Boston College

The College of Arts and Sciences

Department of Earth and Environmental Science

Building A Green Recreation Complex:

Sustainable Considerations for the Future of Boston College Campus Recreation

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1. Introduction

Boston College is a Jesuit Catholic institution situated in Chestnut Hill, MA with a total enrollment of 14,100 students (Boston College, *Facts & Figures*, 2015). One of the many buildings on campus that is actively used by students, faculty, and residents of the surrounding area alike is the Flynn Recreation Complex. With 12,449 unique visits to the Flynn Complex during the 2013-2014 school year, the complex is one of the most important buildings on campus (Boston College, *Fact Book,* 2015). Opened in March 1972, the Flynn Complex is set to be replaced by a new recreation facility as part of Boston College's Institutional Master Plan (IMP) (BCRec, 2015). Because of increasingly strict Massachusetts building codes, a new LEED certification matrix, and Boston College's commitment to creating an environmentally friendly campus, the energy efficiency and sustainable design of the new recreation facility are particularly important.

Due to the location of the site and high projected usage of the new recreation facility, the stakeholders are looking for unique ways to incorporate energy and water saving design features such as increased natural lighting, more advanced heating, ventilation, and air conditioning (HVAC) control, alternative methods of heating both air and water, and low-flow fixtures. These ideas, along with various others must be assessed in order to determine what will yield the most efficient and environmentally friendly building design while remaining within a reasonable budget and preserving the important features of a student recreation facility.

As Boston College is developing the new facility, the environmental issue of sustainability will be considered. Boston College is a Jesuit institution that seeks to protect the natural environment as well as human and ecological health, while driving innovation and not compromising its way of life (Boston College: The Division of University Mission and Ministry, 2014). This study will examine the possible energy efficiency and water saving techniques that can be employed in the construction and design of the new recreation facility in order to achieve the highest level of LEED Silver certification. Research on the energy and water use of the current Flynn Recreation Complex as well as comparable recreation centers at other universities will be used in the hopes of creating an informed study on an energy and water efficient building

2. Background

Because of an increasing population and continuously strained resources, water and energy efficiency are paramount to transitioning to a sustainable future. As a natural resource, water is perceived to be an abundant resource, especially when two-thirds of the earth is covered by water. But less than one percent of the planet's water is drinkable (Glennon, 2009). Water conservation reduces energy use, and reclaiming water reduces water pollution. With regards to energy, the use of renewable and nonrenewable energy sources must be considered. If society continues to use energy without employing proper conservation methods, nonrenewable energy sources may become depleted and renewable energy may be the only option. Understanding the value of energy and water is paramount to understanding why it is important that Boston College seek to incorporate sustainable design features into the new recreation facility.

2.1 LEED Certification

The rubric for how Boston College's new recreation facility will be evaluated is based on the LEED certification matrix. LEED, or Leadership in Energy & Environmental Design, is a framework for identifying and implementing practical building design, construction, operations, and maintenance solutions (USGBC, 2012). The LEED rating systems address different types of projects including schools, healthcare, retail, commercial interiors, homes, as well as the operation and maintenance of existing buildings. For these different projects, LEED certification uses independent, third-party verification to provide the most sustainable design and construction strategies in improving human and environmental health (USGBC, 2012). LEED promotes a "whole-building" approach to sustainability by recognizing performance in five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality (Stinnett, 2013). The scoring is based on a 100-point system in which each credit is distributed on the basis of how the building impacts the environment and human health (USGBC, 2012). This point system is broken down into four categories: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), and Platinum (80+ points).

Diamond, Opitz, Hicks, Von Neida, and Herrera (2006) evaluated the energy performance of 21 LEED certified commercial buildings and found that for this sample (7% of all LEED certified buildings at the time), the mean simulated energy savings was 27%. But they also found that the number of LEED energy efficiency points did not correlate with the actual energy savings. Although LEED certification is a green building certification program which seeks to encourage sustainable development, the amount of water and energy that is used efficiently or conserved is questionable. Newsham, Mancini, and Birt (2009) analyzed energy use data from 100 LEED certified commercial and institutional buildings and compared it to the energy use of general commercial buildings. They found that on average, LEED buildings used 18-39% less energy per floor area than their conventional counterparts (Newsham, Mancini, & Birt, 2009). However, 28-35% of LEED buildings used more energy than their conventional counterparts overall. Newsham, Mancini, and Birt (2009) found that the measured energy performance of LEED buildings had little correlation with the certification level of the building which echoes the findings of Diamond, et al. stated previously (2006). Findings from this research demonstrates that more needs to be done to define green building rating schemes to ensure more consistent success at the individual building level. That being said, the LEED certification matrix is still in its early stages. It is currently undergoing a transition to a stricter rating system in an effort to increase the sustainability of buildings (Reinders, 2016). Therefore, we consider it a valuable system to use when assessing the new recreation complex.

2.2 Sustainability in Recreation Facilities

Sustainability has become a hot topic in higher education in the United States, because of an increased focus on the importance of protecting the environment through sustainable development. A generally accepted definition is the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” from the Brundtland Commission published in 1987 (Bärlund, 2016). Sustainable development supports economic and social development, with an underlying emphasis on protecting the natural environment. In the particular case of a recreation complex, this can be interpreted to focus on the development of healthy individuals, a healthy community, and a healthy environment.

An area that is playing a major role in environmental efforts and sustainable development is facility design and operations. Many facilities are planned, constructed, and operated with long-term sustainability as a prominent goal of architects, contractors, and managers. Enhancing quality of life and effective community relations are typical operating principles for collegiate facility managers, which is in line with sustainability. Stinnett (2013) reports that *environmental* and *fiscal* reasons are the top two perceived benefits of implementing sustainable initiatives. On the contrary, *fiscal* and *administrative* reasons are the top two perceived challenges of moving towards sustainability.

Stinnett (2013) examined sustainability and collegiate recreational sports facilities as collegiate recreation complexes often pose a challenge to this movement due to their size and operational requirements. Recreation facilities tend to be some of the largest and most heavily used buildings on college campuses. At the outset, they require large amounts of steel, concrete, and other materials to be transported during construction. Once completed, they have the potential to be enormous users of water and energy. Nevertheless, research has shown that schools which transition to sustainability or green design save energy and water. A study of 30 “green schools” found that they used an average of 33% less energy than conventionally designed schools, as well as had an average water use reduction of 32% (Stinnett, 2013). Typical energy and water performance enhancement included lighting that is more efficient, greater use of daylight and lighting sensors, more efficient heating and cooling systems, and better-insulated walls and roofs.

3. Methods

To assess the potential for sustainability design in the new recreation facility, we used both qualitative and quantitative analysis. The qualitative analysis helped us to attain a benchmark of existing facilities that demonstrate excellent use of sustainable features and best-practices. Our quantitative work helped us to understand the current state of the Flynn Recreation Complex and come up with recommendations based on projected future usage.

3.1 Qualitative Analysis

An important consideration in designing the new recreation facility is making sure that the building meets the needs of the student body while also remaining competitive with the facilities at its peer institutions. A team of Boston College administrators including Caitríona Taylor (Director of Campus Recreation), Bob Pion (Sustainability Program Director), Rebecca

Cegledy (Associate Director of Facilities and Operations), and Ed Stokes (Senior Project Manager for Capital Projects Management) visited various colleges and universities in the early stages of the design process to determine what features would be important in the new building. While they were able to get some general ideas, such as the indoor track at Auburn University which simulates a running path through the woods or the 30-foot climbing wall at Clemson University, our team felt that it would be important to take an in-depth look at a few select facilities (Stokes et al., 2016). With recommendations from these important stakeholders, we decided to look specifically at the Boston University (BU) Fitness and Recreation Center and the Worcester Polytechnic Institute (WPI) Sports and Recreation Center. Boston University was chosen because of multi-use nature of the facility and the sheer volume of traffic that it handles each day. We hoped to learn about how the design of the building incorporated sustainable features, and how these features impacted the patrons. Our team reached out to Alexander (Alec) Southall, the Associate Director of Facilities, Intramurals, and Club Sports. We decided a conversation with Alec was a logical starting point because of his role as an Associate Director of three important tenets of a college recreation center: facilities, intramurals and club sports. Alec arranged for us to meet with him in person and to conduct a tour of the facility.

We also examined WPI's Sports and Recreation Center, one of the most sustainably-advanced facilities of its kind in the Northeast United States. The relatively new facility opened in 2012 and attained a LEED Gold certification. We felt it would be ideal to examine this facility because it attained such a high LEED score in a climate that is similar to what the new Boston College recreation facility will be built in. Furthermore, we found that WPI's facility makes a worthy comparison to Boston College's current Flynn Recreation Complex in relative terms. Boston College's undergraduate student body is almost twice the size of WPI's student and averaged 49.1 annual visits per student during the 2013-2014 school year (Boston College, *Fact Book*, 2015). This is close to WPI's average annual visits per student, which is 44.9 for the same time period (Merchant, 2016). We hoped that our research at WPI would yield behavioral lessons and management practices in terms of facility operations. With regards to analysis and data collection, our team spoke with Meredith Merchant, the Assistant Recreation Director and Facilities Coordinator. We talked with her about the design of the facility and how this impacts student life. In addition, she provided attendance data for the facility and some best-practices the facility uses to ensure energy-efficient operation.

3.2 Quantitative Analysis

We received quantitative data from Boston College and WPI's recreation departments. The data from Boston College breaks the total visits to the Flynn Recreation Complex down by hour for each day of the week. The data is spread across five separates weeks of 2015 and 2016. They were April 5-11, 2015; July 12-18, 2015; October 18-24, 2016; January 24-30, 2016; and January 31-February 6, 2016. We chose the first four dates because we felt they accurately represented the time of the season (spring, summer, fall, and winter, respectively), and thus the data was indicative of the general seasonal trends. We also requested data for the busiest week of the year, which is the first week of the Spring semester; this is represented by the January 24-30, 2016 range.

The data from WPI is attendance data for three separate school years, broken out by month. The school years are 2012-2013, 2013-2014, and 2014-2015. The data is maintained by Meredith Merchant at WPI.

While the WPI data does not break attendance out by week, it was helpful in analyzing the peak times of the year and comparing them to Boston College. We looked at the peak in attendance for the Flynn Recreation Complex and compared it to how it relates to the management practices at WPI. We then analyzed the data from Flynn Recreation Complex with the goal of making recommendations on when and how to use energy efficient lighting and fixtures for the new recreation facility.

3.2.1 Potential for Solar Power

A previous study of solar power on the Boston College campus was used to create an estimate of what the overall cost of panels would be if installed on the roof of the new recreation complex (Meyer et. al., 2014). This included using calculations to determine the cost of the panels given the area of the roof. The numbers were taken from the previous data collection done in 2014 and does not take into account any possible increases or decreases in wattage or cost of the panels. This data provides a basis for determining whether or not solar panels are economically plausible for the roof of the new recreation complex.

3.2.2 Rainwater Capture

With regards to water efficiency measures, we analyzed the potential for rainwater catchment based on projections for the roof area of the new building. Using a calculation method published by the American Society of Landscape Engineers (Kinkade, 2011), we were able to get a rough estimate of the yearly rainwater runoff that could be collected by a rainwater catchment system. We used a monthly average of Boston area precipitation over the span of 1981-2010 (U.S. Climate Data, 2016). These averages were multiplied by the square footage of the roof area to yield an estimated total of rainwater hitting the roof each month. The estimate was then multiplied by a runoff efficiency coefficient, which is supplied by the ASLE for various different surfaces. This coefficient takes into account the fact that water runs and evaporates differently across different types of surfaces. As a precaution, we also added in a deduction to account for the fact that no system will be perfectly efficient at capturing every gallon of rainwater. We feel this will adequately account for evaporation and other losses. Although we are confident that a brand new rainwater catchment system will be close to 100% efficient, we used a liberal estimate of 90% efficiency to account for any other factors that we may have missed.

We will take the estimate and calculate a potential cost savings for Boston College if it installs a rainwater catchment system. Boston College's Lower Campus is supplied by the Boston Water and Sewer Commission (BWSC) in conjunction with the Massachusetts Water Resources Authority (MWRA) (IMP Chapter 8, 2009). We will use combined Water and Sewer rates from the BWSC in order to determine a yearly cost savings estimate. The BWSC uses a progressive pricing system. Water is priced based on the first 19 cubic feet, with rate increases at the next 20, the next 50, the next 260, and the next 950 cubic feet used. Any consumption over 1,299 cubic feet is priced at the same rate (BWSC, 2016). In order to give some idea of comparison, we will also look at the estimated water demand for the all new infrastructure on Lower Campus as part of BC's Institutional Master Plan (IMP). The most recent information comes from the 2009 submission of the plan to the Boston Zoning Commission (IMP Chapter 8, 2009). Various conversions were undertaken in order to ensure that the comparisons were in the same units.

Our hope is that this estimate can help determine an acceptable payback period as different rainwater catchment systems are compared. The goal in undertaking this analysis is not to suggest specific types of rainwater systems to be employed at the new recreation facility. Instead, we hope to make a judgement as to whether an in-depth analysis of rainwater collection is merited once the design of the building is more laid out.

3.2.3 Lighting

Quantitative data was gathered from articles as well as government sources concerning the cost of electricity, the cost of light bulbs, and the potential energy savings from efficient lighting. This data provides a basis to consider the environmental and economic benefits of energy efficient lighting that can be implemented in the new recreation facility.

4. Results

4.1 Qualitative Data

The sustainable features of the recreation facilities of other universities, as well as the challenges to sustainability these universities encountered, are informative for the new Boston College recreation facility.

Boston University Fitness and Recreation Center was built in 2004-2005 to replace the aging and inadequate Case Gym. Sustainability was not a priority at the time of the design and building. The 270,000 square foot building opened in March 2005 and was completed at a cost of $97 million dollars. It includes an 18,000 square foot weight and cardio room, a 30-foot climbing wall, two swimming pools, and an elevated running track to name a few features (Southall, 2015). Mr. Southall stated the center received about 1.7 million visits each year, with an average of about 4,000-5,000 people each day.

The BU Fitness and Recreation Center gets its energy from one main steam plant and relies on fossil fuels such as gas. Although no renewable energy is used, Mr. Southall explained that the light fixtures were switched to LED lights recently which have a lower energy consumption and a longer lifetime than incandescent lights. Another feature that may contribute to less energy use is the abundance of glass which allows for natural light.

In contrast, the Worcester Polytechnic Institute Sports & Recreation Center was designed and built with sustainability in mind. The new Sports & Recreation Center is a LEED Gold-certified building that receives approximately 190,000 visits each year (Merchant, 2016). The building serves students, faculty, and staff and is a hub for campus life. It opened July of 2012 with a final budget between $65-68 million. The two-story complex features state-of-the-art equipment incorporated into a very bright and spacious area with a "14,000-square feet fitness space, a four-court gymnasium, a competition-length swimming pool, a three-lane elevated jogging track, racquetball and squash courts, rowing tanks, and workout studios" (Mell, 2010). The building includes 50 solar thermal panels on the roof to heat the pool and underground storage tanks that collect rainwater from the roof for the cooling system. This facility exemplifies the energy and water efficiency measures that should be taken when designing new recreation facilities.

4.2 Quantitative Data

Plotting the data received of the Flynn Complex, usage consistently peaks in the mid-to-late afternoon from the hours of 3:00 pm to 6:00 pm. During the morning and early afternoon hours, the building is generally about half as full as it is at the peak. From an overall attendance standpoint, the first week of January was shown to be the busiest part of the year with an average attendance level of 1,153 patrons and a peak of 2,073 at the 4:00 pm hour. July notably has the lowest attendance levels with an average of 256 patrons and a peak of 478 at the 5:00 pm hour. Overall, the data shows that while there are very high traffic times of the day, it is generally concentrated and predictable throughout the year.

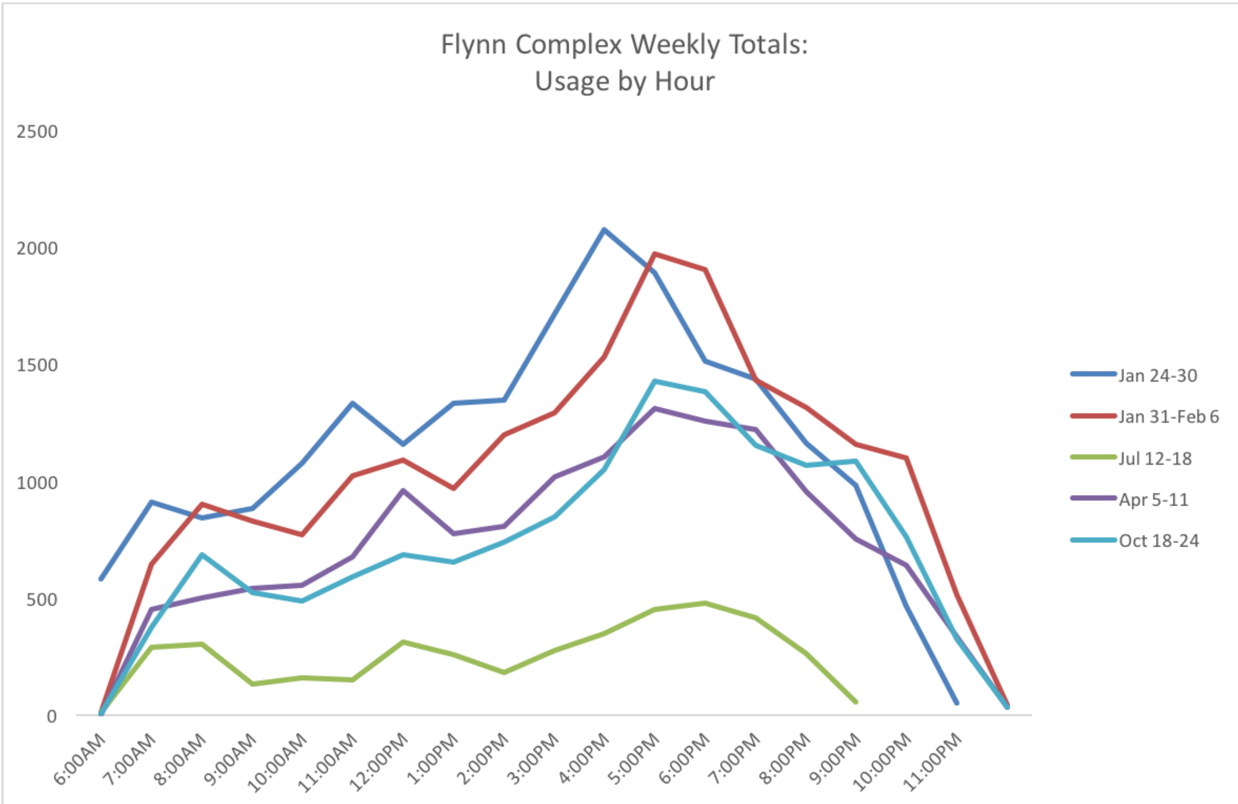

Figure 1: Attendance Data for Boston College Flynn Recreation Complex

Quantitative data analysis was broken down into three separate categories: solar panels, rainwater capture, and lighting. Attendance data was used to supplement these three sections.

4.2.1 Solar Panels

In examining both energy and water efficiency measures for the new recreation facility, different alternative energy initiatives at universities across the United States were studied. Solar panels are common at LEED gold-certified facilities, so an estimate of the upfront cost of installing solar panels on the roof of the planned basketball courts was conducted. Christine Reinders of Cannon Design expects the total area of the basketball roof to be approximately 14,200 square feet. Using the methodology described in a previous study solar panels on campus, the number of panels that would fit on that sized roof was calculated by dividing the total area of the roof (14,200 sq. ft.) by the standard sized solar panel (19.5 sq. ft.) (Meyer et. al., 2014). The result is that the roof can potentially fit 738 solar panels. The standard sized panel produces around 0.25 kilowatts per hour, which can be used to calculate the system size in kWh (Aggarwal, 2014). The system size was multiplied by the price for kWh, which is $2,500. This leads to a net cost of panels at $461,038.96.

4.2.2 Rainwater Catchment System

In estimating the supply of rainwater that could be feasibly captured from the roof of the new building, we used a total roof area of 26,500 square feet (Reinders, 2016). This was multiplied by the average precipitation for the Boston area, which totaled 43.76 inches per year, yielding over 1.1 million inches of rainfall collection potential (U.S. Climate Data, 2016). This figure was then converted into cubic feet, and again into gallons. When the conventional roof runoff coefficient of 0.95 was factored in (Kinkade, 2011), the yearly runoff was estimated to be 663,378 gallons of water.[1] With the additional 10% loss due to inefficiency and evaporation included, it was determined that each year, the new recreation facility can collect up to 597,040 gallons of water from precipitation runoff on the roof. Based on the attendance data and calculations, the collection will peak in the spring and late fall, which coincides with high traffic times at the current Flynn Complex.

[1] For reference, an Olympic size swimming pool holds 660,000 gallons of water.

Table 1: Runoff Collection Estimates for New Recreation Facility

Month	Avg Monthly Precip, in.	Catchment area, sqft.	Runoff Coefficient	Runoff volume (avg), gal.
Jan	3.35	25,600	0.95	50,784.21
Feb	3.27	25,600	0.95	49,571.46
Mar	4.33	25,600	0.95	65,640.49
Apr	3.74	25,600	0.95	56,696.41
May	3.5	25,600	0.95	53,058.13
Jun	3.66	25,600	0.95	55,483.65
Jul	3.43	25,600	0.95	51,996.97
Aug	3.35	25,600	0.95	50,784.21
Sep	3.43	25,600	0.95	51,996.97
Oct	3.94	25,600	0.95	59,728.30
Nov	3.98	25,600	0.95	60,334.68
Dec	3.78	25,600	0.95	57,302.78
Annual	43.76			663,378.26
Potential collection (incl. 90% discount), gal. =				**597,040.44**

The 2009 IMP submission estimated that the total net-new demand on the BWSC infrastructure for Lower Campus will be 113,600 gallons per day. This gives a total of 41,464,000 additional gallons of water needed by the University each year. Estimates were calculated using the most recent rates published by the BWSC in 2016. They are shown in Table 2 below. The water demand from the new construction at Boston College's Lower Campus will impose a significant cost on the University, with estimates totalling $873,107.26 per year. In contrast, the University can save an estimated $11,598.13 per year with the use of a rainwater catchment system on the roof of the new recreation facility.

Table 2: Savings and Cost Estimates for Water Usage on Boston College Lower Campus

Consumption		Water Rates	Sewer Rates	Combined	Combined	New Lower Campus Demand (cost per year)	Rainwater Catchment (savings per year)
(Cu.Ft./Day)		Per 1000 Cu. Ft.	Per 1000 Cu. Ft.	Per 1000 Cu. Ft.	Per Cu. Ft.		
First	19	$49.00	$66.98	$115.98	$0.11598	$804.32	$2.20
Next	20	$51.29	$69.04	$120.33	$0.12033	$1,682.73	$4.61
Next	50	$53.41	$70.44	$123.85	$0.12385	$3,942.99	$10.80
Next	260	$56.79	$74.31	$131.10	$0.13110	$16,384.38	$44.89
Next	950	$59.25	$78.42	$137.67	$0.13767	$64,121.46	$175.68
Over	1299	$61.33	$81.12	$142.45	$0.14245	$786,171.38	$11,359.95
						$873,107.26	**$11,598.13**

4.2.3 Lighting

A significant energy saving initiative can come from lighting. As Tan, Sun, Demir, and DenBaars (2012) explain, the consumption of light has increased as the cost of light has decreased. Today, the world spends about 0.72% of its Gross Domestic Product (GDP) on light. An average person in a well-developed part of the world is effectively surrounded by multiple of 100 Watt light bulbs at all times during his or her waking hours (Tan, et al., 2012). Too much artificial light is consumed, which in turn wastes energy. According to a 2006 report by the International Energy Agency (IEA) and the Organization for Economic Co-operation and Development (OECD), lighting is responsible for about 19% of electricity consumption and about 6% of carbon emissions. Tan, et al. (2012) state that energy consumption used for lighting can be in principle reduced by 50% using LED lighting if the targeted performance is met, and even more, if smart lighting enabled by LEDs is used. Therefore, energy-saving lighting is increasingly essential and should be considered for the new Boston College recreation facility.

The new recreation facility should consider light-emitting diodes (LEDs) fixtures. While cost has been one of the main challenges for this energy conservation technology, it has become less of a burden as Tan, et al. (2012) explains. The rapid developments in LED materials and devices have brought it one step closer to the wide-scale commercialization and adaptation of general lighting. In an article for *The Simple Dollar*, Holly Johnson notes how at today's prices, switching to LED light bulbs is finally an easier decision. The Energy Information Administration (2016) reports the average price of electricity to be $0.12 in the United States. While still more expensive per bulb, the total operational cost over time is significantly less. A $1 dollar incandescent bulb has the average lifespan of 1,200 hours and costs $180 in electricity used (25,000 hours at $0.12 per kWh), compared to an $8 dollar LED bulb which has the average lifespan of 25,000 hours and costs only $38 in electricity used; for more information see Table 3 (Johnson, 2015). Buying longer-lasting, more efficient light bulbs will pay off over time, even if they have a greater up-front cost.

Table 3: Operational Costs of Incandescent Bulbs vs. LED Bulbs

	Incandescent	**LED**
Approximate cost per bulb	$1	$8 or less
Average lifespan	1,200 hours	25,000 hours
Watts used	60W	10W
No. of bulbs needed for 25,000 hours of use	21 bulbs	1 bulb
Total purchase price of bulbs over 25,000 hours	$21	$8
Total cost of electricity used (25,000 hours at $0.12 per kWh)	$180	$30
Total operational cost over 23 years	$201	$38

(Johnson, 2015)

In the Natural Resources Defence Council (NRDC) report on *Collegiate Game Changers: How Campus Sport is Going Green*, the Cornell Athletics department upgraded their lighting system with new lights that deliver twice the brightness of the previous lighting and use 70% less energy (Henly, 2013). The old lights took a long time to warm up, so once they were turned on, they were left on. The new lights turn on and off quickly and are fitted with occupancy sensors. The occupancy sensors not only save energy, but lengthen the lifetime of the bulbs which reduces the annual maintenance cost from replacing the bulbs. The new recreation facility could save energy from installing occupancy sensors which would turn the lights off after a period of inactivity. This would be effective in bathrooms, basketball courts, or group fitness rooms during low usage times such as 6:00 am-11:00 am as well as from 8:00 pm-12:00 am, and particularly effective during seasons of low usage such summer represented by data from July 12th-18th seen in Figure 1.

Lower energy costs from these lights save Cornell approximately $20,000 a year, and the school saves $2,000 annually in maintenance costs since the bulbs do not need to be replaced as frequently (Henly, 2013). Cornell spent $100,000 on this project but received a $47,000 energy rebate from the New York State Energy Research and Development Authority, and the school expects that the improved lighting will pay for itself within 3 years (Henly, 2013). This example shows that a transition to energy efficient lighting can be successful, cost effective, as well as benefit the environment.

Although this report contains no data which is directly applied to the lighting at the current Boston College Flynn Recreation Complex, and there is obviously no data for the nonexistent future recreation facility, this research demonstrates the potential environmental and economic benefits of implementing energy efficient lighting in large and high use facilities such as recreation centers.

5. Discussion

5.1 Solar Panels

Alternative energy sources are continuously being implemented in new recreation facilities across the country. One of the more commonly used sources of alternative energy are solar photovoltaic (PV) systems. PV systems help to offset fossil fuels and reduce carbon dioxide emissions. Colleges and Universities such as Harvard, WPI, and UC schools have installed PV systems on their recreation facilities across the nation and are quickly seeing the benefits.

In 2012, Harvard Athletics completed construction of a $2.1 million, 2,275-panel solar photovoltaic system that spans the roof of the Gordon Indoor Track and Tennis building (Henly, 2013). The system produces approximately 650,000 kilowatt-hours of electricity annually, which reduces carbon dioxide emissions by about 500 metric tons (Henly, 2013). The PV system delivers electricity to Harvard's electrical grid and is used to power the lighting for athletic fields and buildings. The $80,000 to $85,000 in projected annual savings will pay back the investment within approximately eight years (Henly, 2013). This project not only reduces carbon dioxide emissions, but also will reduce costs.

PV systems are not only used for the electricity grid or for powering buildings, but also for heating. At WPI, 80% of the pool is heated with solar panels (Merchant, 2016). Although it takes two weeks to heat the pool, WPI is "saving more than $50,000 in operating costs and reducing carbon dioxide emissions by 4,400 pounds per year, as compared with conventional pool heating" (WPI News, 2010). In 2007, University of California, San Diego (UCSD) and San Diego State University (SDSU) collaborated on 5,000 square feet of thermal solar project for the Mission Bay Aquatic Center 50-meter pool (Henly, 2013). The panels cost "approximately $100,000 and paid for themselves in energy savings in two years" (Henly, 2013). Both these projects had short payback periods and reduced costs for the schools.

The challenge with making suggestions for the new Boston College recreation facility is that the project is still in the early stages of development. In addition, it is not possible to know how much energy will be used by the new building, but what is known is that it will be more than the current Flynn Recreation Complex. Data on the electricity usage of the current Flynn Recreation Complex was unavailable because the power meter is connected to Robsham Theater. No estimates can be made on just how much solar panels would offset the energy cost from fossil fuels for the new recreation complex, but the energy payback for current PV systems has been calculated to range from 3 to 4 years, depending on the type of PV panel (Turner, 1999). The new complex would have a short payback period and long-term energy savings.

Solar panels on the roof of the new recreation facility could also be used to heat the pool and could provide energy depending on the season and peak hours. During the summer months, when there is constant sunlight, longer days, and low usage the solar panels would be able to provide energy for the facility and reduce the summer operating costs (Figure 1).

5.2 Rainwater Catchment

It is hard to visualize exactly how much 597,000 gallons of water is without something to compare it to. Although it would be ideal to compare this potential savings to the projected water usage of the new recreation facility, estimates are not available because it is early in the design phase. Additionally, it is unknown how many toilets the building will have or what sort of cooling system it will use.

For reference, an Olympic size swimming pool holds approximately 660,000 gallons of water. Over the course of a year, a rainwater catchment system would be able to collect almost a full pool worth of water. Because it is rainwater and it is running off of the roof, the collection could not necessarily be used for human consumption (i.e. showering, drinking, swimming). There are, however, many uses for rainwater in a building such as a recreation facility. For example, WPI has a rainwater catchment system that has 50,000 gallons of underwater storage capacity (WPI News, 2010). It uses this water both in the toilets and as part of the cooling system for the air conditioning units. The system is able to offset the consumption of 800,000 gallons of water each year in the Sports and Recreation Complex (WPI News, 2010).

The example at WPI is pertinent for two reasons. First, the new Boston College recreation facility will have an air conditioning system, which the current Flynn Recreation Complex does not have. Given the fact that the new building will be four stories and over 120,000 square feet larger than the current building, the demand on the system will no doubt be significant (Floor Plans, 1972; Cannon Design, 2016). Furthermore, Boston College reported that as of 2014, the University's water and sewer costs had risen over 500% since 2004 (Utilities Management, 2014). And with the additional construction of 2150 Commonwealth Avenue

Residence Hall, the completion of St. Mary's Hall, and the updates to various buildings around campus, the demand for water has increased since then. Finally, there are plans for the construction of multiple new buildings at the Flynn Recreation Complex site, Shea Field, and the Modulars area. This will place an additional demand on the water infrastructure on Lower Campus to the tune of over 41 million gallons per year (IMP Chapter 8, 2009).

The potential for the rainwater system to offset the cost of this new demand is not substantial by any means. One additional consideration is the nature of the site on which the new recreation facility will be built. Due to the location on the site of an old reservoir, underground placement of the tanks might be impossible. This is an additional factor that would need to be assessed upon further examination of this solution.

Whether or not rainwater catchment is considered should depend on the estimates for the specific water consumption of the new recreation facility. If the rainwater catchment system has the potential to offset 10% or more of the building's yearly water consumption, we recommend that it be pursued. This will ensure the new recreation facility is as close to self-sufficient as possible and will ideally push it higher on the LEED Matrix. In addition, the modest cost of installation and passive nature of the system make rainwater catchment a relatively easy addition. Finally, such a system can also be an excellent marketing tool in demonstrating the University's commitment to sustainable design of its new facilities. With potential for minor cost savings in mind, it is recommended that a rainwater catchment system be researched if time allows.

5.3 Lighting

Lighting is one of the most visible forms of energy waste. Although electricity is inexpensive at $0.12 per kWh, massive energy savings can come from a transition to energy-efficient light bulbs (EIA, 2016). Innovative lighting and controls such as LED lights and occupancy sensors which can turn the lights off after 15 minutes of no movement, allow for annual energy savings. Not only do occupancy sensors save energy, but they lengthen the lifetime of the bulbs which lower maintenance cost because the bulbs do not need to be replaced as frequently. Investing in more costly bulbs, such as LED lights, will pay off over time as they have a longer lifespan and use less electricity. With the new recreation facility requiring constant lighting, considering energy efficient lighting can be beneficial although costly up-front.

5.4 Monitoring

One consistent theme throughout the research was a lack of monitoring for energy and water consumption of the current Flynn Recreation Complex. Boston College does not have any sub-meters the current Recreation Complex. The gas meter, which was installed by the utility company, is shared with the Robsham Theater so there is no way to separate the gas consumption of the two buildings. Furthermore, there are only a few water meters for Lower Campus and none are specific to individual buildings. As a result it is close to impossible to gauge the consumption of different facilities.

In order to improve sustainability, it is recommended that the new recreation facility have sub-meters to monitor and record water and energy consumption. This will allow for conscious consumption if quantitative data can be applied to the usage. In addition, based off attendance data, the new facility can adjust their energy use based on predictions of when there will be high periods of volume or low periods of volume.

5.5 Behavioral Changes and Education

The Boston College community should be educated on the sustainable development of the new recreation facility in order to make behavioral changes. Education can be transformative by equipping individuals with knowledge and new ways of thinking which leads to behavioral change. For example, the cleaning crew could come in during low periods of usage rather than coming in when the recreation facility is closed. Currently, the cleaning crew comes in when the Flynn Complex is closed, which requires the lights to stay on and energy to be consumed to heat or cool the building for a longer period of time.

Additionally, educating the student body, faculty, and staff on the new energy and water efficiency efforts is pivotal in communication and better understanding of the new facility. This can be incorporated through tours of the new facility for incoming students during orientation, for the student government, for the faculty, and for the Boston College Police Department. Furthermore, education on the new sustainable measures could be implemented during RA training. These solutions will help to communicate changes such as why the LED lights go out at certain times, how solar panels help to offset fossil fuels, and a better understanding of water conservation. Through this education, the new recreation facility has the potential to be a model for future construction at Boston College and further educate people on the importance of energy and water efficiency.

6. Conclusion

Possible sustainability-enhancing features include, but are not limited to: solar panels, rainwater catchment, and energy-efficient light bulbs. That being said, there are endless options that can be explored such as dual-flush toilets, a graywater system, self-powered machines, and increased glass windows for natural lighting, heating, and cooling. Not only will these benefit the environment, but if employed correctly have the potential to be economically beneficial as well.

The environmental challenges that the world faces today, from climate change to biodiversity loss, have a prominent effect on the operations of large institutions everywhere. Large corporations, apartment complexes, and institutions of higher education are increasingly turning to more ecologically friendly practices to maximize benefits to humans and to protect the environment. Colleges and universities in particular can also play a role in inspiring students to become leaders in addressing these environmental challenges. With this in mind, the sustainable development of the new recreation facility is particularly important. Boston College has the opportunity to further prove itself as a leader in higher education, both in its teachings and in its operations. By combining a state of the art facility that serves the needs of a diverse student body with design elements that can run it efficiently, the university can build a center that will improve the health of individuals and the environment at the same time.

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