Natural Lighting: A Proposal for ES2

ERS 250

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CONTEXT

ERS 250, Greening the Campus and Community is a unique educational experience based on the idea that academic institutions should model the ideals they teach. With this in mind the class strives to "green" an aspect or area of campus and has had several past successes, implementing several of the project ideas in areas such as waste management and campus policies. "We envision UW transforming itself into a showcase of sustainability, a true ecosystem in harmony with its environment. We refer to this process as "Greening the Campus". This undertaking presents an opportunity for students, staff, and faculty to improve the quality of their environment, while decreasing the overall operating cost of the University." (Cook, 2004) Together with WATGreen, which was formed in order to help institutionalize some of the ideas that Greening the Campus promotes. Together they set a backdrop for tangible and sustainable education. This process offer great opportunity and challenge in developing and implementing sustainable solutions to the ES2 building with the help of students and staff. ERS is an interdisciplinary course, and in this way it made good sense to examine natural lighting as a solution for "greening ES2, the project focus, as it too relies on the insight and knowledge of a multidisciplinary crew. Lighting has always been a factor in the overall usage of the university since the university uses a lot of electricity to light up every building in the campus. Thus, modern technology, in combination with practical knowledge, would provide solutions to change lighting efficiency. In contrast, many challenges are involved in lighting because of the expenses and structural limitations. Because the project focuses on a retrofit of an existing building, the group took on a number of challenges in proposing a modern solution to an outdated architect. Overall, the group’s effort has produced recommendations and possible solution to resolve and reinstitute the necessary components to harmonize the ES2 building with the environment.

Purpose

Upon examination of the space in ES2 to be “greened”, one would notice how overwhelmingly dark it is (without the use of artificial lighting) despite the presence of many large windows. We came to the idea of natural lighting by both forecasting and backcasting. By incorporating both of these techniques we applied what we already knew, or suspected, about lighting and what would be our ultimate dream of ES2. Both of these pointed to daylighting. Daylighting is a popular technique for allowing a resource that already exists to supply the light in a building, saving money and the environment by eliminating or reducing the need for artificial lighting which relies on the energy grid, causing pollution. By examining the room, we were surprised to see how many windows that existed and yet how little natural light existed within the space. There were a few obvious obstructions such as trees in front of window and paint colour, but we realized it would take more than just this to illuminate the space. As we began to research different technologies in the field of lighting, we came up with a few basic principles which outlined the purpose of our project:

- Incorporate natural lighting
- Reduce reliance on artificial lighting
- Distribute sufficient light for students and staff to work
- Maintain the current level of safety

Questions/Objectives

When we began to examine implementing daylighting into ES2, we had a numerous questions. These are divided into three sections below; *initial questions*, *secondary questions* and *final questions*. They reflect the extent of our knowledge and the comprehension level of our subject at different stages in our project.

Initial Questions

- Is ES2 currently energy efficient?
- Are there any structural barriers within the building?
- What will the building be used for and what kind of light is sufficient?
- How much time/money/effort is the University willing to commit?
- What light sources does ES2 currently rely on and is it sufficient?
- How will the area be divided and designed?

These were broad-based questions which laid the foundation for our research. Based on these questions we found a number of possible solutions by consulting with Patti Cook and Paul Kay as well as using an internet search to gain swift knowledge of our topic. Through these resources we compiled a list of several issues we wanted to pursue including solar tubes, fiber optics, thermochromic windows, light shelves, paint colour and anidolic mirrors. When we were in the process of preparing our methodology statement we found these following questions to be the most pressing.

- Would the Fiber Optics and Solar Tubes be functional in our space?
- What is the cost of installing traditional fiber optic lighting system?

- What is the expected lifespan and maintenance?
- Is it possible/desirable to have mixture of natural light source and artificial light source?
- Would light shelves and anidolic mirrors be appropriate for our purposes in ES2 and is it possible to install them in the existing space?
- What would be the expected cost in the installment and maintenance?
- Do light shelves and anidolic mirrors need special support columns?
- Would this affect the building's temperature? If so, how?
- How will it affect the working conditions within the space?
- What colour would be able to best reflect, and therefore maximize, the light?
- What colour would be suitable for people's comfort?
- Would the paint used be environmentally sound?
- What are the costs vs. benefits of a new paint colour?
- Real example of places installed the fiber optic lighting system, how are they working, any pros and cons and how do they relate to our project?

From these questions we went on to examine the more technical aspects of our report, and came up with the following list of questions as our final obstacles.

Final Questions

- Could the pipes and the ventilation system be in the way?
- How much light will it bring in?

- Technical questions such as: feasibility of the concept of incorporating natural light into the traditional fiber optic lighting system
- Cost of total replacement of current windows with thermochromic system
- If windows will contribute to energy savings
- How many years will it take to pay off the cost of installing fiber optics, windows shelves, and windows sharing?
- Will any of our ideas interfere with the integrity of the work space?

Results and Analysis

The summary of data and evidence of the results below are categorized based on five sections; current costs, natural light tubes, fiber optics, window shelves, low-e windows. Refer to Appendices for detailed calculations

1) Current costs for lighting (a) ES2 and the (b) University and other relevant costs results from calculations

(a) ES2 spends $587.64/year lighting the second floor rooms that are assigned. This does not take into account any other appliances plugged and the cost of other electrical appliances; only the 212 light bulbs that are on 7 hours per day, 6 times a week.

(b) The university spends $4.5 million and $60 000 service charges on electricity, using approximately 70 000 000 kW/h of electricity annually (Artificial Lighting, 2004).

2) Natural Light Tubes

Natural light tubes are one of the most innovative and effective technologies currently on the market for increasing daylight. They reduce the reliance on electricity and artificial lighting and require little reconstruction of the existing building structure (Westfall, 2003). A compact roof-mounted reflector system collects light and directs it down a highly reflective cylinder to a light diffuser in the ceiling level that looks like a standard light fixture. Natural light tube cost about $538.00 for a 21 inch kit and a 2 foot extension pipe (EV Solar Products, 2004). The pay back period is actually 1.02 years per light tube. Depending on the number of light tubes required to illuminate the ES-2 rooms, it would take at least one year for ES2 pay per light tube by redirecting its annual electricity bill. The natural lighting group proposes putting in at least 20 light tubes in the ES2 rooms to increase the area covered by natural light. As of now, the size and the space between each light tube could only be determined by architects and engineers who have more advanced technical areas in math in designing the actual blueprint and the building council and planner who would finalize the plans for the space. The natural lighting group, however, suggest putting light tubes throughout the ES2 studio, hallway, and possibly the computer room.

3) Fiber Optics

Fiber optic is also an excellent way of indirectly illuminating the dark areas of ES2 by using the energy of the sun that is transferred to tubes diverging to different locations of the building. The chemical energy transferred from the solar receptors on top of the ES2 roof is then converted to light energy. As a result, light will be redirected in the room, mainly at a high intensity, depending on the size of the tubes. It will cost approximately $1.03 million to cover all of the area of the ES2. This option is very effective in lighting the room as well as decreasing the use of electricity. Unfortunately, it is unlikely that ES2 could pay this large sum at once. Instead, the university could look at this option as a very important aspect in replacing artificial light bulbs in the future and examine it as a possible long-term campus goal. If implemented, the actual project could pay for itself similarly to natural light tubes.

4) Window shelves

Window shelves are reflective mirrors place between the top and bottom half of the Window. Refer to Appendices C for the picture of the window shelves. It lies perpendicular to the windows going up and down. Its result are improving illuminating distribution and reducing unwanted glare that is undesirable for the the workplace. The shelves are also designed to block lights. Window shelves will be placed on the rooms facing ring road of ES2, where the sun is coming from the south, in order to maximize their light illuminating potential. Window shelves are cheap and feasible because slight modifications will be necessary in the existing windows.

5) Low-e windows

Low-e windows respond to the weather outside of the building. In short, the argon gas filament only reacts to heat caused by direct sunlight. If it is hot, especially when the sun is out, the window keeps the room free of direct sunlight by forming a gaze caused by the reaction of heat and the argon gas between the two layers of the low-e windows. As a result, additional heat caused by light energy in contact with the floor or anywhere in the room without the low-e windows, would be reduced because of the opaque argon gas barrier. Therefore, heat does not go in the building during summer times. When it is cold, the windows do not gaze since it is not warm outside. Therefore, more daylight comes in the room, but when direct sunlight heats up the windows, the gas reacts with the heat on the glass, which creates that barrier. This technique would provide maximum light without over-stimulating the work space. The heat in the room would still be trapped, contributing to the efficiency of heating and cooling the rooms in ES2 because the windows are double-layers. Overall the low-e windows would cost $18 500 and could be paid in time.

ANALYSIS

The whole group proposal was basically determined by the expense of the particular project and its feasibility in either short-term or long-term goals. This factor had divided the proposals in the five categories mention above which could help decision-makers in selecting what options are preferable for the retro-fit of ES2 based on feasibility. It should be noted that the university pays for $4.5 million of electricity annually (Cook, 2004) that means that it is necessary to develop a sustainable solution to alter the on-going dependence of the university on electricity from companies. In addition, the university also pays for $60 000 worth of services charges annually. The space in ES2 (to be transformed into the new Environment and Resource Studies offices) currently spends an estimate of $587.64/year on electricity which may increase as computers and other appliances are used. Therefore, those rooms should depend more on natural lighting in order to minimize the use of electricity, thereby reducing pollution. Based on our research, there are several clear ways the university could use some of that money in aiding the ES2 rooms with its natural lighting proposal.

Natural lighting in ES2 is feasible because the available technology is suitable for the project. First, natural light tubes may be the solution for this project because it is cheap and the savings from the current ES2 annual electricity bill could pay off one natural light tube per year. In 1.02 years, a light tube can be installed according to the Total Payback period for this particular proposal. Also, solar tubes as small as 250 mm can provide more illumination than a two-foot skylight, and because of their small size, no remodeling is required. Eventually, electricity will not be needed during the days for classroom and office operations since natural light tubes could offer free, abundant natural light. Because solar tubes capture ambient light in combination with direct light, which allow for exceptional natural lighting even during cloudy periods and at minimal-light periods of the day. (Westfall, 2003) Natural light tubes could cover the entire studio and the hallway area of the ES2 2nd floor and also the current computer and administrative offices, and could help increase work efficiency and productivity among staff and students.

Another short-goal proposal is installing window shelves that increase lighting for the rooms facing the south side or Ring road. These rooms are exposed to sunlight throughout the year, and its ideal to increase their natural lighting by reflecting the light throughout the room, which means artificial lighting is unnecessary. The windows facing the PAS building do not need to be replaced because the trees in that area are blocked by trees and cutting them would just eliminate the shading that the building receives from the trees. Moreover, each window will only cost $0.50 - $2.00 square foot for adding a horizontal, reflective window in the existing window. Fundraising and savings will help ES2 this cost achieves over a small period.

Furthermore, the cost of low-e windows is about $18 500, and this proposal is ideal for further improving lighting with heating & cooling at the same time. As mention, the windows are doubled layer with an argon gas filament between the glasses. During cold weather, the windows are not gazed because of the lack of heat on the windows, but could also heat up if the sun is out during the winter. The light would still enter indirectly from the gazing of the filament. The double-layered window would also improve insulation by preventing heat from escaping. Oppositely, the summer heat and light would be reflected by the gazed window since it is not letting additional heat to enter the room, causing additional stress to the cooling system of the building. Thus, less cooling is required, saving the school money in heating and cooling, while increasing lighting. With this moderate price implementation, the ES2 building could benefit from two factors and not just only one.

During the calculation of possible cost and savings, many evidence were found. Although it would cost ES2 and the university money to install these projects, it is however noteworthy that these projects are self-sustainable. They can function on their own without extreme maintenance. Also, it is more logical for the school redirect to eliminate or gradual decrease the yearly bill of $4.5 million plus by developing a system where the university depends on renewable resources. Not all of these projects would be implemented at one time, but at least let one project being passed so a start in renovating ES2 could develop. It is after all the first university in Canada to create its own faculty of Environment Studies, dedicated in responsibly managing resources effectively evident in the past WATgreen projects. Furthermore, the university could decrease its ecological footprint by a large amount. Hopefully the impact assessment and life-cycle analysis to be done by other upper year students on of the amount of energy (70.0 million kW/h) used could suggest to the boards of directors that a sustainable solution is required now.

CONCLUSIONS

Our conclusions can be summarized in the following points:

- We recommend continuing implementing the ideals of natural lighting (combining modern technology with renewable resources) via natural light tubes, window shelves and low-e windows in ES2
- We recommend using low-e windows for decreasing sunlight from entering the room causing uneasiness to the eyes, affecting the work area. Use low-e windows to insulate the building by saving energy for heating and cooling, and damage to furniture due to UV light
- Decreased reliance on electricity for light sources reduces pollution and energy bills for the campus
- Lighting project would be an excellent educational tool, promoting “green” ideas in other faculties
- Further research in natural lighting among upper year classes and project facilitators is necessary

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APPENDICES A: Calculations

Possible Cost and Savings and Total Payback Period Calculations

1) Cost of electricity used in current ES2 rooms for one day:

Given:

1 day= 7 hours of class room time

1 month= 26 days, Sunday not included

1 year= 323 days or 46 weeks of school (Burke et al, 1996)

Assume the last two weeks of every term had no classes or examinations

Number of hours lights are on in a classroom on average= 7 hours*

*Based on Case studies on Classroom time in Engineering 1 room (Burke et al, 1996).

Number of light bulbs in ES 2 rooms= approximately 212 because some rooms were locked

Light bulb power requirement based on Watt= 20W (.20kW)

Current rate for electricity= 5.5kW/h after 750kW**

**Assumed that university uses more than 750kW/h since there are other parts of the university that uses electricity more than ES2. This is evident in 70 000 000 kW/h required per year from Patti Cook.

Required:

Amount of money spent on electricity in ES2 per year

Solution:

Amount of money used just for 1 day

# of hours lights are on in the classroom * # light bulbs in ES 2 rooms * Power required to light the light bulb * rate for electricity

= 7 hours * 212 light bulbs * .02 kW* 5.5kW/h

=163.24/100

=$1.63

Amount of money used for electricity for a month (30 days)

=$1.63 * 30

=$48.90

Amount of money used for electricity for a year (323 days)

=$1.63 * 323

=$528.12

Therefore, the ES2 rooms alone pay $528.12 dollars per year excluding other costs for the parts of ES2 and eventually the entire school.

If the ES2 did not use electricity by relying on natural lighting, then it can save $528.12 dollars a year, which can be used to pay off short-term and possibly long-term expenses.

2) Cost of Proposal:

Short-term goals:

i) Total cost for low-e windows $18, 500.00

($30.5/ sq ft * 600 sq ft (24 windows))

ii) Total cost for Natural light tubes= $538.00

21-inch Kit ($480)+ 2-foot extension pipe ($58.00)

Long-term goal

i) Total cost for fiber optics lighting= $1 033 335.00

($100/ sq ft * 10333.35 sq ft)

3) Pay back period for low-e windows and fiber optics lighting

<u>Given:</u>

Total cost for low-e windows $18, 500.00

Total cost for fiber optics lighting= $1 033 335.00

Total cost for lighting ES2 rooms for a year= $528.12

Total cost of electricity for the whole school= $4.5 million + service charge of $5000/month ($60 000/year)

Required:

1) Payback period if the annual electricity bill for ES2 rooms ONLY are used as payment for the total cost of (a) low-e windows and (b) fiber optics as forms of savings ES2 rooms, since electricity billing is inapplicable due to natural lighting.

2) Payback period if yearly electricity bill for the University are used as payment for the total cost of (a) low-e windows and (b) fiber optics as a form savings for the university, electricity is inapplicable due to natural lighting.

Solution:

1. (a) Low-E windows

Total cost of proposal = Pay Back Period

Total Savings Per Year

=($ 18 500.00) / ($528.12/year) = 35.0 years

*The electricity bill for the ES2 rooms becomes a savings because the rooms no longer require paying since they are relying on natural light.

(b) Fiber Optics Lighting

Total cost of proposal = Pay Back Period

Total Savings Per Year

= ($1 033 335.00) / ($528.12/year) = $1 956.6 years

2. (a) Low-e windows

Total cost of proposal = Pay Back Period

Total Savings Per Year

=($ 18 500.00) / ($4 500 000 000/years) = .004

(b)This means that the university can afford the system, which also applies to the fiber optic system.

Therefore, these two systems can be implemented if the university chooses to use natural lighting.

4) Pay back period for Natural Light Tubes

Natural Light Tubes

Total cost of proposal = Pay Back Period

Total Savings Per Year

=$538.00/$528.12

=1.02 years

If the university was to use natural lighting, then $528.12 would be redirect in paying for the cost of the natural light tubes proposal. Thus, it would take 1.02 years.

Appendices B: Natural Light Tubes Figure

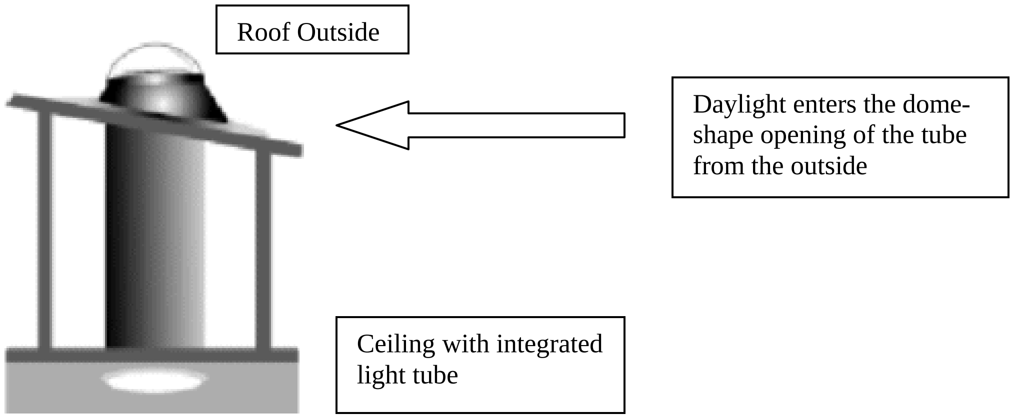

Figure 1.0 General system of light tube.

Source: EV Solar Product, 2002

Appendices C: Fiber Optic Figures

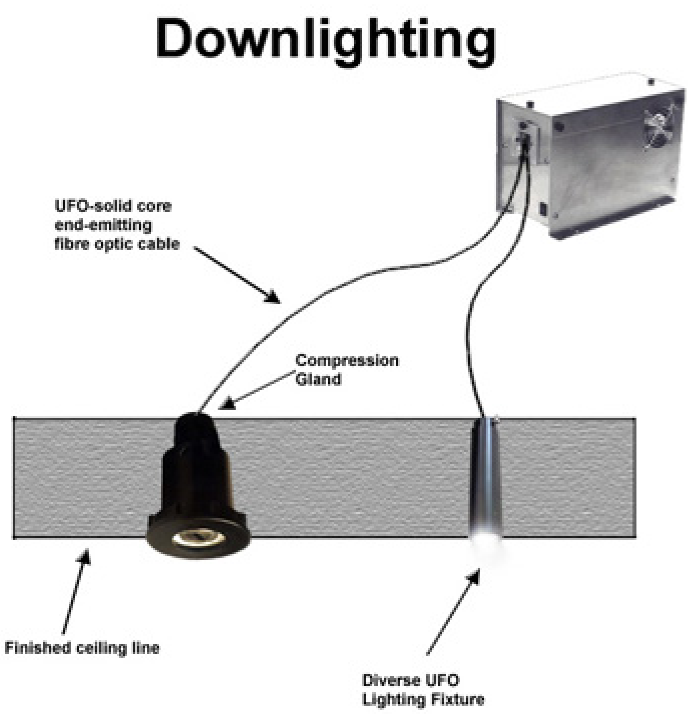

Figure: 1.0 Fiber-optic lighting system

Source: Ultratec Fiber Optic, 2004

Figure: 1.1 Examples of fiber-optic lighting fixture

Source: Flexion Optical Fiber Ltd, 2004

Figure 1.2 Before and After Fiber-Optic System

Source: Fiberstarts, 2004

Figure 1.3 Fiber-Optic in Office

Source: Fiberstars, 2004

Appendices D: How Window Shelves and Low-e Windows Figures

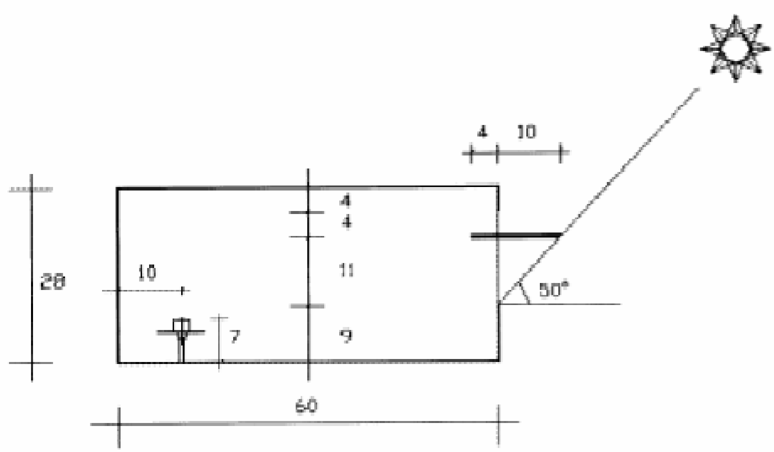

Fig. 1. Dimensions in cm for the light shelves and the 1:10 scale models.

Source: Alfornso 1997

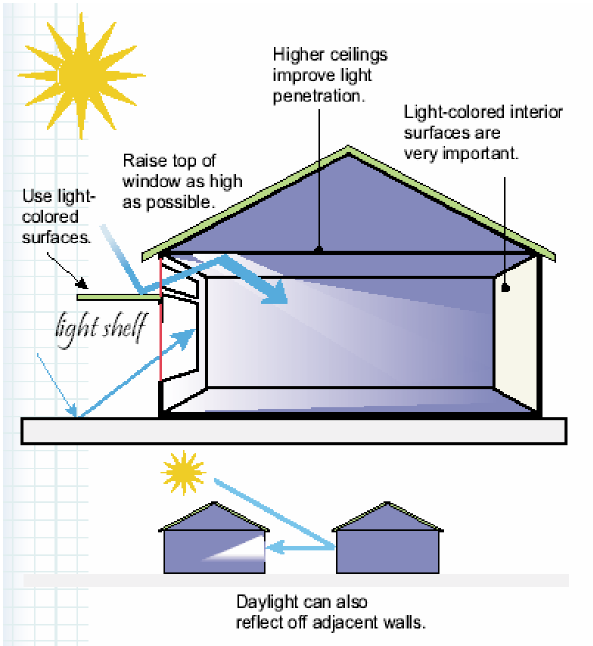

Figure 1.1 Importance of light shelf and possible conditions for light shelf's best performance

Source: DBEDT State of Hawaii, 2004

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Figure 1.2: Low-E window with window shelves; design of light shelves being perpendicular to the window. Tint glass is low-e window. Clear glass above allow light to enter the room.

Source: Enveloped & Room Decisions, 2003