IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 2 Ser. I (Mar. – Apr. 2021), PP 34-44
www.iosrjournals.org

Daylight Harvesting As a Control System in the Reduction of Energy Consumption

Nkeleme Emmanuel Ifeanyichukwu
Department of building, Federal university of technology Owerri Imo state

Anosikekelechi Evan

Okereke Godson C
Department of building, Federal university of technology Owerri Imo state

Mohammed Umar Faruq
Department of building, Federal university of technology Owerri Imo state

Muhammad AbdulqadirKabir
Estates and works Department Federal University of TechnologyOwerri

Abstract
Lighting in office buildings can account for approximately 30% of electrical use. This provides an opportunity for energy efficient technologies to be implemented to reduce this load. Automated daylight control systems are part of a growing industry, based on complex electronics and careful placing of light sensors. In an economy that is accepting the need for energy reduction due to the realization of limited fossil fuels, it is important to maintain and enhance energy efficient systems. Research highlighted that previous studies used physical measuring approach, computer based software or an occupant survey to understand how well automated daylight control systems are working. This thesis combined all of these approaches to quantify how much energy automated daylight control systems are saving while ensuring that occupant satisfaction and comfort is maintained. The ICT seminar room was analyzed to investigate the average energy saving from automated daylight control systems. Energy savings reported from other research studies ranged from 15% to 80%, with an average of 49%.Daylight Harvesting takes advantage of our largest energy source the sun. The daylight sensor placed in a room continuously measures natural light levels. When sufficient sunlight is present, electric lighting is reduced or eliminated. The introduction of more daylight into the building, since the case study area is located at the top floor of the building, the application of skylight and light tubes will go a long way to saving energy and cost use. Daylight sensors and detectors should be put to efficient use in educational and other forms of buildings so as to regulate and ultimately reduce the energy and cost consumption rates.

Keywords: *Daylight harvesting, control, systems, energy, buildings*

Date of Submission: 01-03-2021 Date of Acceptance: 14-03-2021

I. Introduction

A building can be compared to a system with a variety of physical processes interacting with each other and with the environment. From the control point of view, it is considered as having multivariant dynamic subsystems showing linear or non-linear behaviors. Environmental and occupancy changes in a building increase the complexity of control operations. Occupants not only impose control goals related to thermal comfort, visual comfort or indoor air quality but also influence the building processes impacting indirectly on the control functions of the different processes (HVAC, lighting, etc.).

Lighting or illumination is the deliberate use of light to achieve a practical or aesthetic effect. Lighting includes the use of both artificial light sources like lamps and light fixtures, as well as natural illumination by capturing daylight. Daylighting (using windows, skylights, or light shelves) is sometimes used as the main source of light during daytime in buildings. This can save energy in place of using artificial lighting, which represents a major component of energy consumption in buildings. Proper lighting can enhance task performance, improve the appearance of an area, or have positive psychological effects on occupants.

Lighting control systems reduce energy usage and cost by helping to provide light only when and where it is needed. Lighting control systems typically incorporate the use of time schedules, occupancy control, and photocell control (i.e. daylight). Some systems also support demand response and will automatically dim or turn off lights to take advantage of utility incentives. Lighting control systems are sometimes incorporated into larger building automation systems.

Many newer control systems are using wireless mesh open standards (such as ZigBee), which provides benefits including easier installation (no need to run control wires) and interoperability with other standards-based building control systems (e.g. security).

The first lighting controls level, also the most widely used, is the manual switch to put on or off an individual luminaries or a group of luminaries. This type of control is not robust enough with respect to energy efficiency as it relies solely on the behavior of the occupants who are not necessarily concerned by energy savings, especially in the tertiary sector buildings. Lighting control strategies provide additional cost-savings through real time pricing and load shedding. Reducing lighting power during electricity peak-use periods when energy rates are at the highest can also be achieved through a Lighting Management System (LMS). Lighting Management Systems allow building operators to integrated lighting systems with other building services such as heating, cooling, ventilation, in order to achieve a global energy approach for the whole building, in particular for green building or an energy-producing building.

The time scheduling control strategy enables switching on or off automatically based on time schedules and occupancy patterns for different zones. Twenty-four hour timers allow the occupants to set certain times for lighting. The timer is set to switch lighting on during occupancy. Measurements have shown that the best energy efficient solutions are combining the use of a cut off system with a manual switch on system; potential gains are between 10 and 15% (without daylighting) (Floyd et al. 1995, Rundquist et al. 1996). Note that the gain may be more than 50% in case of 24 hours lighting (Maniccia et al. 1999, NBI 2003). This strategy is used most widely in applications where building occupancy patterns are predictable and follow daily and weekly schedules like classrooms, meeting rooms and offices.

The Dusk or Dawn control strategy is a type of predicted occupancy strategy based on sunrise and sunset which can be calculated for every building location. Light is switched on automatically when it gets dark, and off when there is enough daylight. This control type is not often applied for indoor lighting but is very efficient for atriums with good daylight availability or for glazed corridors linking buildings. This strategy is not necessarily achieved with an outdoor daylight sensor. The on and off hours can be provided by a scheduler.

The Daylight Harvesting Control Strategy (DHCS) allows facilities to reduce lighting energy consumption by using daylight, supplementing it with artificial lighting as needed to maintain the required lighting level. The Daylight harvesting control strategy uses a photocell to measure the lighting level within a space, on a surface or at a specific point. If the light level is too high, the system’s controller reduces the lumen output of the light sources. If the light level is too low, the controller increases the lumen output of the light sources. Sensors are often used in large areas, each controlling a separate group of lights in order to maintain a uniform lighting level throughout the area. The result is a system that minimizes lighting energy use while maintaining uniform lighting levels. This system can also provide the constant luminance strategy.

Daylight harvesting systems are generally used in spaces that have relatively wide areas of windows or skylights. Typical applications include classrooms, high-rise office buildings and retail facilities. The savings potential varies from 20% (daylight-harvesting alone) to more than 50% (daylight harvesting plus real occupancy (NBI 2003). In office buildings, predicted occupancy control strategy (based on scheduler) allows 10% gain whereas real occupancy (based on presence detector) allows 20% gains. We can notice that Daylight-harvesting impact depends on the climatic zone. So, in office building potential gains vary from 30% (Paris) to 40% (Nice). Coupling of different strategies should result in more energy gains, for instance, daylight harvesting and real occupancy achieves up to 50% gains. These gains are function of the room and window sizes, building orientation and sensor(s) position(s).

Due to the increase of environmental concerns, lighting control systems will play an important role in the reduction of energy consumption of the lighting without Impeding comfort goals. As mentioned in the IEA Annex 31 (IEA 2001), energy is the single most important parameter to consider when assessing the impacts of technical systems on the environment. Lighting is often the largest electrical load in offices, but the cost of lighting energy consumption remains low when compared to the personnel costs. Thus its energy saving potential is often neglected. According to an IEA study (IEA 2006), global grid based electricity consumption for lighting was about 2650 TWh in 2005, which was an equivalent of 19% of total global electricity consumption. To fulfill the requirements about comfort and energy efficiency, building managers have implemented programs to reduce lighting energy requirements by installing more efficient light sources and luminaries. However, this is not sufficient. Lighting energy management has to provide the optimal lighting level for the tasks being performed using the most efficient light source suitable for

the application, and providing light only when and where it is needed. This can be achieved by using lighting control strategies and lighting control system. The main purpose of these systems is to reduce energy consumption while providing a productive visual environment. This includes:
— providing the right amount of light
— providing that light where it's needed
— providing that light when it's needed

II. Literature Review

Energy is very important in everything that we do. Without energy there is virtually nothing we can do. All the things we need to do on daily basis, we need energy to do them. The same way, just as man cannot do without energy, no country can develop without energy. We need energy for domestic, agricultural, industrial, commercial and official activities. Access to energy is the dividing line between the poor countries and the rich countries. This explains why the developed countries of the world have and consume far more energy than the developing and underdeveloped countries. If any country must tackle the problem of poverty, the country will need to provide energy for her citizens. Energy efficiency does not mean that we should not use energy, but we should use energy in a manner that will minimize the amount of energy needed to provide services. This is possible if we improve in practices and products that we use. If we use energy efficient appliances, it will help to reduce the energy necessary to provide services like lighting, cooling, heating, manufacturing, cooking, transport, entertainment etc. Hence, energy efficiency products essentially help to do more work with less energy. For instance, to light a room with an incandescent light bulb of 60 W for one hour requires 60 W/h (that is 60 watts per hour). A compact fluorescent light bulb would provide the same or better light at 11 W and only use 11 W/h. This means that 49 W (82% of energy) is saved for each hour the light is turned on.

Energy savings measures originated as a spontaneous and rational retort to the oil prices hike of 1973-74 and 1979-80. The distress felt majorly by the nations with high energy consumption rate heightened the necessity to scale down on the consumption of energy. Developing and developed nations were obligated to evaluate their standing energy strategies and adopt effective ways of conserving energy and end-use efficiency improvements as an essential constituent of their national policy (Unachukwu, Zarma &Sambo 2008). Energy efficiency is defined as "the variations that occur as a result of lessening the quantity of energy used to create one component of a daily activity or to match a peculiar energy prerequisite for a particular height of comfort" (World Energy Council, 2004). To further elaborate, if an institution produces more, utilizing a particular quantity of energy and at a different time utilizes a smaller amount of energy to achieve the same extent of production, then energy is said to be used more 'efficiently' (Carbon Trust, 352).

Energy Efficiency

When we talk about end-use efficiency, we refer to technologies, appliances or practices that improve the efficient use of energy at the level of the final user. For example the appliances we use in our houses and offices. Though this term is not limited to electrical appliances, it can also be used for other areas of efficiency such as measures to improve the ability of houses to absorb and retain heat in winter and keep out heat in the summer. On the side of utility companies, providing electricity, they can also device ways and technologies to promote the efficient use of energy. This is referred to demand-side efficiency or management.

Energy Conservation in Buildings

If the building envelope and building materials were adequately taken care of to allow for a longer time period for day lighting, and maximum indoor space cooling, this would reduce the time of need of electrical energy for both lighting and cooling devices. Consequently, this will promote energy conservation. Apart from the building envelope, a lot of opportunities also exist for energy conservation in the lighting and cooling devices subsectors. For instance, due to the high first cost of fluorescent bulbs, incandescent bulbs (40- and 60-W rating) are still the predominant electric lighting device in the country. Hence, approximately 34.3% of total electricity use in urban households goes to lighting (Adegbulugbe&Akinbami, 1995). The tropical climate of Nigeria definitely makes space cooling an essential energy service. This is provided by electric fans and air-conditioners. Fans have a much higher market share than air-conditioners in Nigerian households because of their lower investment costs and lower electricity consumption.

Energy usage in public buildings

According to the US Department of Energy, lighting ranks as the most significant use of electricity in commercial buildings. Lighting uses more power on average than cooling, ventilation and refrigeration combined. Whether in existing facilities or in new construction, the easiest route to energy savings is to shed lighting loads.

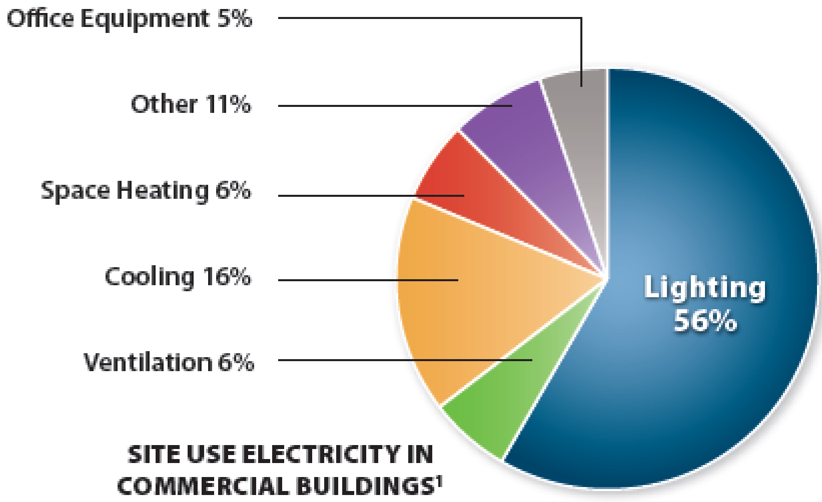

Figure 1: energy usage in public buildings

Automated Daylight Control Systems

Vaidya's (2005) research found that "switching or dimming automatic control systems do not always provide the required energy savings. The possible reasons for an unsuccessful application of daylighting controls are numerous. It seems prudent to look for object lessons for success and failure from the set of early adopters". Expanding on this, Vaidya stated that "if energy efficiency through daylighting controls is to proliferate as a strategy its success rate needs to be improved. Success has been achieved, but our intention here is to elaborate on the weak areas of automated lighting so that future research and development on improving the process can be more preside" (Vaidya, 2005, p. 564). Vaidya's research reinforces the need for further analysis into how to improve automated daylight control systems by understanding problems arising from their implementation. Sustainable buildings are gaining more interest and with this are energy efficient technologies. Yet such technologies are still not being implemented into buildings as standard designs. Before these technologies are widely accepted, further research is required to ensure that they are developed to a point that will minimize poor performance issues.

The main reason for installing an automated daylight control system into a building is to reduce energy use. This benefits operating costs by reducing the overall energy use, as described by Choi and Mistrick where "using a daylight responsive dimming system becomes an appropriate option to reduce the electric lighting energy consumption in spaces where daylight can be a useful source of illumination" (Choi &Mistrick, 1999). However, this does not exclude the need for artificial lighting altogether as "no matter how good the daylighting design, virtually every building needs an artificial lighting system as well for night time use, for windowless spaces, or to supplement daylight when it falls below acceptable levels" (Energy Research Group, 1994).

Buildings were configured throughout architectural history to use daylight until inexpensive electricity and technological developments such as air conditioning, fluorescent lighting, steel frames, and elevators enabled the economic construction of taller, deeper buildings. Developers and owners often are not willing to offset the first cost associated with large building perimeters with potential energy savings. Current research results are leading to a realization of broader economic benefits from daylighting, a dividend that may strongly justify initial construction expenses. (Leslie, 2003)

An automated daylight control system recognizes the presence and quantity of daylight (illuminance value) using a sensor. The sensor relays this information to a controller where the illuminance value is assessed. A signal is then sent to the artificial lights which are adjusted to keep the light at a constant level. Thus through a combination of natural and artificial light the system provides a constant light level - dimming or increasing the intensity of the artificial lights to suit. Each system has a set point (point of change - a predetermined lux level), which is set to a certain illuminance level of daylight. If the daylight is higher than the set point, the controller will communicate with the lighting controls (normally electronic ballasts) and reduce the artificial light output. . However, studies have shown that by using daylight harvesting technologies, owners can see an average annual energy savings of 30%.

Automated daylight control systems differ in design and layout from one building to the next, but all have the same fundamental principles. As Figure 1 illustrates, a simple automated daylight control system consists of five separate components; an Ethernet Network, a DALI gateway or controller, a separate power supply, electronic ballasts and dimmable lamps. In this example, daylight sensors are also occupancy sensors.

These dual sensors allow relay information back to the controller about the amount of light in a space and if there is anyone present in the space (Information sourced from DALI by Design, 2011).

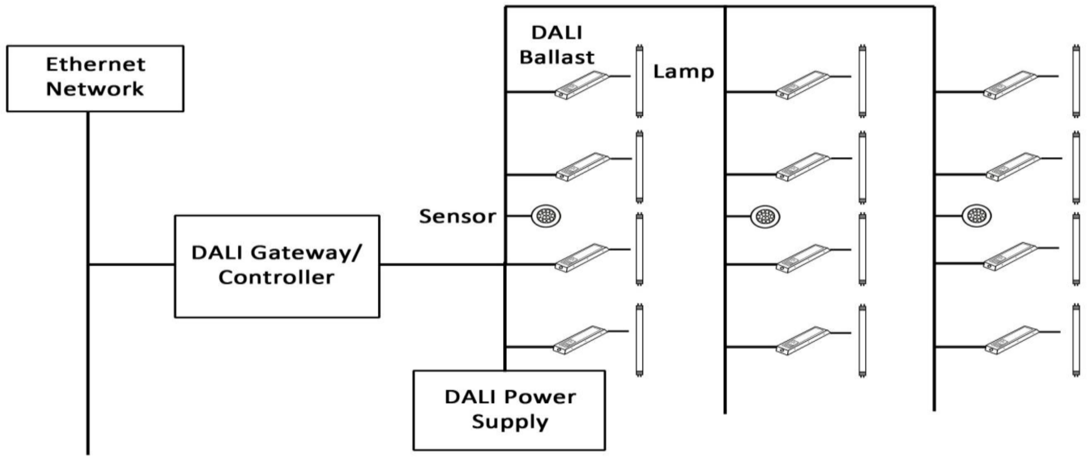

Figure 2: schematic diagram showing lamps and sensor distribution

Automated daylight control systems can also help with operational and maintenance issues. The interface can tell the building manager if there is a faulty lamp and direct the building manager to it as each lamp is individually addressed. With each lamp individually addressed, it allows the building manager to alter, dim or set each lamp to a different lighting intensity. This has the potential to increase occupant satisfaction by attending to personal preferences of lighting requirements and can also save energy by having less lights on in less frequently used areas such as corridors, storerooms and filing areas.

There are various ways in which automated daylight control systems can be commissioned. In the example of Figure 1, the artificial lights can be dimmed individually or by row. By having one sensor per row there is better control and an even light distribution throughout the space. This setup allows the lamps closer to the window to dim more as they receive more daylight than those further into the building. This gives an even lighting level for the users sitting under each row of lights.

Daylight Harvesting

A benefit of a building that is designed to allow natural light to enter is the visual quality and occupant preference of work place light. When “given a choice, people prefer to work by daylight and to enjoy a view” (AS/NZS 1680.1:2006, p. 10). Fluorescent lighting is able to produce constant high levels of light and will always be required but is no substitute for daylight. “Lighting of good color quality aids visual discrimination, and so reduces the quantity of light required for many tasks. While artificial light sources with a spectral composition very close to daylight are available, clearly, other things being equal, daylight itself is preferable” (Energy Research Group, 1994). “Daylighting is experiencing a renaissance since aspects of this approach have been shown to significantly increase human, environmental and economic performance compared to standard construction with electric lighting” (Ternoey, 2000). This resurgence in the use of daylight design has come from understanding that occupants require good lighting in their built environment. This has led to building designs changing to adopt energy efficient technologies and smarter building techniques, which is further highlighted by the IEA:

Everyone is interested in saving energy thus the greater need and benefit of using it to our advantage. The sun is shining the whole year and gives a bright and natural light – some periods more than others give. This leads to proper use of daylight, the more daylight the less need for artificial light.

Types of Daylight Harvesting

Switched daylighting

In switched daylighting, loads are turned off when the daylight meets a minimum desired level. This type of daylighting uses a delay-to-off and hysteresis in order to prevent frequent on-off behavior. In the chart below, the electric lights have been designed to supply the desired amount of light at desk height. You can see as the sun rises the total light in the space increases. Once the daylight entering the space is enough to exceed the minimum required light level (with a built-in hysteresis), the electric lights will turn off. The electric lights will then remain off until the point in the day at which the natural light can no longer provide the minimum required light level in the space. One of the downsides of switched daylighting is that the space is over lit just before there is enough daylight the space to provide the minimum required light level.

Bi-level daylighting

Bi-level daylighting is very similar to switched daylighting, but with the addition of a 50% light level. Electric lighting to the left will move from 100% to 50% to off as the daylight becomes more abundant. In the figure below, you can see how the electric light contribution in the space is additive to the daylight entering the space. As the total light in the space increases, the electric lights will dim to 50%. They will turn off once the daylight entering the space is enough to provide the minimum required light level for the space. The bi-level, or 50% level, helps avoid having the space be over lit before there is enough daylight to provide the minimum required amount of light.

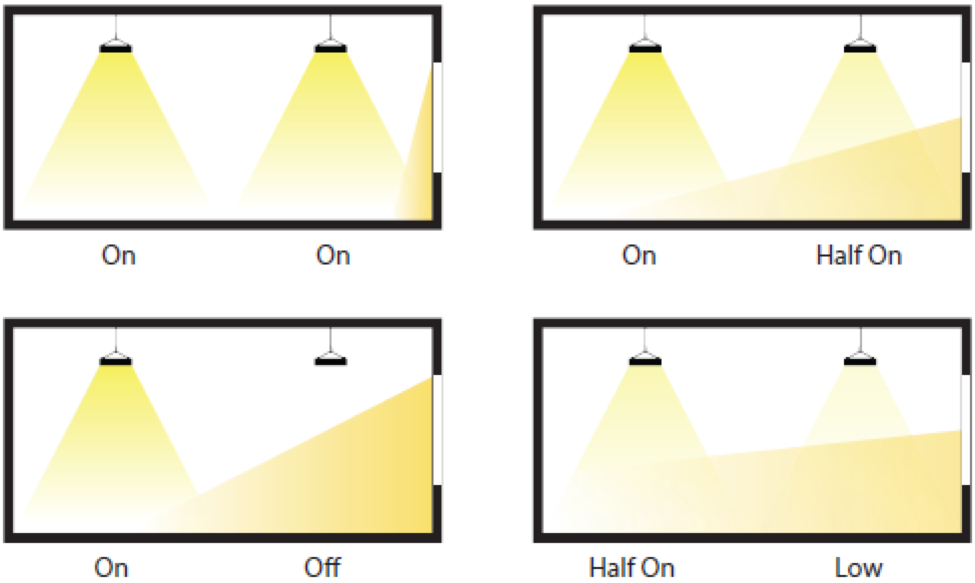

Figure 3: showing the dimming light levels

Continuous Daylighting

Continuous daylighting involves smooth, continuous dimming from low end to high end in order to maintain the desired light level. Continuous daylighting adjusts lights based on the amount of daylight that's always in the space, ensuring that the minimum light level is achieved without over-lighting the space (as in switched and bi-level daylighting).

Daylight sensor

This sensor system is taking into account the amount of daylight received in a certain area and then dims the electrical lighting the daylight level increases, thus reducing the energy required to maintain a proper lighting level. The system aims at keeping a specific level of light at the workspace.

A ceiling or skylight mounted Daylight Sensor senses light coming into the classroom and reduces the GEN (general) lighting levels when sufficient daylight is present.

Daylighting controls

These are devices that regulate the level ofillumination provided by electric lights in response to the presence ofdaylight. They usually consist of a sensing device (photocell or photosensor) that monitors either the total light level in the space or theavailable daylight level at the daylight aperture, and a control module thatthen switches or dims the electric lighting to maintain the neededillumination with minimal energy use.

Strategies to reduce energy use for lighting Strategies to reduce energy use for electric lighting in offices include:

1) Strategies directly related to the electric lighting installation: • Improvement in lamp technology; • Improvement in ballast technology; • Improvement in luminaire technology; • Use of task/ambient lighting; • Improvement in maintenance factor; • Improvement in utilance or utilization factor; • Reduction of maintained illuminance levels; • Reduction of switch-on time; • Occupancy sensors and/or manual/automatic dimming.

2) Strategies related to daylight harvesting: • Effect of latitude and orientation; • Effect of window characteristics; • Effect of shading devices; • Effect of reflectance of inner surfaces; • Effect of ceiling height; • Effect of partition height.

Reduction of switch-on time.

The total number of units of electricity consumed by the lighting installation will also obviously be affected by the length of time the lighting is switched on. The European standard EN 15193 recommends a total utilization time for electric lighting in offices of 2500 h (2250 daytime hours + 250 nighttime hours). In the Swedish context, for example, recent calculations have shown that reducing time of use of electric lighting in offices to 2600 h/yr would reduce energy intensity for electric lighting by 1.3 kWh/m2 yr thus going from the actual 21 kWh/m2 yr to 19.7 kWh/m2 yr. An annual time budget of 2500 h corresponds to about 48 h per week and thus 9.6 h per day (5 days/week) of total switch-on time, which is feasible even taking into consideration flextime

Use of manual/automatic dimming and occupancy sensors.

Several studies have generated promising results showing that electrical energy use can be substantially reduced by using lighting control systems such as manual dimming and occupancy sensors. For manual dimming, the electric lighting energy savings obtained range between 7–25%. Note that Moore et al. reported on a survey of user attitudes toward control systems and the luminous conditions they produce in 14 similar UK office buildings. They observed that controllable systems were typically operated at 50% of maximum output but they did not specify the exact corresponding electricity savings. For switch-off occupancy sensors, lighting electricity savings range from 20 to 35%. According to Guo et al., automated control systems save energy compared to manual switching, but differences between observed savings and industry estimated savings that result from the application of these systems are often observed. Studies comparing energy use after installation of occupancy sensors with manual switching on as the baseline, show energy savings of about 25% in private offices with a sensor time delay setting of 20 min, which is the lower bound for manufacturer claims.

Most commercial spaces have enough daylight next to windows to eliminate the need for electric lighting (apart for buildings located in the far north of Scandinavia where there is hardly any daylight in the winter). The exploitation of daylight, commonly referred to as 'daylight utilization' or 'daylight harvesting', is recognized as an effective means to reduce the artificial lighting requirements of nondomestic buildings. Daylight utilization may allow energy savings compared to electric lighting due to its higher luminous efficacy. For a given quantity of illumination, light from clear blue skies delivers the least amount of heat gain. Research has shown that daylight-linked lighting control systems such as automatic on/off and continuous dimming have the potential to reduce the electrical energy consumption in office buildings by as much as 30–60%Dimming electric lights based on available daylight is also expensive with significant 'equipment (dimming ballasts) and commissioning costs. Papamichael et al. claimed that to date, only a small fraction of side-lit dimming applications operate satisfactorily. While useful in low daylight areas, dimming is not really necessary in areas with high levels of daylight, where dimming is only useful during the early morning and late afternoon. More-over, dimming ballasts are less efficient than non-dimming ballasts and consume 10–20% power even at the lowest possible light out-put.

Daylight sensors in conjunction with well-designed lighting systems can maximize the qualities of daylight. The highest efficiency can be reached in environments with ample daylight coming through windows. The intensity of artificial lighting is constantly adjusted to reflect the incoming natural luminous flux. At noon all or most of the illumination can be provided by sun while early or late in the day this function is taken over by the artificial lighting system. The sensor itself should not be placed opposite to the sources of strong light or reflections, such as windows or mirrors, as this would negatively affect its readings. The detection depends strongly on the colour of the area under the sensor, which can lead to extreme circumstances, such as when a book is placed on an otherwise dark wooden tabletop. For such cases the changing of the lighting can be set to happen gradually as to not affect the comfort of the user.

III. Methodology

Research Design

This research tries to analyzed data to show the importance of light sensors/detectors in the reduction of both energy use and cost incurred in the use of artificial lighting within an educational building environment. The research makes use of software (DIALuxEvo) to run simulations, which provided basis for inferences and conclusions.

Study Area

My case study area is located at the School Of Information and Communication Technology (ICT); the boardroom is the area of concentration, it is at the top floor of the entire building.

Walk Through Survey

The reconnaissance survey was carried out to get a firsthand description and characteristics of the boardroom; the survey was carried out over a period of four weeks to ensure the appropriateness of the chosen area of survey.

The board room is polygonal in shape with two concrete pillars located at the far end of the east and west side of the room, 15 no of lamps, wall surface is painted off-white, with cherry maroon colored wood table, black cushioned chairs and a swirl office chair at the end of the table, and a sand colored rug.

Plate 1: Picture showing the ICT seminar room 7

Model Description

The model started off with drawing the plan on AutoCAD and importing it into the dialux software, then the model was developed by adding the appropriate furniture types, windows and doors, with their respective colors, and importing lamps and luminaries.

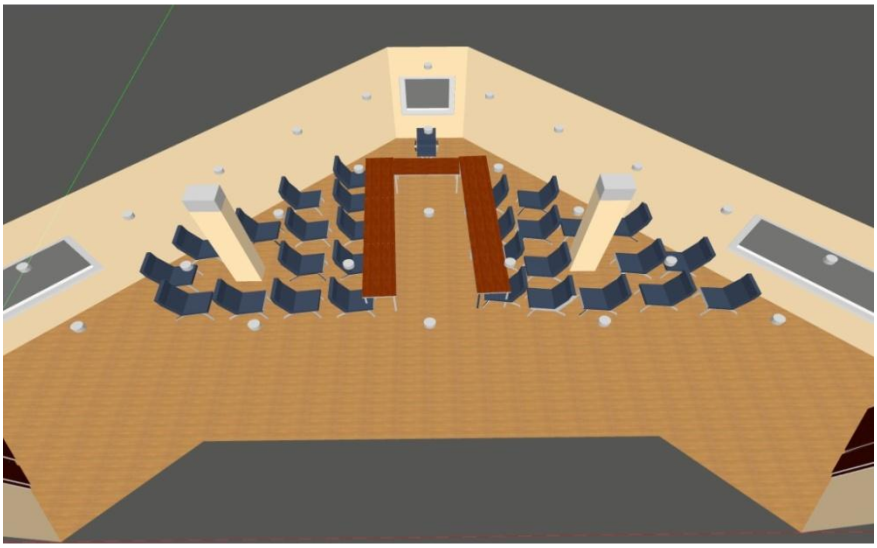

Figure 4:A model of ICT board room using Dialux-Evo

The simulation will be ran based on four different strategic levels:

Strategy 1: At this stage, a model of what is present at our area of study was produced, showing the exact specifications of the base case scenarios with the exact number of lamps without the application or use of sensors or light detectors. A simulation of this model was ran using Dialux-Evo software and results were obtained showing the energy and cost use.

Strategy 2: This stage shows a display of the model of the case study area illustrating the base case scenario of what is available as explained in stage 1. However application of light controls/detectors was introduced at this stage.

Strategy 3: Here the model was designed with an entire re-modification of the lamp types available in case study area, LED lamps were used instead of the contemporary compact fluorescent lamps (CFL's) present, without the application of light controls and detectors.

Strategy4: in the strategy four, the re-modified model as described in strategy 3 with the use of LED lamps was in play with the application of light controls/detectors.

Full range dimming is ideal for environments where variations in lighting should be subtle, such as classrooms or offices. Daylight dimming can be applied to up to four rows of lighting when 0-10v dimming ballasts are installed in the lighting luminaires. Sensors automatically adjust light levels up or down depending on how much available sunlight is penetrating the room. Each zone is independently adjusted so that lighting was maintained and energy savings maximized.

IV. Findings and Discussions

In this research study, light sensors with automatic dimming and on control abilities were introduced to help minimize the amount of artificial light used in the seminar room. The various data gotten from the simulated environment of the seminar room using DialuxEvo lighting design software with different case scenarios will be analyzed using charts and tables gotten as results from the software in this chapter

s/n	Strategy	Description	Cost N/a	Energy (kwh/a)	$KgCO_{2e}$
1	Base case	15 CFL lamps no sensors	60,000	800	370
2	Strategy 1	15 CFL lamps + sensors	35,000	560	259
3	Strategy 2	30 tiny LED lamps no sensors	42,500	550	254
4	Strategy 3	30 tiny LED lamps +sensor	7,250	165	76

Table 1: showing the energy usage and cost for the different strategies

The table above shows the different strategy cases with their corresponding energy usage, cost, and carbon emmitance rate. Base case strategy comprises of what is presently obtainable at the ICT seminar room, which consists of 15 compact fluorescent lamps (CFL) with no controls/sensors.
Strategy 1: comprises of 15 no. of compact florescent lamps with controls.
Strategy 2: consists of 30 tiny LED lamps were introduced with no control
Strategy 3: consists of 30 tiny LED lamps with light controls and sensors

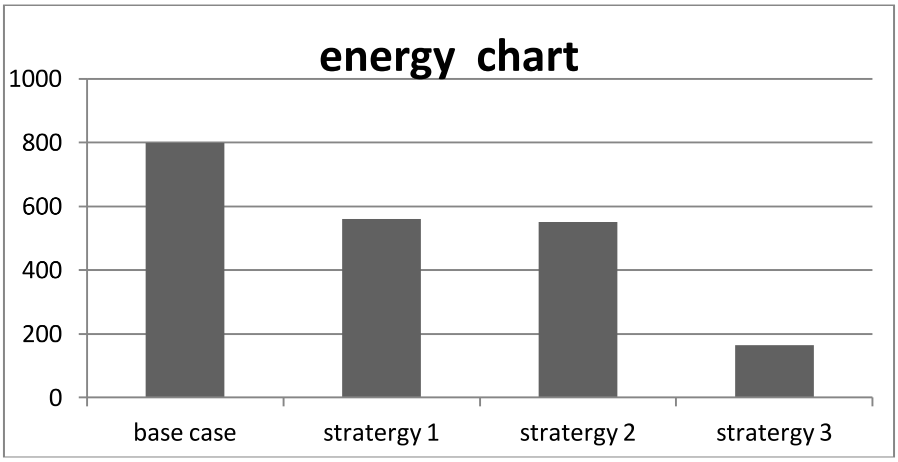

Figure 5:Showing the energy consumption rates

From the chart above the base case has the highest energy consumption pattern with 800kwh/a with strategy 2 and 3 having relatively similar energy consumption pattern of 560kwh/a and 550kwh/a respectively. The highest emery saving strategy as shown above is the strategy 3 with energy consumption rate at 165kwh/a, which is a 79% saving if compared with the base case scenario.

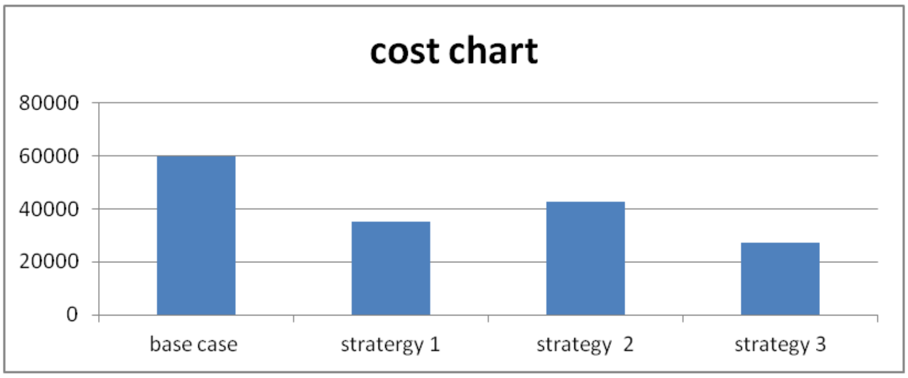

Figure 6: Showing the cost consumption rates

The cost chart shows that the base case which was presently obtainable at the ICT seminar room cost more than the other strategies thereby making strategy 3 the most cost effective strategy.

Figure 7: showing the carbon emittance rate at each strategy

V. Conclusions and Recommendations

Daylight Harvesting takes advantage of our largest energy source the sun. The daylight sensor placed in a room continuously measures natural light levels. When sufficient sunlight is present, electric lighting is reduced or eliminated. The room remains well lit but energy use is dramatically reduced. The US Green Building Council LEED, CHPS Collaborative for High Performance Schools, California Energy Commission, Department of Energy as well as lighting designers, school districts and municipalities nationwide, increasingly recommends Daylighting as a best practice in lighting design.

In relation to the simulations run and the data gotten from the entire research work, here are a few listed re-modifications advised/ recommended that can be applied to the already existing building, and can also be used in the construction of any new building. They include

1. Use of LED lamp instead of the normal/ existing compact florescent lamps which are presently in play
2. The introduction of more daylight into the building, since the case study area is located at the top floor of the building, the application of skylight and light tubes will go a long way to saving energy and cost use.
3. Daylight sensors and detectors should be put to efficient use in educational and other forms of buildings so as to regulate and ultimately reduce the energy and cost consumption rates.

   Clearly, savings can only be achievable in spaces with substantial daylight where electric lighting would have been otherwise used. daylight harvesting works best in spaces with access to, skylights, light tube, glass block walls, and other passive daylighting sources from sunlight; and where electric lighting would otherwise be left on for long periods. Such spaces include offices, seminar rooms etc.

References

[1]. Adeyemi A. Ogundipe, 2004, Center for Sustainable Building Research: Book on Daylighting Systems and Components, [cited 28 September] available from: Department of Economics and Development Studies, Covenant University, Ota,
[2]. Carmody, J., Selkowiz, S., Lee, E. S., Arasteh, D. and Wilmert, T.
[3]. Choi, A. S., &Mistrick, R. G. (1999). Analysis of daylight responsive dimming system performance.Building and Environment , 34, 231-243.
[4]. Choi, A. S., Song, K. D., & Kim, Y. S. (2005). The characteristics of photosensors and electronic dimming ballasts in daylight responsive dimming systems. Building and Environment , 40, 39-50.
[5]. DALI by Design. (n.d.). Q&A About DALI. Retrieved January 10, 2012, from DALI by Design: http://www.dalibydesign.us/faq.html
[6]. Energy Research Group - University of Dublin. (1994). Daylighting in Buildings. Dublin: University of Dublin.
[7]. Floyd, D.B., Parker, D., 1995. Field Commissioning of a daylight-dimming lighting system. In Proceedings of Right
[8]. IEA (International Energy Agency) (2007),
[9]. Intelligent Control and Automation, **2013, 4, 102-107** http://dx.doi.org/10.4236/ica.2013.41014 Published Online February 2013 (http://www.scirp.org/journal/ica)
[10]. International Energy Agency (IEA)2001, 2006. Daylight in Buildings: A SourceJournal of the IES, 28(2):42-56.
[11]. Leslie, R. P. (2003). Capturing the daylight dividend in buildings: why and how? Building and Environment , 38, 381-385.Light Three, 3rd European Conference on Energy Efficient Lighting, Newcastle, UK, pp. 83–88
[12]. Maniccia D, Rutledge B, Rea MS, Morrow W. 1999. Occupant control of manual lighting controls in private offices.
[13]. NBI 2003. Advanced Lighting Guidilines, New Building Institute Inc., 2003.
[14]. Philips Lighting. (2011). OccuSwitch Occupancy Detector Family . Retrieved December 19, 2011, from OccuSwitch DALI:
[15]. Pleasant Hills, CA: 2010 Electric Power Research Institute.programmer/IEA/Documents/Praesentationer_fra_IEA_konference_16_06_2010/Energy Efficient_Future_Electric_Lighting_for_Buildings.pdf, Aalto University of science and technology.
[16]. Reinhart, C. F., &Selkowitz. (2006). Guest Editorial: Daylighting – light, form, and people. Energy and Buildings , 38 (7), 715-717.
[17]. Rundquist, R. A., McDougall, T. G., and Benya, J. R. (1996). Lighting controls: Patterns for design. (TR 107230)

[18]. Ternoey, S. (2000). Daylight Every Buildings. Wisconsin: Daylighting Collaborative/Energy Center of Wisconsin.
[19]. Vaidya, P., McDougall, T., Douglas, J., &Eijadi, D. (2005). Making daylighting work: Learning from failures to improve the design and implementation process. ECEEE.Window Systems for High Performance Commercial Buildings,
[20]. X. Guo, D.K. Tiller, G.P. Henze, C.E. Waters,2010The performance of occupancy-based lighting control systems: a review, Lighting Research and Technology 42 (2010) 415–431.

Nkeleme Emmanuel Ifeanyichukwu, et. al. "Daylight Harvesting As a Control System in the Reduction of Energy Consumption." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(2), 2021, pp. 34-44.