Feasibility of Implementing Energy-Efficient Designs in the Illini Hall Replacement

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Executive Summary

This project researches the feasibility of implementing energy-efficient technologies in the design of the new Illini Hall replacement at the University of Illinois at Urbana-Champaign (UIUC). University buildings consume large amounts of power thus increasing costs and decreasing sustainability. For example, Illini Hall spends around $264,000 annually on power. As part of UIUC's plan to address this, Illini Hall is set to be replaced with a new, energy efficient building by 2023 (Evenson 2019). This project focused on three specific technologies that could increase the energy efficiency of this new building: solar windows, rotating solar panels, and occupancy sensor lights. Solar windows work by capturing and storing energy from the light passing through them. Rotating solar panels change orientation to capture the optimal amount of sunlight throughout the day. Occupancy lights conserve energy by only turning on when motion is detected and turning off after a period of no motion.

We began our project by performing a literature review of past problems, reviewing the codes, and visiting the site. Then, we performed an energy analysis of each of the three technologies and computed their energy outputs scaled to Illini Hall and their energy savings. Our next task involved computing the cost of incorporating each technology, which was accomplished by scaling the costs based on Illini Hall's dimensions. We then calculated the time after which each design would yield a positive profit. Lastly, we summarized our data in a final report, which was presented to UIUC.

Through our research, we calculated that the addition of tracking solar panels to Illini Hall's replacement would produce 325,000 kwh annually, while solar windows would only produce 11,000 kwh. Adding motion sensor lights would save 240,000 kwh, about 60% of the total energy used on lighting. Installation costs would be $475,200 for tracking solar panels and $50,000 for solar windows. Motion sensor lights are the least expensive, at only $9,200 total. Combining data, the payback period is 13 years for solar trackers, around 550 years for solar windows, and less than a year for occupancy lights. Based on our study, we recommend that UIUC incorporates occupancy lights into the construction of Illini Hall's replacement, since they are energy efficient and inexpensive. Solar windows appear unfeasible: although they would produce a significant amount of energy, their payback period is very large. We believe that UIUC should consider installing tracking solar panels because they produce a lot of energy and have a short payback period; however, the constraint of their weight on the roof should also be considered.

Introduction

Illini Hall is set to be replaced by a new, energy and cost-efficient building in 2023 (Evenson 2019). With the incorporation of some of the latest sustainable technologies, Illini Hall's replacement (Figure 1) will be able to gain the Leadership in Energy & Environmental Design (LEED) Platinum certification (Kuhl 2020). One of the LEED requirements that would be fulfilled is the renewable energy requirement, which requires that the environmental and economic harms associated with fossil fuel energy are reduced by increasing the self-supply of renewable energy (USGBC 2019).

Figure 1: Illini Hall is located across from Altgeld Hall, on the corner of Wright Street and John Street (Clark 2021).

A large amount of energy is required to power university buildings. The average cost of power in Illinois in August 2021 per kwh was 11 cents (EIA 2021). Illini Hall is 140,000 square feet (Kuhl 2020). Using this value, Illini Hall spends $264,000 annually on energy costs. The traditional method of acquiring this energy is through the burning of fossil fuels. Illini Hall uses this traditional method (Hardwick 2021) which requires more energy and increases costs compared to a modern electric system (EIA 2018). This leaves a large carbon footprint and releases harmful chemicals into the atmosphere. One such source of carbon is air conditioners. Illini Hall does not have a built-in air conditioning system, so it uses box air conditioners. Given that there are approximately 87 air conditioners in Illini Hall (Illinois Department of Mathematics 2015), the collective carbon footprint is about 130 tons of carbon (Muruganathan 2021) just from air conditioning. This, combined with the other outdated technology in Illini Hall, leads to a very large carbon footprint.

There are cleaner forms of energy that can be used to power buildings without having any of the negative side effects of burning fossil fuels. One such example is traditional solar panels, which are a common choice to harvest clean energy. The UIUC campus uses these panels on some buildings such as the Electrical and Computer Engineering Building (iCAP 2021). However, they lack optimum efficiency as traditional solar panels only gain energy from sunlight of a specific frequency, wavelength, and angle (Office of Energy Efficiency and Renewable Energy 2021). Consequently, most of the sunlight reaching the building is not converted into electricity. An average commercial solar panel converts only about 17-20% of sunlight into electricity (Sunrun 2021). A better solution would be to install solar panels with trackers. As shown in Figure 2, solar trackers capture more sunlight due to their rotational ability, which allows them to produce more energy.

Another clean energy alternative that we studied are solar windows. Solar windows are transparent solar panels that are installed in place of regular windows as shown in Figure 3. They are a good addition to future buildings like Illini Hall's replacement because more solar panels result in more sunlight captured which yields more electricity. Each solar window produces around 4 watts of electricity per square foot (Austin 2018) while regular windows produce no electricity. One downside to solar windows is that they can be expensive to install initially.

The final energy efficient design that we investigated are occupancy sensor lights. Occupancy sensor lights are installed in all the newly renovated halls and buildings on UIUC's campus (iCAP 2021) and are a good addition for Illini Hall's replacement. There are countless times when lights are left on when no one is present in areas like hallways or lounges. This can add up to become a large cost both financially and environmentally. Figure 4 shows the type of occupancy sensor lighting that we are interested in using. By installing occupancy sensor lights, we can reduce our energy consumption from lights by 17% (EIA 2012).

We plan to investigate the feasibility of utilizing rotating solar panels, solar windows, and occupancy sensor lighting at Illini Hall's replacement.

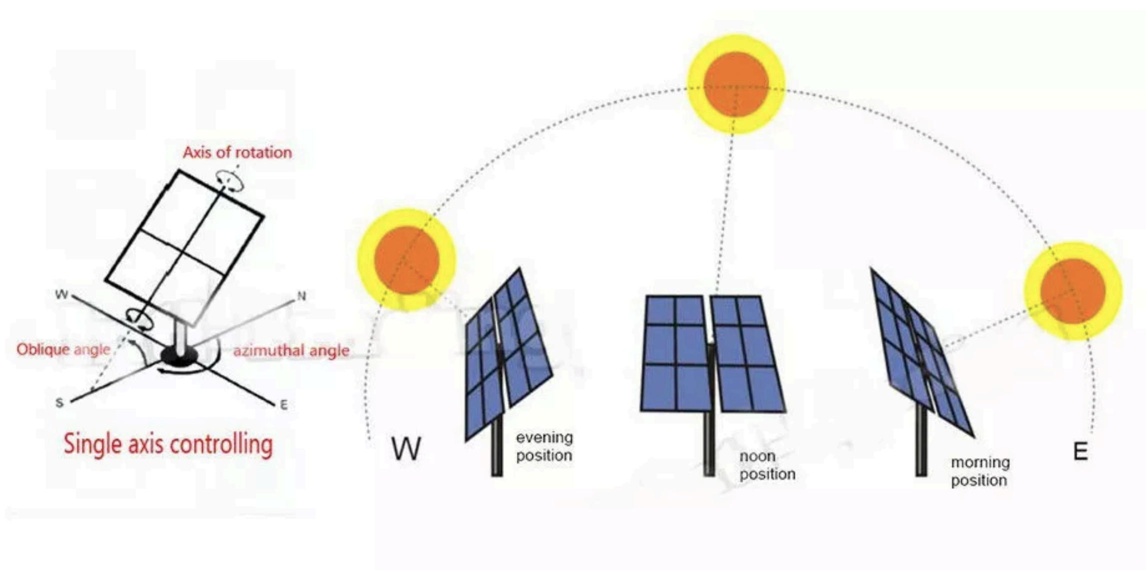

Figure 2: Rotating solar panels capture more energy from sunlight because they can capture light throughout the entire day (Alibaba.com 2021).

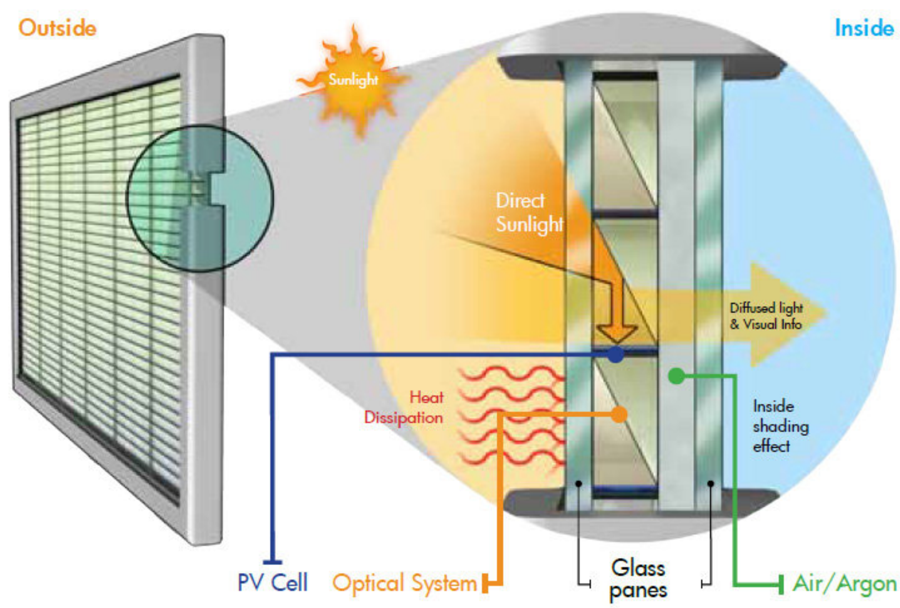

Figure 3: As sunlight hits the window, some of the re-emitted light is reflected and therefore trapped inside the glass where solar cells set into the window frame collect the energy (Elinwa et al., 2020).

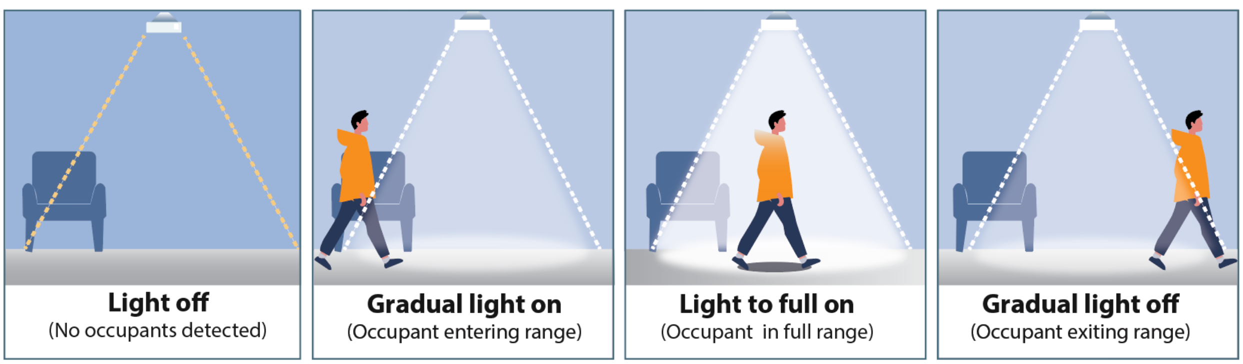

Figure 4: Pictured above are lights similar to the ones that we will study the feasibility of. Motion sensor lights conserve energy by turning off when there is no motion nearby (AS Mag 2019).

Objectives

The objective of this study was to research the feasibility of implementing occupancy sensor lights, solar windows, and rotating solar trackers on the new Illini Hall replacement. Through their power generation or savings, these designs will be able to reduce spending on external power sources, allowing the university to use this money elsewhere. Environmentally, the designs will limit the energy usage from fossil fuels thus decreasing pollution. In terms of LEED, with these designs the Illini Hall replacement will be able to earn points in the renewable energy category (USGBC 2019). We researched material costs and energy data involving these energy-saving methods to determine the environmental impacts as well as possible economic benefits in implementing these designs. This entire process took place over the course of the past 9 weeks, and we presented a final report to the university with our findings, including our energy-efficiency and cost analysis, the overall feasibility of each design, and our recommendations.

Methodology

The following section describes the tasks and subtasks that were performed to complete this study. The first task focused on conducting preliminary reviews of construction codes and current practices. Then, we performed a thorough energy analysis of all the possible designs. Through a detailed cost analysis, we determined both cost and savings. Finally, we made a final decision on the feasibility of each technology and composed a report that summarized our findings.

Task 1: Literature review

This task was important because it provided us with guidelines. For instance, we needed to ensure that the methods we considered abided by the area's codes. Investigating the practices currently in place ensured us that the plan we developed would be effective.

First, we reviewed the construction codes involving solar panels, solar windows, and motion sensor lights within Champaign, Urbana, and UIUC specifically. We also visited Illini Hall and determined which energy-saving practices are currently in place and researched the cost and energy efficiency of these practices.

Task 2: Energy Efficiency Analysis

This task was important because it provided necessary information for the feasibility study. The goal of these designs was to make the new Illini Hall more energy-efficient, so we needed to measure the amount of energy they would save to determine their feasibility. This information also provided background information for the following economic analysis, so that we could compare the costs and benefits, seeing if the designs would be feasible.

First, we determined the energy production associated with solar windows by finding how much energy the windows produce scaled to Illini Hall. Then, we did the same for solar trackers. We also researched how much energy is used by lighting and how much is saved using occupancy sensor lighting scaled to Illini Hall. Lastly, we determined the total energy consumption of Illini Hall and calculated how much energy is saved using each of the designs.

Task 3: Economic Analysis

Cost was the main factor in determining the feasibility of implementing these solutions. Even when we found there to be environmental benefits through clean energy, the cost of the designs was the largest obstacle in implementing them. Therefore, it was vital to perform cost estimations to examine if the environmental benefits were worth the costs, and if there were economic benefits over time.

We began by performing cost estimations of rotating solar panels, solar windows, and occupancy sensor lights. This involved gathering the cost per unit and area of coverage for all three, then scaling these costs to Illini Hall. We also aimed to determine the savings of each option. We accomplished this by determining the annual cost benefit of implementing each solution and estimating the payback period. We decided not to research past projects, as previously planned, since we found it more feasible to perform a bottom-up analysis than a top-down analysis.

Task 4: Deliverables

This task was essential because it allowed us to present the information that we gained through our project. Based on our efficiency and cost data, we determined whether implementing the proposed designs would be feasible. We provided a conclusion by stating the feasibility of each of our designs based on their costs and energy-efficiency. Then, we compiled all our findings into a report and presentation intended for the university.

Results and Discussion

The first set of research was performed to determine the energy efficiency or production of each individual design. This was vital to completing the cost analysis for the designs because it provided an idea of how much energy can be produced by the building itself instead of relying entirely upon external power supplies.

Before starting the analysis of energy production, we needed to find proper dimensions to scale our data. Because the blueprints for Illini Hall's replacement building have not been released to the public, we used the current Illini Hall to scale our data. We discovered that Illini Hall is 140,000 ft^2 (Kuhl 2020) and has an approximate rooftop area of 9,300 ft^2. The rooftop area was calculated using the measuring tool on Google Earth. We assumed that each window in Illini Hall would produce solar power. We counted 120 windows with an average area of 24.5 ft^2 equating to a total window area of 2,940 ft^2. Some of these figures, along with cost calculations that will be discussed later in this report, are displayed in Table 2 on the next page.

After finding the proper dimensions for scaling, a comparison of traditional solar panels to tracking solar panels was completed. We found that traditional solar panels produce about 500 kilowatt hours (kwh) per year per panel or set (Leonardo 2021) which equates to 28 kwh per ft^2 annually. This power production, scaled to Illini Hall, will produce around 260,000 kwh annually.

Utilizing a tracking system with the solar panels would bring the production up to 625 kwh per year per panel or set. This translates to about 35 kwh per ft^2 based on a 25% production increase (Solar Reviews 2021). This would equate to 325,000 kwh annually.

Special notice will need to be taken regarding the weight of the proposed solar panels with trackers and the weight capacity of the roof on the Illini Hall's replacement because the solar panels with trackers are heavier than traditional solar panels. The exact weight difference depends on the designs implemented. Because of the large variability of the weights of tracking systems and the lack of information on the structural integrity of the planned building, we cannot determine whether using rooftop tracking solar panels is feasible from a structural engineering standpoint.

Looking at solar windows, they produce about 3.8 kwh per ft^2 annually (Extance 2021). Scaled to the Illini building, this production will be around 11,000 kwh per year. All the solar data calculated is based on average conditions, so the actual values may vary slightly based on weather conditions.

The energy production of these three designs is summarized in Table 1 below. The scaled total production and production per ft^2 are displayed for each design. This energy production can also be considered energy saved.

Table 1: Energy Analysis Data

	Annual Energy Production (kwh per ft^2 / Total)
Tracking Solar Panels (Leonardo 2021)	35 / 325,000
Traditional Solar Panels (Leonardo 2021)	28 / 260,000
Solar Windows (Extance 2021)	3.8 / 11,200

Motion sensor lighting or occupancy sensor lighting also has the potential to save a large amount of energy. Implementing occupancy sensor lighting can increase energy savings by 60% and reduce energy waste by 68% (EC&M 2001). This 60% would only be energy savings from light, which uses up about 17% of energy within a building (EIA 2012). To find the savings for motion sensor lights, we needed to find the total energy consumption of Illini Hall. We found that an academic building uses about 17.4 kwh per ft^2 annually (EIA 2016). Scaled to the area of Illini Hall, this is 2,400,000 kwh annually. Since light will use around 17% of this, and 60% of that value can be saved using occupancy lights, the savings will be about 245,000 kwh annually.

After determining all the possible energy savings, we began calculating economic savings. To do this, we needed to establish what our units were and determine the cost per unit. After finding the cost per unit, we found the total cost of each design based on the established areas discussed earlier in this report.

We began the cost analysis with occupancy sensor lighting. Using common practices for implementing motion sensors (Lutron 2014), it was assumed that each room in the building would have a motion sensor and that each hallway would have three motion sensors. Under these guidelines, we estimated that 115 sensors would be needed using an Illini Hall floor plan (Illinois Department of Mathematics 2015). Since one motion detector costs $80, we scaled the total cost to be $9,200.

To estimate costs for solar windows, we found that solar windows cost $186 per ft^2 of window (Understand Solar 2021) or in our case $4,600 per window. Using this and the total area of 2940 ft^2, the approximate scaled cost of implementing solar windows is $550,000.

As we did for solar windows, we found the scaled cost of solar panels and solar panels with trackers using the established total area, which was 9,300 ft^2. Since one set of solar panels is 18 ft^2 and costs $330 (Consumer Affairs 2020), we divided the total area by 18 ft^2 to find number of sets and multiplied by $330 to find the total cost of $171,700.

We followed a similar approach for calculating the cost of solar trackers. We found that one set, which fits twelve 18 ft^2 panels, costs $7,000 (EcoDirect 2021). Then we multiplied the area of one panel by twelve to get 214 ft^2. Finally, we divided the total area, 9,300 ft^2, by 214 ft^2 to get the number of sets and multiplied this number by cost per unit. From these calculations, the approximate scaled cost of solar trackers is $303,500. To find the true cost of using rotating solar panels, we combined the cost of the panels and the trackers to get a total value of $475,000.

All of these cost calculations and estimates are summarized in Table 2 below. The table also shows the total areas and number of units used.

Table 2: Cost Estimation Data for Illini Hall

Item	**Cost per Unit**	**Units**	**Total Area / # of Units**	**Approximate Scaled Cost**
Solar Panel Rotational Tracker (EcoDirect 2021)	$7,000	1 set (Fits twelve 5.5x3.25 ft panels)	9,300 ft^2 / 43 sets	$303,500
Solar Windows (Understand Solar 2021)	$4,600	1 window (24.5 ft^2)	2940 ft^2 / 120 windows	$550,000
Motion Detector (1000bulbs 2021)	$80	1 unit	115 units	$9,200
Solar Panels (Consumer Affairs 2020)	$330	1 set (5.5ft x 3.25ft)	9,300 ft^2 / 520 sets	$171,700

Our final step in the cost analysis was to determine if the projects were financially feasible. We based this mainly on calculated payback periods and annual savings. To calculate money saved for each design, we first discovered that the average cost of power in Illinois in August 2021 per kwh was 11 cents (EIA 2021). Using this value, Illini Hall can expect to pay $264,000 on power annually. When scaled to the kwh savings found in our designs, Illini Hall can save about $29,000 using traditional solar panels, $36,000 using trackers, $26,000 using occupancy sensor lighting, and $1,000 using solar windows every year.

To determine the approximate payback time, the initial cost was divided by the savings each year. For traditional solar panels, the payback period was calculated to be 6 years, while adding solar trackers increased the payback period to 13 years. The use of solar windows would call for a payback period around 550 years. Finally, using occupancy sensor lighting would have a payback period of less than a year. From a financial standpoint, solar windows will not be worth the cost, while both occupancy sensor lighting and solar tracker panels will be worth the initial cost. These payback periods are summarized in Table 3 below.

Table 3: Payback Periods for Implementations

Design	**Payback Period (Years)**
Rotating Solar Panels	13
Solar Panels	6
Solar Windows	550
Occupancy Sensor Lighting	<1

In this section, we found the proper dimensions of Illini Hall to scale our data. Then, we determined the energy production of the solar designs per ft^2 and scaled it accordingly to find the total production. To find the savings of the occupancy sensor lighting, we found the total energy use of Illini Hall and calculated the savings from occupancy sensor lighting based on 60% savings and 17% light-energy use. To perform our cost analysis, we found the cost per unit of each implementation then scaled this to Illini Hall. With these initial values, we found the payback periods of each by dividing the initial cost by annual savings.

Conclusions

The addition of tracking solar panels and motion sensor lights to Illini Hall's replacement are cost-effective methods of improving the building's energy efficiency. The implementation of solar windows would not be feasible because of their high cost and low savings. The study was performed to fulfill the university's goal to make Illini Hall's replacement sustainable to combat a major problem: university buildings consume vast amounts of electricity thus increasing cost and carbon footprint.

The annual savings of rotating solar panels, solar windows, and occupancy sensor lights were calculated to be $36,000, $1,000, and $26,000 respectively. Furthermore, the payback periods were around 13 years for rotating solar panels, 550 years for solar windows, and 1 year for occupancy sensor lighting. Based on this, we concluded that the rotating solar panels and occupancy sensor lights are feasible and that solar windows are not feasible because of the long payback period. Because we did not have access to the blueprints for the new Illini Hall, our data was scaled to the current Illini Hall. This could have produced inaccurate results. Additionally, we determined rotating solar panels to be economically feasible, but they may not be feasible for the new building based on their weight and the structural capacity of the roof. Our results are relevant because the university will continue to explore similar designs to create more sustainable buildings.

Before starting this report, we hypothesized that all three designs would be feasible based on our experiences. Based on our findings, we recommend that the university implements occupancy sensor lights, considers implementing tracking solar panels, and conducts a second phase of this study, which should involve investigating the effect of solar trackers' weight upon their feasibility.

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Disclaimer

This report was created for academic purposes only and is not intended for professional use. Our recommendations may be based on incomplete information and data.

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Group Reflections

Over the past three months, our group has worked to determine the feasibility of implementing solar windows, rotating solar panels, and occupancy sensor lighting in Illini Hall's replacement building. Through doing this project we have learned a lot. First and foremost, we learned how to work better as a team. Before this project, we did not know each other at all, and this presented some challenges with initial communication. While we have had some disagreements over the past three months, we have been able to come to agreements and have become better team members because of it.

As a team, we learned how to create an effective engineering report. While all of us have written reports before, none of us had ever written a report this complex or detailed. There were some parts that we were not familiar with prior to the class, such as the scope.

Some errors in our data might include the energy production of the solar components. These were calculated using online sources, which may have different weather conditions than UIUC experiences or different panel efficiencies. To obtain better data, we would need to conduct a yearlong study here on campus on the energy production of each solar component. Another source of error may be the area of the rooftop on Illini Hall. This was calculated using Google Earth which may lead to some slight inaccuracies. To improve this measurement, we would have to measure the rooftop directly.

In terms of doing things differently, we would try to pick a project that is generally smaller. Completing a feasibility study of three separate designs for an entire building, one that we knew little about, presented many challenges. Picking a project on a smaller scale would have allowed for more precise measurements and less time commitments dedicated to research.