Lighting a Green Dorm

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EE15N
March 22, 2006

I. Abstract (By Syed Sayeed)

Wasteful lighting has environmental as well as economic costs. Our group addressed the question, “How can we make a more efficiently lighted dorm for the future?” We researched an array of different lighting technologies, power management options, and alternative energy sources to come up with combination of options for a more efficient lighting system in a dorm. We settled on technologies including light emitting diode (LED) lighting and solar powered voltaic cells to present the most efficient lighting and powering sources. We also suggest that smart power management options like timed lighting or other types of “smart” switches be used. The result: a cheaper, cleaner dorm.

II. Executive Summary (By Steven Scardato)

The complete design of this project addresses the components of an LED lighting system in a residential setting, the physical arrangement of lighting placements to maximize the lighting efficiency, and the application of supplemental solar lighting all with the aim to achieve the highest cost to operation ratio.

The components of the lighting system will consist of high efficiency LED light bulbs, the appropriate hardware to run the bulbs, and the necessary switches, timers, and sensors called for by the application, which in combination will minimize the amount the light consumption, thereby minimizing cost. It is difficult to determine the type of bulbs that will be used because LED technology is still in its infancy and has just begun to become a feasible lighting option in certain situations. The current technological progress in LED lighting proves to make it a viable option for the industrial and residential market use in the near future.

The physical arrangement of the lighting placement will be application based. A major contributor in power consumption in terms of lighting is the use of extra lamps in dorm rooms because of the inefficient and uneven manor in which a single overhead light provides. The most effective method for alleviating this issue is to implement multiple light sources in each room. This will not only allow one side of the room to stay lit while the other person in the room can sleep, it will also eliminate the need for extra light sources. The amount of ceiling lighting sources would depend on the size and shape of the room.

A large part of the cost optimization in this lighting system is the partial reliance on solar power. This percent reliance depends on how many panels can be incorporated and the most practical type of electrical storage medium for each application. Although just a supplement to a hard-line power source, the aim of the solar power would be to provide a substantial percent of the total power consumed in each application.

The integration of high efficiency lighting, more effective control methods, and supplement solar will yield a cost and saving alternative to present day solutions that not only benefits the consumer monetarily, but also environmentally because of the large decrease in energy needs for lighting.

III. Introduction and Overview (By Syed Sayeed)

The Cost of Electricity:

According to the Energy Information Administration's *End Use Consumption of Electricity* report for 2001, the average American residence consumes 10,656 kilowatt-hours of electricity per year.[1] With 107 million households in the US, that translates to 1,139.9 billion kilowatt hours of electricity per year. Of this, 9.1 percent of the

[1] http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html

electricity goes to lighting—that's about 110.6 billion kilowatt hours of electricity consumed for residential lighting per year.

How much does this cost? According to the Department of Energy, in 1998, the average cost of electricity was 8.3 cents/kwH in the US—that computes to about 9.2 billion dollars nationally in residential lighting costs.[2] The cost may be greater to the environment. Burning coal produces 2460 kilowatt hours per ton. To power just one 100 watt incandescent lightbulb for a year would require burning 740 pounds of coal. Byproducts of burning this much coal include five pounds of Sulfur Dioxide (the main cause of acid rain), five pounds of Nitrogen Oxides (the main cause of smog and one of the main causes of acid rain), and 1,852 pounds of Carbon Dioxide (the main greenhouse gas that is leading to global warming).[3]

If the pollution and cost figures aren't convincing, the importance of creating an efficient lighting system in our dorms hits home when you consider that a typical laptop computer can be run with the electricity consumed by a 60-watt light bulb, which can typically be found in any desk lamp.[4] There is about one on every Stanford student's desk.

Our Problem and How We Will Go About Solving it:

Lighting is one of the most obvious areas through which to address the issue of energy consumption. Not only is this a source of much of the energy wasted in dorms today, but there are numerous ways—many resulting from cutting-edge science—to address the problem. Our group chose four areas to emphasize in our proposal for a green dorm lighting system. We focused on the production of the light through different

[2] http://michaelbluejay.com/electricity/cost.html
[3] http://science.howstuffworks.com/question481.htm
[4] http://michaelbluejay.com/electricity/computers.html

lighting technologies, power generation and alternative energy sources, power management and controlling when the lights are turned off and on, and placing lights in the most efficient setup to meet students' needs.

IV. Lighting (By Steven Scardato)

Cost Reduction:

The most effective way to reduce cost in a lighting system is to reduce the amount of power consumed. We have addressed the different ways to minimize light consumption in regards to lighting control, but the most significant power draw comes from the method of illumination. The newest technology in regards to lighting is the light emitting diode (LED), which is what we plan to use as a method for cost reduction in our lighting system. Currently, this technology has not been implemented in the industrial lighting market mainly because of the issue of supply. This technology is still in its infancy and because of this production is low and cost is relatively high. There is also no standardization which makes large scale implementation very difficult. The overarching technology associated with LED development is called solid-state lighting. It is called this because a block of semiconductor is used as a means for illumination as opposed to a gas or electric filament.

Benefits:

The benefits of solid state lighting are very clear. An LED is much more durable compared to any other type of lighting because there is no tube or filament to break. The life spans of a typical LED is much greater than that of comparable lighting methods. Incandescent bulbs currently carry a typical rating of 1000 operating hours where LED's currently have an average operating time of 100,000 hours. The heat loss compared to other forms of lighting is much reduced therefor reducing the amount of energy lost to heat. This in turns adds to the overall efficiency of solid state lighting. The size of LED's makes them very attractive methods of lighting because of the added flexibility in design. The circuitry necessary to drive LED's is much simpler and less expensive than the circuitry used in fluorescent technology, and the whine associated with many fluorescent circuits is not present in LED circuitry.

Disadvantages:

Current LED efficiency does not meet or exceed many of the current lighting options available today. Current LED technology is only able to deliver at most 60 lumen/watt. The lack of market availability has made prices for LED bulbs many times more expensive than their incandescent and fluorescent counterparts. LED are also most efficient as a single wavelength light source. This makes emitting white light more difficult and less efficient. The most efficient current white light LED technology uses a blue LED coated in a material that emits white light when exposed to the wavelength of blue light. In order for this technology to become the standard in the industrial world, the creation of an LED market will be necessary. Since there is no demand there is no market, and until there is a demand there will be no market. Early adopters of this technology will pay the price becuase of the hardware prices but they will be the ones who spur the development of the market and ultimately allow for solid state lighting to become a viable standard.

Future:

The future of solid state lighting is very bright. The two current major contributors to solid state lighting development are the Department of Energy and the

Industry Development Association. They both spend millions of dollars funding all the research that is going into solid state lighting technology. The DOE currently has spent $50 million dollars funding forty five research projects on high efficiency LED's development alone. Some of the most significant research is going on by Sandia National Laboratories, Rensselaer Polytechnic Institute, and the National Electric Manufacturer's Association. They predict that solid state lighting will emerge as the choice method of lighting for all circumstance by the year 2025. The predictions based from current technology trends is that solid state lighting will have an efficiency of 200 lumen/watt compared to 104 lumen/watt from fluorescent lighting, its closest competitor. The benefits of a mature solid state lighting technology are predicted to be extremely significant. The overall world power consumption used for lighting would see a decrease in consumption by 50 percent and an overall total ten percent decrease in consumption, which would in turn greatly reduce the amount of carbon dioxide produced as a by product from power plants.

V. Power (By Greg Ter-Zakhariants)

As described earlier, the majority of conventional electricity provided to the typical household is produced by burning coal in power plants, which pollutes the atmosphere with many chemicals. For this reason we decided to look for another means for producing electricity. A very environmentally-friendly way of acquiring electrical energy is using solar panels.

On a bright, summer day, the sun produces about 1000 Watts per square meter on the earth's surface. For this reason, we have decided that using the sun's energy to power our green dorm. Since this project would be expensive under the current circumstances, not all the energy for the dorm will be produced by the sun. The energy from the sun's light can be captured by solar cells and panels, distributed on a photovoltaic (PV) module.

Since silicon is a semiconductor, and is the second most abundant element in the earth's crust, it is the material of choice when it comes to solar cells. The most common type of solar cell used for PV modules is single crystal silicon. Other types include: polycrystalline silicon, amorphous silicon (having no crystal structure), gallium arsenide, copper indium diselenide. Different materials have different band gaps, the amount of energy required to knock an electron loose and begin the process of starting a current that combines with the voltage to produce electricity (different band gaps capture different frequencies of light). The single crystal silicon has proven to be the most efficient when it comes to power.[5] Many other materials have been experimented with only with the intention of reducing costs. However, the low-costing materials have reduced efficiency, which is why the single crystal silicon is the most commonly used. To make up for the unused energy (because of a material's band gap), some solar cells are made with several layers of material, each with a different band gap, so that the cell could capture more light, and be more efficient. However, this type of cell is quite expensive to produce, so the singly crystal cell remains the favorite.

Now we move on to storing the energy that the PV module produces. a PV module has to store its energy somehow, and one way of doing so is a battery. However, a battery is hard to maintain, and is unsafe when cleaning, and is an overall hassle. In order to be completely powered by the sun, though, a battery is necessary. Another method of storing energy is connecting the PV module to the power/utility grid

[5] http://www.solarserver.de/wissen/photovoltaik-e.html

to which the rest of the city is connected. Though this is convenient, it is at the same time a nuisance. Firstly, the utilities cost money, so on a cloudy day, the PV module would get energy from the utility, and then when the PV module produces more energy than needed during a sunny day, the energy would be sold back to the utility company. With this transference of power, special hardware needs to be installed for the transfers to run with no problems concerning safety. Secondly, the PV module produces direct current, while the utilities produce alternating current. Therefore, an inverter needs to be installed in the solar cell system, so that the AC current could be converted to DC. We will therefore use a PV module with an inverter built into it, called conveniently an AC module.

Today, because of all the hardware needed for the installation of a PV module, the whole installment ends up costing $9 per Watt.[6] So, with these measures, a module producing 5 kW of power would cost $45,000. The costs are high because solar cells cannot yet compete with the utilities. However, as research of solar power continues, costs continue to decrease. It is expected that some day the cost of solar cells will be low enough to be massively produced and will become fairly common.

There are many projects such as ours going on around the world, both on larger and smaller scales.

One example is the wholesale club, BJ's. With one location in Deptford, New Jersey, BJ's wholesale club donated its roof space in 2001 to Green Mountain Energy Solar at Southern New Jersey (owned and operated by Sun Power Electric). Green Mountain built 12,000 sq. ft. of solar cells, consisting of 1,330 – 2 x 4ft. panels, producing 52 kW. Because of these solar panels on the roof of BJ's, Green Mountain

[6] http://science.howstuffworks.com/solar-cell11.htm

has estimated that the emission of carbon dioxide would be reduced by 40 tons annually. As a result, BJ's saved over $1M and 12M kW-hours in that year. In exchange for the roof space donation, BJ's receives discounts on its electricity.

Another example, more closely related to our project, is going on in Synergy House at Stanford. The system they installed in 2003 is 7.5 kW, and although it cost them $77,816 initially, Synergy saves 11,164 kW-hours per year, $1,978 in costs per year. Over 30 years Synergy will have saved $131,432, and will have avoided 221 tons of carbon dioxide. Synergy has already avoided almost 30,000 lbs. of carbon dioxide and 9 lbs. of nitrous oxide.[7]

If our PV module will follow any examples, it will follow the example of the Stanford dorm, Synergy. In order to receive the most sunlight, the PV module will face true south, since we are in the northern hemisphere. The PV module will be an AC module, built with an inverter to convert DC current to AC. Finally, the solar cells will be made of single crystal silicon.

VI. Power Management (By Taylor Bragg)

In our group's design of an energy efficient lighting system in a dormitory, one of the main components that our group discussed is power management. That is, to how minimize energy consumption when lighting is not needed around the dormitory. We believe that the first step to improving a lighting system would be to reduce the unnecessary energy waste of the existing method. To answer this question, our group researched a number of different power management applications, including Photosensors, Occupancy Sensors, Dimmers, and Timers. These devices are used to turn the lighting on when needed or turn it off when it is no longer useful.

[7] http://www.stanford.edu/dept/hds/shs/conserve/pastprojects.html

When dealing with our design, we set our design spectrum to cover the three general areas in the dorm: the hallway, the lounge area, and the dorm room. In order to accurately determine the level of power management needed for our energy efficient lighting system, our group first examined the different uses and lighting demands of each of the three areas.

Dorm Room:

For dorm rooms, we concluded that current methods of operating the lights are already optimal, because each student has their own schedule and will need to control the lights at their own leisure. In addition to the mechanical switches, our group came up with possible improvements that would make the lighting system more efficient, including the installation of dimmers and by giving energy management workshops to the students. Light dimmers would allow students to control the lighting level, and energy consumption, of their rooms during times when they may not need that much light. Prices for light dimmers can range anywhere from $20-30.[8] The energy management workshops would inform students how minimize energy consumption while maximizing the lighting of their rooms by using natural light, turning off the lights when they are not needed, etc. These ideas, however, are merely meant to be in addition to the current system of managing lighting in dorm rooms.

Hallways:

In regards to dorm hallways, our group's main concern was how hallway lights are left on all day, every day of the week. We all agreed that this was not the most

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8 http://www.homedepot.com/prel80/HDUS/EN_US/diy_main/pg_diy.jsp?CNTTYPE=PROD_META&CNTKEY=misc%2fsearchResults.jsp&BV_SessionID=@@@@0902636345.1143012386@@@@&BV_EngineID=ccchaddhfmgkdikcgelceffdfgidgjn.0&MID=9876

effective way of lighting the hallway, because there are always hours in a given day when no one is going to be in the hallway, specifically the hours between the very late at night and the very early in the morning. In response to this, our group decided that a timer equipped with a motion sensor override would be the most effective way of turning of the lights during times when many people are not going to need them. The motion sensors would override the timer, so that if someone is walking in the hallway while the lights are turned off from the timer, they will turn on. Price quotes for timers and motion sensors range from $40-50 and $20-60, respectively.[9] We believe this is the best solution because it minimizes unnecessary energy usage during the hours when the lights are not needed.

Lounge:

The final location that we included in our project is the lounge area of a dorm. Commonly, the lighting in these areas is operated by mechanical switches that can be accessed by students at their leisure. Our group found that, during the day, these lounge areas are already very well lit and do not require much more lighting. In these instances, having the lights on when the room is already lit is unnecessary as well as wasteful of energy. A viable solution to this would be to place photosensors in the lounges which would monitor the light levels in the lounge and turn on the lights when the levels get below a certain level. Normal prices for photosensors can range from $40-60.[10]

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[9] http://www.homedepot.com/prel80/HDUS/EN_US/diy_main/pg_diy.jsp?CNTTYPE=PROD_META&CNTKEY=misc%2fsearchResults.jsp&BV_SessionID=@@@@0131598076.1143013544@@@@&BV_EngineID=ccdfaddhfmgkfejcgelceffdfgidgll.0&MID=9876

[10] http://web1.automationdirect.com/adc/Overview/Catalog/Sensors_-z-_Encoders/Photoelectric_Sensors?source=google&keyword=photosensors&type=search

VII. Lighting Direction (By Syed Sayeed)

Residents of any room have specific needs for lighting that should be addressed when planning how a lighting system is going to be laid out in a room. When these problems are not taken into account, students take actions on their own to fill their lighting needs that often lead to environmentally inefficient situations.

Currently the system employed in dorm rooms is that of one large overhead light. In most dorm rooms today, since desk lighting is not provided, students purchase desk lamps that use incandescent bulbs, the most inefficient type of bulbs today. Students also often purchase inefficient lamps that serve as decorative lighting.

We considered a few different alternatives. In the first, which is currently in practice, there is one overhead light that will be provided by the dorm in each room. In another, the dorm will have a high-efficiency desk lamp attached to each desk for each student. This will eliminate the need to purchase desk lamps. Finally a last alternative would be an all-included lighting system, which would contain spotlights on the ceilings that would allow students to light any part of the room they wanted, eliminating the need for students to purchase any additional lighting systems that could otherwise present inefficiencies.

The overhead light serves the most general need for students to have a lighted room. It provides the least physical cost in producing a lighting system since only one light fixture is installed. However, it creates the need to purchase additional lighting, which often proves inefficient and costly.

When desk lamps are also included, the majority of students' needs are met completely. High efficiency desk lamps would dramatically reduce the overall power consumption of the lighting system in the dorm and would also reduce costs for students, including purchasing desk lamps, storing them and replacing light bulbs.

An all-included lighting system would eliminate the need for any additional lighting. However, this might prove inefficient as the system might go unused by students. It would create a much higher cost in terms of purchasing and installing equipment.

We decided on including both one overhead light to light the whole room and desk lamps for each desk in the room. The housing system would keep an inventory of these desk lamps just as they keep an inventory of room furniture. While they may present an additional upfront cost in terms of equipment, the energy savings in the long run would outweigh those costs.