IPRO 337 Final report

Spring 2007

Energy Efficient Lighting Design Using LEDs and Other Technologies

Advisor: Nancy Hamill Governale

0.1 Introduction

Energy efficiency is a really big problem in today's society and Ipro 337: "Energy Efficient Lighting Design Using LEDs and Other Technologies" was introduced in an effort to find a lighting system that reduces the amount of energy wasted in conventional lighting solutions used today. This lighting system will be developed for a real world application for construction. For the purposes of this IPRO, though, we will use the 4th floor of machinery hall on IIT's campus as a testing ground. The goal of this IPRO is to create an ultra low energy consuming lighting system, with emphasis placed on creating the maximum amount of artificial lighting requiring the least amount of watts per square foot as possible. With the use of LED technologies, one of our biggest problems is the initial cost of this type of system. Because it is fairly new, we have to figure out a way to utilize the efficiency of LEDs and/or other lighting technologies.

0.2 Background

The Zero-Energy Lab was sponsored by IIT & donors to turn 4th floor of Machinery Hall into a research and teaching lab that demonstrates zero-energy usage. In order to achieve the objective, the IPRO team must come up with a design that implements the most energy-efficient lighting scheme available.

The lighting products available on the market fall into two categories: The first is conventional lighting including fluorescent and incandescent lights. These are the "traditional" or "old" types of lighting scheme that are widely used. The second is Light-Emitting Diode (LED) light. LED lights are the emerging technology that has very respectable efficiency.

Fluorescent and incandescent lights had been used for so long that they became the norm in residential and commercial lighting. The effectiveness of a light medium is measured loosely by the light it produces (measured in lumens) versus the power it consumes (measure in W). Typical incandescent light bulb has an efficiency of ~5% [1] with a light output around 15lm/W for a 60W bulb. Fluorescent light can last twice as long as incandescent and has twice the efficiency of an incandescent. Research conducted by the team led to a new feature of fluorescent light that incorporate light sensor to utilize sunlight thereby cutting back energy consumption. Axis Technology Inc. is the creator of the design and claimed that it would save 70% of the electricity bill[2]. Due to the nature of this project, the use of incandescent light was eliminated from the design.

[1] Consumer Utilities Services, http://www.cus.net/electricity/subcats/eleclighting.html
[2] http://www.axistechnologyinc.com/home.html

LED, on the other hand, uses less electricity to produce roughly the same amount of illumination[3]. In 2002, Philips Lumileds introduces a 5W power LED with a range of 18-22lm/W. Higher efficacy LED lighting are also available on the market. One of the final products selected for this design is the Sealed LED tube light from LEDtronics, a web-based LED specialist manufacturer[4].

An issue with implementing a LED lighting scheme is the initial cost. It takes longer for the energy-efficiency to balance out the initial cost, and even longer for users to benefit from savings on the utility bill. The second issue is that almost all building structures were built to accommodate the fluorescent and incandescent light, so introducing LED might pose potential problems such as re-wiring, relocating light source, etc.

Energy saving is an important benefit from this project because wide uses of energy-efficient applications will reduce the dependence on fossil fuel and therefore eliminate pollutions and create a safer environment for future generations. Further more, renewable energy is gaining popularity now so it is only a matter of time before the public fully embrace it. This IPRO will serve as a role model for the use of renewable energy because the power source for the lights comes from a 5.5kW Photovoltaic panel. In the mean time, gaining public support for LED-base lights will be difficult because they are new, expensive and not widely available. As mentioned earlier, incandescent lights are still the norm of general illumination, therefore LED-base light will have to achieve a certain level of widespread use before it can fully compete with incandescent and fluorescent. Hopefully with the increasing numbers of energy-conscious consumers, LED light will reach that state soon.

0.3 Purpose

The purpose of Ipro 337 was to incorporate energy efficient lighting technologies into an existing 6,000 sq ft space, thereby adding to the transformation of the space into a new useful zero-energy lab. Through the Testing and measurement of energy consuming Devices that are scaled for renewable energy systems such as photovoltaic, battery storage, and fuel cells it would be possible to provide better energy efficient designs. With the demonstration of the use of day lighting for ambient light and incorporating a scoop to make the best us of the natural light available we would be able to reduce the amount of common light fixtures; furthermore, with the use of low energy consuming systems for task lighting and night time lighting the amount of used energy would diminish. With the development of low energy consuming lighting systems including fixture mock ups, lamp mock ups, day lighting harvesting

[3] http://www1.eere.energy.gov/femp/newsevents/release.cfm?news_id=10040
[4] http://www.ledtronics.com/product_news/cpower_article_053006.htm

systems, fiber optic day light utilization systems, fixtures utilizing LED, low wattage fluorescent and direct and indirect lighting fixture design we would be able to provide new and possible better fixtures then what is currently available.

0.4 Research Methodology

In order to accomplish the problem set forth in this IPRO The team conducted a site visit to get a feel for the space. During the subsequent sessions, we listed all the tasks needed to accomplish the goal from beginning to end. Then the tasks were grouped into phases. There are 3 phases: Analysis, Design and Implementation.
In the Analysis phase, we created two sub-teams and named them Design/Rendering and Product Research. The D/R team was responsible for designing the layout of the space, rendering a 3-D model of the space with actual light fixtures and illumination analysis. The P/R team was responsible for doing extended research on the different lighting solutions including: LEDS, different types of fluorescent bulbs, hybrid solar systems, lighting ballasts(i.e dimming), motion and light sensors. We also had two guest speakers, one from Focal Point and one from Phillips lighting company to give us more insight on fluorescent lights and LEDs.
In the Design phase, the team then decided that we should design our own light fixture as an example of a future solution for a lighting system. So both sub-teams came back together to come up with about two designs per team member.
The implementation phase lead us to regroup into two new teams: The lighting fixtures Team and the light scoop/Mock- Up team. The lighting fixtures team was responsible for researching existing lighting solutions, coming up with fixtures to use in the space, as well as, selecting a couple fixture designs that the team came up with to build for the space. Due to the lack of time, the lighting fixture group only had time to build one fixture. The light scoop team was responsible for researching light shelves and scoops, the different materials that could be used, refining the design of a light scoop for the space, building the light scoop, and then measuring the foot candle difference with and without the scoop. The light scoop team selected a portion of the space for a test section and constructed the light scoop in that space, trying three different materials for the light scoop.
All results of the research and tests was documented By the sub-groups and team members then made available to everyone to have access to all of the findings. Results were then analyzed and evaluated and recommendations for further research in the continuation of this IPRO next semester were made.

0.5 Assignments

Since the midterm report, the team organization has shifted. We started with product research and design and then moved into light fixture design and mock-up. We also added a website design team. The breakdown of team assignments for the entire project are as follows:

Team Leaders

- Anthony Glencoe
- Leslie Ann Williams

Sub- Teams

1. Product Research Team

    - Marcin Antol
    - Patrick Bowles
    - Michael Ericksen
    - Anthony Glencoe
    - Christian Hubbard
    - Minh Nguyen
    - Leslie Ann Williams

2. Design Team

    - Olasoji Denloye
    - Colin Emch-wei
    - Carolina Hidalgo
    - Omar Husain
    - Brian Neiswander
    - Hin Hei Ng

3. Deliverables Team

    - Anthony Glencoe
    - Omar Husain
    - Minh Nguyen
    - Leslie Ann Williams

4. Web design team

- Patrick bowles
- Brian Neiswander

5. Mock– up team

    - Marcin Antol
    - Anthony Glencoe
    - Carolina Hidalgo
    - Brian Neiswander
    - Hin Hei Ng
    - Leslie Ann Williams

6. Light Fixture Design/Mock–Up

    - Olasoji Denloye
    - Michael Ericksen
    - Christian Hubbard
    - Omar Husain
    - Minh Nguyen

Sub– Team Leaders

- Minh Nguyen– Product Research Team
- Colin Emch–wei– Design Team
- Omar Husain– Deliverables Team
- Patrick Bowles– Web Design team
- Marcin Antol –Mock– up team
- Minh Nguyen– Light Fixture Design

Sub Team Responsibilities

1. Product Research Team

- Research existing energy efficient lighting solutions.
- Research conventional lighting solutions.
- Research Led lighting solutions.
- Research most efficient lighting solution for the best price.
- Come up with an original lighting design fixture.

2. Design Team

- Revise the Design scheme for proposed space.
- Draw floor plan of space in Autocad.
- Make a 3D model of space and render model on computer.
- Come up with an original lighting design fixture.
- Implement original lighting design fixtures into 3d model of space and render different solutions.

3. Deliverables Team

- Keep track of Deliverables and deadlines.
- Revise project plan and complete the midterm report.

4. Web design team

- Design a website for ipro 337 that is able to be easily navigated.

5. Mock- up Team

- Build mock-up of lighting solutions
- Help take mock- ups down.

6. Light Fixture Design Team

- Select fixtures to be used in design of space from individual designs.
- Build a sample of selected fixtures that might be used in space.

Sub- Team Individual Responsibilities

1. Product Research Team

- Marcin Antol- Research energy efficient Fluorescent lighting solutions.
- Patrick Bowles- Research daylight harvesting systems.
- Michael Ericksen- Research light/motion sensors.
- Anthony Glencoe- Research Led lighting solution.
- Christian Hubbard- Research solar hybrid solutions and LED lighting solutions.
- Minh Nguyen- Research Led lighting solutions and light/motion sensors.
- Leslie Williams - Research daylight harvesting systems and solar hybrid solutions on computer.

2. Design Team

- Olasoji Denloye- Research materials for space.
- Colin Emch-wei- Computer aided simulation.

- Carolina Hidalgo– Research materials for space and assigning uses to space.
- Omar Husain– Research photometric standards(lighting levels).
- Brian Neiswander– Research materials for space and assigning uses to space
- Hin Hei Ng– Design/ furniture layout of space.

3. Deliverables Team

- Anthony Glencoe– Parts 1.0 of midterm report.
- Omar Husain– Part 3.0 of midterm report.
- Minh Nguyen– Parts 2.0 and 5.0 of midterm report.
- Leslie Ann Williams– Part 4.0 of midterm report.

4.Web design team

- Patrick Bowles– will upload all of the team information and pictures to the website.
- Brian Neiswander– will come up with design for the website pages.

5.Mock– up team

- All Team Members– will help build a mock–up of the lighting solutions that we come up with and decide to test. This included a light scoop that was designed and tested in the space.

6. Light Fixture Design Team

- All Team Members– will help in selecting the lighting fixtures designed by the individuals on the IPRO team that will be suitable for implementation into the proposed space. Then they will help with the building of said light fixtures.

The overall team organization remained the same. However, in order to move forward in this ipro, it was necessary that a mock–up and lighting fixture Design team be developed so that we could start building some of our lighting design solutions. There was also a need for a website team so that we could document and have all of our information readily available.

0.6 Obstacles

The main difficulty was the research phase of the project. Even though team members were given separate product types to research, the overwhelming product availabilities made it time-consuming to pick out the appropriate one. For example, when choosing the best energy-efficient conventional light, a team member has to search through several companies with hundreds of products to offer.

The next difficult phase was deciding the lay-out of the space because illumination levels depend entirely on how the space will be used.

After deciding on the layout of the space, then came the process of narrowing down our research to which light fixtures we would use. This was difficult because as aforementioned, the product availability was massive. However after we decided to just pick one of our own light fixture designs things got moving again. Considering the space we were using the mock-up team ran into a few problems trying to get the space in a condition suitable for working. In order to do this we needed IIT's Facilities to clean the windows where we planned to construct the mock-up and it was difficult getting them to do this in a timely manner but we eventually just decided to do it ourselves for the sake of time. An obstacle that also still exists is the cost of an energy efficient lighting solution. The initial cost of implementing this new system is still quite costly. So in the future, more research needs to be done as to how this system can be accomplished for the smallest cost. Further cost analysis needs to be done.

Two of the main obstacles that we had, time and money, still exist. We didn't have enough time to try more light fixtures in the space and the money needed to completely renovate the space and implement a lighting system needs to be fundraised or something. For the sake of this semester, though, we wrapped up everything we did do and can to conclusions based on that. We did the best we could with the resources that we had, thereby making it worth while for the project to be continued and completed by a continuing ipro team with the time in the future. For continuation of this IPRO into another semester, we propose fundraising. This will help with the cost to renovate the space. Also, more sponsors are needed to help with the cost of completely renovating this space and implementing the energy efficient lighting solution designed by the IPRO team. So obstacles still remaining are time, money, research, and cost analysis.

0.7 Results

results of IPRO 337 were five sub-teams in the project, with team members alternate between sub-teams depend on weekly tasks. These five teams are: Product Research, Rendering, Mock-up, Website Design and Deliverables.

- Product Research: In addition to research for the right products, team members were able to invite industry professionals to give demonstrations and workshops for the entire project team. These guests were:
    1. Mr. Barry Kies from Key Lighting Sales, Inc
    2. Carl Cindric a Lighting Distributor came and gave a Demonstration of different lighting elements and the visual effects they produced. The project team learned about lighting standard for different scenario's from the brochures that were given to us.
    3. Mr. Tim Moss an Electronic Design Engineering from Philips Lighting Electronics.
    4. Also a Visits to Focal Point was organized where Phil Mancuso was kind enough to show us around there local manufacturing plant and explain many different aspects of how lighting fixtures are constructed.

- Rendering: Team members conducted on-site visits, data collection and created a clear and concise lay out of the space. Additional rendering were done when new lighting schemes were designed by the Product Research Team.
- Mock-up: Team members ordered samples from finalized products authorized by faculty advisor and project team. Mock-ups were created to demonstrate outcome of the design.
- Website Design: Team members collect inputs from project team and organized them to create an informative website to showcase the entire project. www.iit.edu/~ipro337s07
- Deliverables: Team members kept track of deliverables and deadlines along with

	Conventional	*LED*	*HSL*	*Sunlight*

working on fulfilling the final requirements for the IPRO office.

Products considered	T-series bulbs (T8, T12, T5)	Panel, Directional,		
Pro	Inexpensive High-efficient Long Lasting	Superb efficiency Long lasting	Virtually unlimited source Low initial cost ($4.00/ft^2)	Free! Higher light output Really long lasting
Con	Inexpensive High-efficient Lon	Expensive Low light output	Size vs. Efficiency[5] Low return rate ($500.00/20yrs/system) Long Lasting	Variable efficiency Space location

Several types of illumination were considered to accomplish project's goal. They are: conventional light, LED light, Hybrid Solar System (HSL), and sunlight.

Elements from our space and different lighting fixtures were studied and incorporate into proposed designs. For example, new light fixtures were created by molding the aluminum and metal in different direction to maximize reflected light. Another idea is to hang large decorative picture panes with special coating to reflect sunlight. The project team considered all options available to achieve our goals.

Samples and materials were obtained to create mock ups of both several scoop designs and a lighting fixture. Which were then tested to see there effects within our space. Below is a cost chart which shows the funds which were spent for IPRO 337.

ITEM	UNIT PRICE	QTY	PRICE	PURPOSE
Gutter guard and string	$10.59	1	$10.59	Light fixture
LED Light Bulb	$29.99	2	$59.98	Testing lighting output
Fabric	$26.09	1	$26.09	Light scoop
Foam core board	$11.74	1	$11.74	Light scoop
Metal Flashing	$37.75	1	$37.75	Light fixtures
Nylon String	$2.99	1	$2.99	Light Fixtures
led rope lights	$17.99	1	$17.99	to test effects of light and develop new lights
Acrylic	$4.99	1	$4.99	Light Fixture
IPRO day	$80.00	1	$80.00	poster printing and set up materials
Total:			$252.12	

5 (4ft^2 roof-mount dish/1000ft^2 illumination)

With spring 2007 IPRO 337 almost complete our team has gain extensive knowledge on lighting products and technologies to team work and effort to bring an objective to a completed state. Through the process of research, design, deliverables mock ups, information sharing, constructive criticism to our IPRO day we have all been exposed to many new experiences and information. Furthermore, these experiences and information have affected each of us in a different manner which can only be explained by each individual.

0.8 Recommendations

Our further recommendations to the future IPRO 337 and to the planners of the existing space at the top of Machinery Hall is that In order to use the space to it's fullest extent in becoming an energy-efficient space; continuing research and renovation of the space must be completed. Further research and testing that should be accomplished is more extensive Studies of current energy-efficient lighting technologies and the amount of energy which is really saved which was presented to us by Mr. Key's when discussing led technology. More lighting mock-up's should also be designed and created for testing to see if there are better ways to multiply the amount of light created with using the least amount of wattage. While looking at what was created by the Spring IPRO 337 ideas on both designs and materials can bring inspiration to new ideas and technologies. Furthermore, more data and testing needs to be collected to see the exact amount of energy which can be produced and stored from the current photovoltaic cells located on the top of machinery hall. A final plan for the lighting Plan and space plan of the space would also need to be completed.

As for the Renovation of the space; further removal of all the existing items in the space should be concluded. All the walls, windows, floors and ceilings would need to be cleaned and prepped for work which would include painting, flooring and possible replacement of existing windows.

Finally the implementation of the lighting layout and furniture plan would need to be installed. This would allow for the final occupancy and presentation of the space.

0.9 References

RESEARCH
1. LED Sealed tube light from LEDtronics:

Spec sheet:
http://www.ledtronics.com/DS/tbl3xx/

news release:
http://www.ledtronics.com/product_news/cpower_article_053006.htm

2. Department of Energy's LED Funding for research article (used for part of product comparision)

http://www1.eere.energy.gov/femp/newsevents/release.cfm?news_id=10040

3. Daylight Harvesting Ballast from Axis Technologies Inc.

www.axistechnologyinc.com

4. Basic FYI about fluorescent and incandescent:
fun-led-light:
http://www.fun-led-light.com/incandescent-vs-fluorescent.html

PHOTO reference

Used in Abstract:

Darkroom: www.ntticc.or.jp
Light prism: encyclozine.com/Physics/PropertiesofLight.html

For final report

Used in Background session:

Consumer Utilities Services:
http://www.cus.net/electricity/subcats/eleclighting.html

Department of Energy, Federal Energy Management Program
http://www1.eere.energy.gov/femp/newsevents/release.cfm?news_id=10040

Other Useful sites

http://www.lrc.rpi.edu/programs/NLPIP/lightingAnswers/t8/abstract.asp

http://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/lat5/abstract.asp

http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SR_DEB99.pdf

0.10 Acknowledgements

We would first and foremost like to thank Nancy Hamill Governale for making IPRO 337 a reality. As our advisor and a key part of our project from assisting us in decisions making, answering questions, setting up speakers to guiding us till the very end of our IPRO 337 experience she has helped us reach our completion of the project.

Secondly we would like to thank Mr. Barry Kies from Key Lighting sales, Inc. for coming to our class and providing us with light sensor ballast and very useful information on how they perform and can save cost and energy.

We would also like to thank the Carl Cindric from Pilipuf Grist which gave a demonstration of different lighting elements and the visual effects they produced. He also provided us with numerous amounts of product books and pamphlets which were very helpful.

Mr. Tim Moss From Philips Lighting Electronics also should be acknowledged for his extensive presentation on lighting and LEDs and samples he let us use. His presentation not only provided recollection to earlier knowledge but also provided us with many things we have never seen or even heard of before.

Finally, Phil Mancuso of Focal point was also very kind in providing us with a tour of one of their local plants and explained many aspects of lighting and design to how lights are actually made.