
$13887.30-$9108 =	$4,779.30	
Savings subsequent years =		
$13887.30-$828 =	$13,059.30	
Computer/monitor calculations at $0.10 per kWh		
1042 kWh x $0.10 =	$104.20	cost/computer and monitor/yr
$104.20 x 414 =	$43,138.80	Smith Hall computers and monitors/yr
198390 kWh x $0.10 =	$19,839.00	potential savings
Time it takes to see savings		
$9108/$13887.30 =	0.46	years
0.66 months x 12 =	5.5	months
Savings first year =		
$13887.30-$9108 =	$10,731.00	
Savings subsequent years=		
$13887.30-$828 =	$19,011.00	

FLAT SCREEN MONITORS

Calculations of potential cost savings resulting from replacing CRT monitors with flat screen (LCD) monitors

LCD monitor	26 Watts
CRT monitor	71 Watts
Difference (savings if change to LDC)	45 Watts
45W x 24 hours/day x 365 days/yr =	394.2 kWh (saved/year)
394.2 kWh x $0.07	$27.59 savings per year at $0.07 kWh
394.2 kWh x $0.10	$39.42 savings per year at $0.10 kWh
Cost of LCD monitor	$300.00
Cost of CRT monitor	$140.00
Additional expense for LDC	$160.00
Time it takes to see savings at $0.07 kWh	
$160/$27.59	5.80 years
Time it takes to see savings at $0.10 kWh	
$160/$39.42	4.06 years