Implementing Net Zero Energy Elements into the Construction Innovations Center

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As the environmental status of our planet declines, it is becoming increasingly important for the construction industry to adapt. Leadership in Energy and Environmental Design (LEED) is becoming an unspoken requirement for all new and tenant improvement construction, and now, with the goal of Net Zero Energy (NZE) for all new commercial buildings by 2030, NZE is becoming the way of the future. As of late, California Polytechnic State University in San Luis Obispo (Cal Poly) has made grand efforts to retrofit several of the older buildings on its campus in order to achieve LEED certification. One of the younger buildings on campus that performs very efficiently compared to other buildings on campus is the Construction Innovations Center (CIC), home of the Construction Management (CM) program. Due to the structure being barely ten years old, it was looked over for the LEED retrofitting project. However, being one of the top CM programs in the nation, Cal Poly should display its innovation and prowess by utilizing strategies based on a past tenant improvement project by DPR Construction (DPR). Cal Poly can implement the strategies DPR used into the CIC in order to make the building become more sustainable and eventually NZE.

Key words: Net Zero Energy, Sustainability, Green Buildings, Tenant Improvement, Cal Poly

Background Information

In 2008, Cal Poly completed construction on the CIC and then two years later completed construction on the Simpson Strong-Tie Lab (SST). As one of the top CM programs in the nation, Cal Poly should to be on the forefront of industry innovation. NZE is becoming the new leading construction practice for sustainability. By definition, NZE is a building that produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector (U.S. Department of Energy, 2015). Due to the fact the CIC is almost ten years old, costly extreme tenant improvement (TI) measures are considerably unwarranted; however, there are several elements that can implemented into the building in order for it to become more sustainable, and perhaps even NZE.

Introduction

The first certified NZE commercial building in San Francisco (SF), California, was DPR's regional office building. DPR was both the owner and general contractor for the TI and wanted to pursue the project in order to highlight their knowledge and skill for constructing NZE buildings. One of the company's core values is *Ever Forward*, and they show this innovation through a companywide goal to have every single one of their offices be NZE. For the San Francisco office in particular, they faced some challenges due to the confinement of the existing structure. After interviewing one of the lead project managers, Mike Messick, as well as researching a case study of the building, I was able to evaluate the strategies DPR used in order to achieve NZE for their SF regional office.

Electrical

There are several different sustainable measures that can be implemented into a building to help it achieve NZE status. The biggest influence on commercial NZE buildings is electricity. The first solution is to counter electricity consumption by installing photovoltaic (PV) panels. PV panels harness energy from the sun to help produce energy for the building they occupy; therefore, reducing the need for outside energy producers, like PG&E. DPR installed three hundred and forty-three (343) SunPower 345-watt PV panels to produce a 118 kilowatt (kW) renewable energy system and provide power throughout the office (DPR, 2016). In regard to lighting, they installed solar tubes and skylights to bring more natural light into the building, thus eliminating the need for almost any lights to be on during the day. Rooms that do not have access to the natural light, like the back-conference rooms, gym, and restrooms, are powered by the PV panels and also have motion and heat sensors installed so that lights are only on when the room is occupied by someone (Messick, 2016). The next largest energy consumer was plug loads. To mitigate the consumption plug loads had on the building, they installed “smart” plug strips that use plug load management software, which contributed to substantial energy savings (Messick, 2016). The final electrical element that DPR installed into their office is a vampire switch. Messick explains that whoever is the last person leaving the office will flip the vampire switch, which then kills all non-critical power in the building (Messick, 2016). What many forget is that buildings are like living creatures, and they continue to run even when no one is occupying them. Killing all non-critical power at the end of each day saves DPR both energy and money.

Mechanical

The next biggest energy consumer in commercial office buildings are mechanical systems. DPR was able to lower its mechanical energy consumption by installing two elements, controlled and monitored by Honeywell Command Wall Touch technology incorporated Building Management System (BMS) (DPR, 2016). The first element was replacing some of the windows with automatic windows which are monitored and controlled by the BMS. Based off the BMS readings, those select windows will automatically open or close in order to keep temperatures optimal and comfortable for the tenants inside the building (Dean, 2016). The second element they installed were Big Ass® fans (DPR, 2016). These large fans rotate slowly throughout the day and increase air flow, which does not necessarily cool down the building, but tenant's claim they feel cooler with the fans on (Messick, 2016). Since the tenants feel cooler, the need for air conditioning decreases. Both the automatic windows and Big Ass® fans are integrated into the mechanical system to supplement the Heating Ventilation and Air Conditioning (HVAC) system. With all these systems working together cohesively, DPR reduced the use of the mechanical system (Dean, 2016).

Plumbing

Lastly, DPR installed just a few utilities that helped save both energy and water. First, they heat all their potable water using solar thermal water heating technology harnessed from the PV panels (DPR, 2016). Because they have showers in their office building, this helps save an incredible amount of energy that would have otherwise been used to heat the water in a less efficient manner. Second, they have ultra-low flow and flush plumbing fixtures (DPR,2016). It takes considerably less water to dispose of non-solid waste than it does to dispose of solid waste, so it is impractical to flush more gallons of water than necessary. Third, DPR installed a rain-runoff collection system. They use this system to water the Living Wall in the atrium of the building; however, this system is only effective during the rainy months of the year (Messick, 2016). Even though water consumption is not integral to the energy saving equation, it still plays an important role in making a building environmentally efficient.

Goals & Objectives

Each commercial building has its different limitations and boundaries, which are dependent on several factors including usage, location, climate, etc. Based on an energy data analysis of the CIC and SST collected via Energy Star’s Portfolio Manager, I was able to use Energy Star’s Target Finder to establish a goal Energy Use Intensity (EUI). Additionally, by comparing the CIC to the DPR San Francisco office, I found that almost all the strategies DPR used Cal Poly might be able to use as well to implement into the CIC. However, since the CIC is still a new building, the more time and cost intensive improvements that are commonly used in a TI, might not benefit the CIC in the short run. As mainly occupied during the months of mid-September through mid-June, upgrades made to the building would most likely have to be made in the months between that. With these time constraints in mind, it is important to evaluate the relative size of the materials being considered for installation. With time and money being the determining factors of possibly pursuing these upgrades, it was integral for me to develop a rough estimate so that I could then perform the necessary financial analysis.

Methodology & Deliverables

There are several minor upgrades that Cal Poly can do to enhance the CIC and make it more energy efficient in the short run, but to become a NZE building, would require a full-blown tenant improvement. Considering how young the CIC is, it would not be cost effective to make such drastic upgrades to it yet during this point in the building's life. The three main areas of focus for improving the CIC are electrical, mechanical, and plumbing. After assessing what materials can most likely be installed or upgraded into the CIC, I will be better equipped to create a rough estimate and perform a return on investment (ROI) for the materials I suggest being installed.

Electrical

The biggest contribution to making the CIC NZE is savings in electricity. The most monumental thing that we can do surrounds the lighting situation. Anyone who has spent any time in the CIC knows that the use of lights is excessive. There are several ways for us to eliminate the overuse of lights. The first would be to install motion and heat sensors in all of the rooms. There are countless times where I walk into a classroom where no one is there and all the lights are on. For the amount of occupants the building sees every day, it is unrealistic to assume that every student and faculty will turn off the lights if they are the last persons to leave. The next solution revolves around the acoustical sound panels in each of the rooms. As I learned in my Jobsite Construction Management class, the CIC is flawed in several ways. One of these flaws that showed itself after construction was complete had to do with the acoustics. Acoustics in buildings are not usually something that is give a substantial amount of thought until the building is in use. This was the case for the CIC, and in order to solve this problem, Cal Poly installed acoustic panels along the windows of each of the classrooms. Although solving the acoustics problem, the panels also block a substantial amount of natural light. By finding an alternative solution to these panels, Cal Poly could increase the natural light in the classrooms, and therefore decrease the need for artificial light. Other than lighting, another was to save on energy savings is to install "Smart" plug strips that use plug load management software. Students are constantly charging their laptops and other electronic devices, so installing these "Smart" plug strips at student cubicles would have a considerable effect on energy savings.

Mechanical

The second most contributing factor of energy savings in the CIC is the mechanical system. In regard to the current mechanical status, the air conditioning used to cool the building is overly necessary. Over the summer and winter months, there is no need to provide such high levels of air conditioning into the three wings of the CIC. In order to minimize the overuse of the HVAC system that is in place, we can implement strategies that DPR used such as automatic windows, Big Ass® fans, and an integrated mechanical system. Looking at the classrooms now, the fans would have nowhere to be installed; however, if we can reduce the need for lighting, we can remove one to two lighting strips and install one fan per room.

Plumbing

The plumbing will have the least effect on the sustainability of the CIC. Unlike many other buildings on campus, the CIC fortunately has heated water at sinks, which is a luxury. However, the hot water is powered by the building's gas boiler, which is exceptionally inefficient. By eventually switching to a solely electric-powered building, Cal Poly can utilize the PV panels to heat the potable water using solar thermal water heating technology. Lastly, rather than having automatic flushing toilets that waste hundreds, if not thousands of gallons of water each year, installing dual-flush system toilets would benefit the CIC both economically and environmentally.

Results

The first step I took before researching what methods could possibly be installed into the CIC was figuring out how much energy the CIC uses in an average month. In order to do so, I met with several Cal Poly faculty, where I was finally introduced to architecture lecturer Stacy White, who is one of the key players in the Cal Poly sustainability movement. During my meeting with White, she showed me Energy Star's Portfolio Manager and granted me access to the CIC profile. Energy Star's Portfolio Manager in a web based software that allows its users to track and measure a buildings energy consumption, therefore allowing its users to see where the building is performing efficiently and where it could use some improvement.

Energy Consumed

By using Energy Star's Portfolio Manager, I was able to discover the amount of energy the CIC and SST consumes on a monthly average. There are two types of energy use types, the first being source energy use and the second being site energy use. Source Energy Use is the total amount of raw fuel that is required to operate your property, and Site Energy Use is the annual amount of all the energy your property consumes onsite, as reported on your utility bills (Energy Star, 2017). Based off the most recent reading in November 2016, I was able to find the following energy consumed, shown below in Table 1.

Table 1

Energy consumed by the CIC for the month of November 2016

Energy Use Type	**Quantity**	**Unit**
Source	6,195,333	kBtu
Site	3,183,086	kBtu
Total	9,378,419	kBtu

White explained to me that there are two units of measurement when dealing with energy use, kilo British thermal units (kBtu) and kilowatt-hours (kWh), and there is simple conversion that must be performed in order to figure the cost of the energy being measured (White, 2017). After using the conversion factor of roughly 3.412 kBtu to 1 kWh, I calculated that 2,748,543 kWh of energy were consumed for the month of November 2016. The cost for electricity in San Luis Obispo through Pacific Gas & Electric (PG&E) is $0.14/kWh (PG&E, 2017), which means that for that month, Cal Poly spent $386,995 to power the CIC.

Potential Energy to Produce

Next, I utilized a web based technology, called PVWatts® Calculator, through the National Renewable Energy Laboratory (NREL) website to calculate the potential amount of energy that could be produced if PV panels were to be installed. Due to the layout of the CIC, only the A wing and B wing would be able to provide enough room for PV panels, as the roof of the C wing is dedicated to mechanical systems. To use the PVWatts® Calculator, I entered in the Cal Poly address and from there the Calculator will adjust the settings of the proposed PV panels to fit with the location of the building. I tested which tilt angle would provide the optimal energy production and found that 31 degrees produced the most energy. Then, the Calculator allowed me to draw a proposed roof installation area on a satellite map of the address that I originally inputted. After doing so, it generated the following results shown below in Table 2.

Table 2

Potential energy that could be produced by PV panels if installed on the CIC

Wing	**Quantity**	**Unit**
A	60,958	kWh
B	99,015	kWh
Total	159,973	kWh

Using the results generated by the Calculator and the price per kWh of $0.14/kWh (PG&E, 2017), I found that the Cal Poly could save close to $22,524 per month. Based on the pricing of various PV panels estimates, I found the average to cost $2.14/Watt. This converted to roughly $0.05/kWh, leaving the total estimated cost to come out to approximately $8,216. The installation costs could be almost immediately paid back for in full; however, the implementation of the PV panels would put a minor dent in the overall cost needed to power the CIC. Nevertheless, if Cal Poly were to install PV panels and make minor upgrades to the CIC, the energy to power it could decrease considerably.

Potential Energy to be Saved

After I had calculated the amount of energy the CIC could produce by installing PV panels on the A and B wings of the building, the next step I took was deciding what materials might be the best to be installed into the CIC to reduce its energy consumption. Once I had done so, I then performed a material quantity take off based on the amount of rooms in the CIC and then rough estimate of the materials I felt that had would have the most success being implemented into the CIC. Table 3, shown below, is what resulted from that.

Table 3

Estimate of materials that could be purchased and installed into the CIC

Item	**Quantity**	**Unit Cost**	**Total Cost**
Heat & Motion Sensors	77	$164	$12,628
"Smart" Plug Strips	175	$33	$5,775
Automated Windows	38	$595	$22,610
Big Ass fans	22	$579	$12,738
BMS System	1	$215	$215
Solar Water Heater	1	$2,510	$2,510
Dual Flush Ultra-Low Flow Plumbing Fixtures	54	$149	$8,046

Note. The reserve values are based off average prices, not one specific product in general

In total, my estimate came out to about $64,522. Unfortunately, I was unable to generate a simulation to get an estimate of how much energy could be saved by integrating the materials listed above into the CIC. Due to the fact that I was unable to generate a quantity of energy to be saved, this hindered my ability to produce a ROI. Nonetheless, using Energy Star's Target Finder, I was able to produce a goal EUI for the CIC and SST. By filling out the buildings details; such as the gross square footage of the building, weekly operating hours, number of students enrolled, number of full time workers, quantity of computers/laptops, and a target EUI; Target Finder was able to provide me with an estimate of how much energy I have to produce and save in order to achieve the goal I inputted.

Analysis & Conclusion

After reviewing several different methodologies and elements that will contribute to the CIC producing its own renewable energy, the best solution in the near future are the minor upgrades listed above. For a longer look ahead, in order to reach complete NZE, a TI will be necessary. The CIC achieving complete NZE status at this time is technically impossible because the building is not ran solely using electricity. By implementing the suggested elements stated above, and by switching our mechanical system from gas-powered to electric-powered, then the CIC's chances of becoming NZE are far greater.

Future Research

There is still so much that could be analyzed and discovered by researching further into the CIC and NZE best practices. If another student were to further pursue my research, I would recommend that they partner up with either an electrical engineering and or mechanical engineering student. This way, they could work together as a team to run hypothetical tests to see how much energy there is to be saved, but potentially even install the materials into the CIC or another building on campus. Another topic I would recommend is looking into the Life Cycle Analysis (LCA) of the CIC. By using a Building Information Modeling (BIM) software like Tally, would provide whoever the tools to conduct a LCA on the CIC, as well as track its status and progress as more and more sustainable elements become integrated into the building. If this project is decided to be pursued by someone, regardless of who decides to pursue it, the Construction Management department could use it as a teaching opportunity and have students install the materials themselves. I realize that could be risky, but I think it still has the potential to work itself out nicely and save on installation costs. As stated before, I believe that the implementation of NZE elements into the CIC is completely possible, it will just require an investment in time and money.

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