<u>Solar Energy and Boston College:</u>

A Case Study on the Renewable Applicability at Boston College

Abby Host, Aidan Kilpatrick, & Carlos Tramonte

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Professor Tara Pisani Gareau

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Abstract

As implementation of solar energy has increased dramatically, coinciding with mass public support, improved financial returns, and unique practical benefit, Boston College still operates no renewable energy generation systems. Peer universities in New England and across the country have made renewable energy their marquee action in mitigating climate change. The following research investigates the viability of a photovoltaic (PV) solar system on Boston College's campus from operational, financial, and social perspectives. Included in this research is an analysis of the most viable on-campus rooftops for solar installations, with the ultimate determination that upper-campus dorms would be best suited for an initial installation. Financial analysis was then pe

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Introduction

Problem Statement

Boston College currently receives none of its electricity from solar energy (Energy & Engineering). The school has made efforts to reduce electric use in order to save money by "retrofitting buildings with efficient lights" as well as implementing computerized systems that operate heating, ventilation, and air conditioning (Energy & Engineering). However, all of Boston College's energy and heat comes from nonrenewables: fuel oils, natural gas, and the central heating plant that maintains three steam boilers. Boston College would benefit from transitioning to generating the electricity it needs from renewable energy, particularly from solar photovoltaic (PV) energy panels on certain campus buildings. Solar energy would help Boston College offset its sizable carbon emissions and move the university towards becoming a carbon neutral school, like other elite college campuses such as Colby College and Bowdoin College (Wise). Therefore, if Boston College wishes to remain competitive with these greener schools in order to attract environmentally-minded applicants, and move toward saving costs in helping combat climate change, it is imperative that BC pursues this investment in solar generation.

development, efficiency has increased so that the average rooftop panel on the market today is

Therefore, the property owner pays no installation cost and gets an average of 25% of their electricity bill, but the third party benefits from the lion's share of value produced by the solar system. Finally, an organization could choose to invest in the up-front costs of installation, which would net them a considerable profit over the warrantied-life of the system after a payback halls, and between 2016 and 2019, these arrays have saved University of Washington the equivalent of about 270 metric tons of carbon dioxide (Williamson). A similar student-led organization and initiative exists at Georgetown University where a group entitled Georgetown Energy developed a proposal for rooftop installation of solar panels in 2012. This club also proposed solar thermal heating on campus as well, in efforts to create a greener campus (Manger). As a result of this student initiative for solar energy, the University began its transition to renewable energy and in 2020, Georgetown University announced a 15-year Power Purchase Agreement that states that the University will begin to “source two-thirds of its energy needs statistics and use the available sunlight to their advantage by transitioning to solar energy on campus.

Solar at Boston College

With nearly 9,000 undergraduate and graduate students, 20 student dormitories, 3 dining hall locations, and 2 full sized stadiums, Boston College's energy consumption is high (Dixon, Sustainability and Energy Specialist). Currently, Boston College currently receives none of its electricity from solar energy (Energy & Engineering) or any renewable energy source, and

Methods

Choosing a Location

In combination with talks with BC's Sustainability and Energy Specialist, Bruce Dixon, and the previous study on the application of solar panels on Boston College's Brighton Campus in 2014 (Meyer, 2014), we had many different perspectives to take into consideration when establishing solar energy on campus. Through the previous literature and talks with specialists, the determination of where to establish our solar panels was based on a series of criteria, which included 1. Aesthetics and location, 2. BC's Institutional Development Master Plan (Fig. 1), and 3. The overall financial feasibility and potential profitability. Our first variable, aesthetics and location, was integral to the overall viability of solar implementation was location. Sánchez-Pantoja, a researcher at the University of Jaume in Spain, concluded that the visibility, size, and degree of integration are extremely important when looking at the aesthetic impact of solar panels (Sánchez-Pantoja et al, 2018). As such, it was important to be able to emphasize these criteria, and provide a qualitative framework that can be used in the process of integrating solar energy on campus. Through the analysis of BC's architectural cohesion, we knew that any solar panel integration on Boston College's campus would also have to go through the framework presented (which looks at rooftop use, system energy, glare, size, color, and shape).

This was determined by examining the different areas on campus, which include Main campus, Newton campus, Brighton campus, and the Weston Observatory. In addition to the different campuses, it's important to denote what constitutes Main Campus, as it is broken up into different sections given its size. **Lower Campus**, is all of the buildings east of and including Merkert, Conte, Maloney, Comm. Ave. Garage, Hillside dorms, 90-Thomas More, and St. Ignatius including T-More Apartments. **Middle Campus** is all of the buildings west of the aforementioned buildings. **Upper Campus** is all of the dorms within the Tudor Rd., Hammond St., and Beacon St. triangle, including Roncalli, Welch, and Williams Hall (Dixon, Sustainability

Gasson, Lyons, Stokes North and South, Devlin, and Fulton as well as buildings in close proximity to the gothic architecture, which includes McGuinn, Merkert, Maloney O'Neill, Conte Forum, Higgins, Carney, and dormitory buildings on Lower Campus. This left us with a reduced amount of buildings to choose from, leading us to focus our attention to upper campus's dormitories (Medieros (Fig 2A), CLFX (Fig 2B), Fitzaga (Fig 2C), Williams, Welsh, Roncalli, Kostka (Fig 2E), and Cheverus (Fig 2F)), which are tucked away from BC's administration; compromising with both the visual continuity within the Gothic architecture of BC and the renewable energy vision of the 21st century.

The second criterion, BC's Institutional Development Master Plan, was important to take into consideration as it would be nearly impossible to get approval for solar generation if a building would be torn down within the next 30 years. This is because solar PV panels have a natural lifespan of 25-30 years (Richardson). As such, buildings like Carney, McElroy, McGuinn and the College Road houses were not viable options for the placement of solar PV panels, further strengthening our reasoning for choosing the upper campus dormitories. Additionally, following BC's Master Plan, three new undergraduate dormitories will be built in the upper campus dormitory section, future proofing our renewable energy plan since the infrastructure will already exist and new solar panels on these buildings will be able to connect to the system with ease. The final criterion, and possibly the most important to consider for Boston College, is the financial feasibility and profitability of the buildings. Because we wanted to choose buildings with relatively large surface areas that would not detract from the aforementioned aesthetic, upper campus dormitories are the best fit for the criteria we have to consider. Additionally, Given the upfront costs associated with installing solar panels, we wanted to make sure that the return on investment would be reached within a reasonable amount of time. This resulted in a cutoff point of 4,000 square feet of usable space for our solar PV panels, and since all upper dormitories fit this description (with the exception of the Shaw House and O'Connell House Student Union Building), the feasibility for these buildings to provide an adequate amount of solar energy is manageable and will provide a return on investment in a reasonable timeframe.

It is also important to bring up potential arguments against this project, one being that the upper campus dormitories do not use energy year-round (i.e., drastically reduced energy costs during the summer), reducing the effectiveness of the project and thus should not be considered for solar PV panel placements. Although it is true that those buildings do not account for high energy usage during the summer months (Mid May - Late August) and winter months (Mid December - Mid January) due to breaks within the semesters, our project considers that to reduce the costs of future maintenance, it would be much more cost effective in the long term to attach the electricity generation by solar panels to the existing energy meter instead of having closed systems for each individual building.. This would allow the energy offset from the panels to come out of the total campus energy use rather than just out of the building it is installed on, allowing high consuming buildings such as Higgins and Conte to have more of the total energy expenditure come from renewable energy sources.

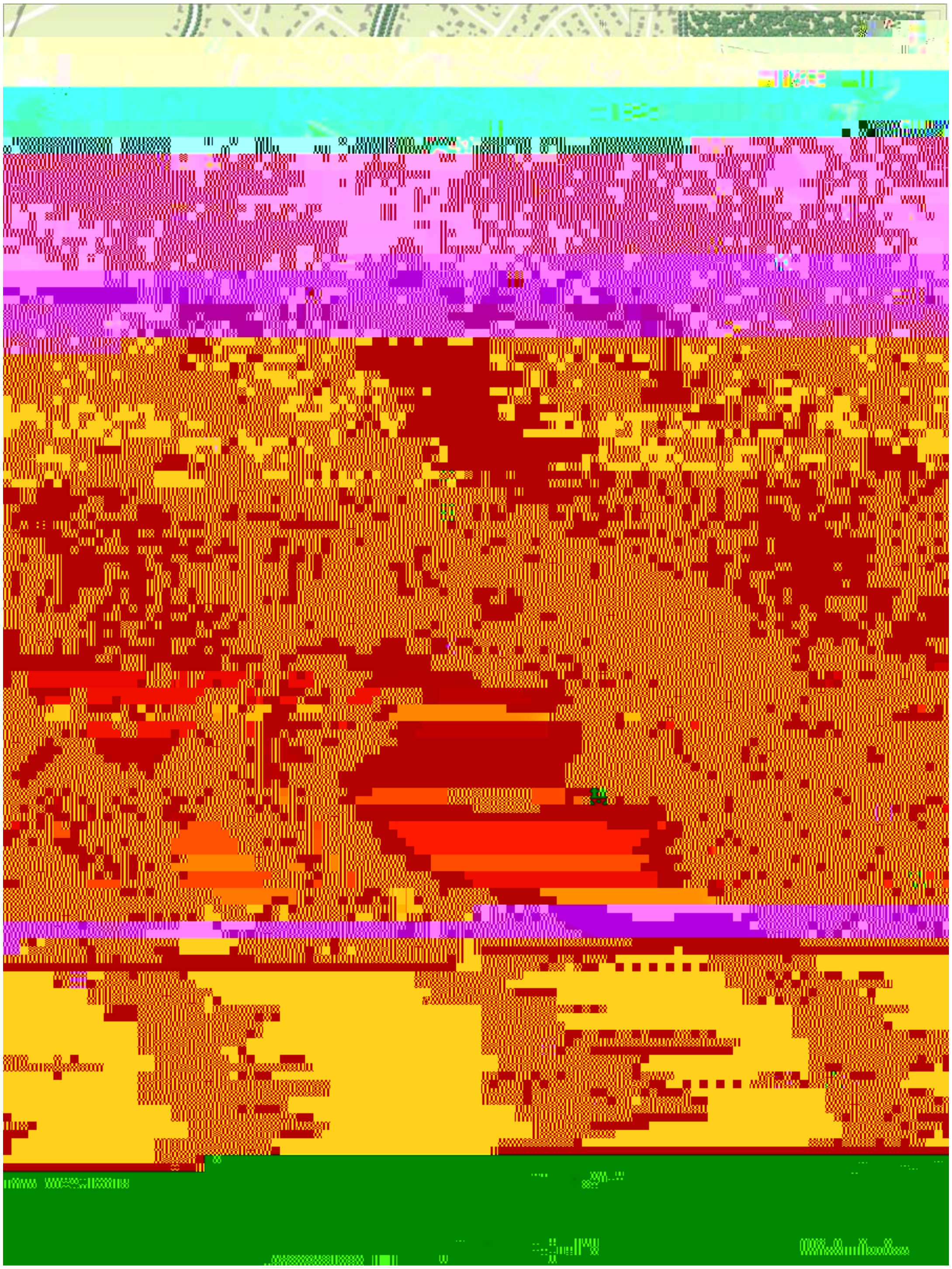

Figure 1: 30-50-year vision for Boston College's Master Plan Program Summary.

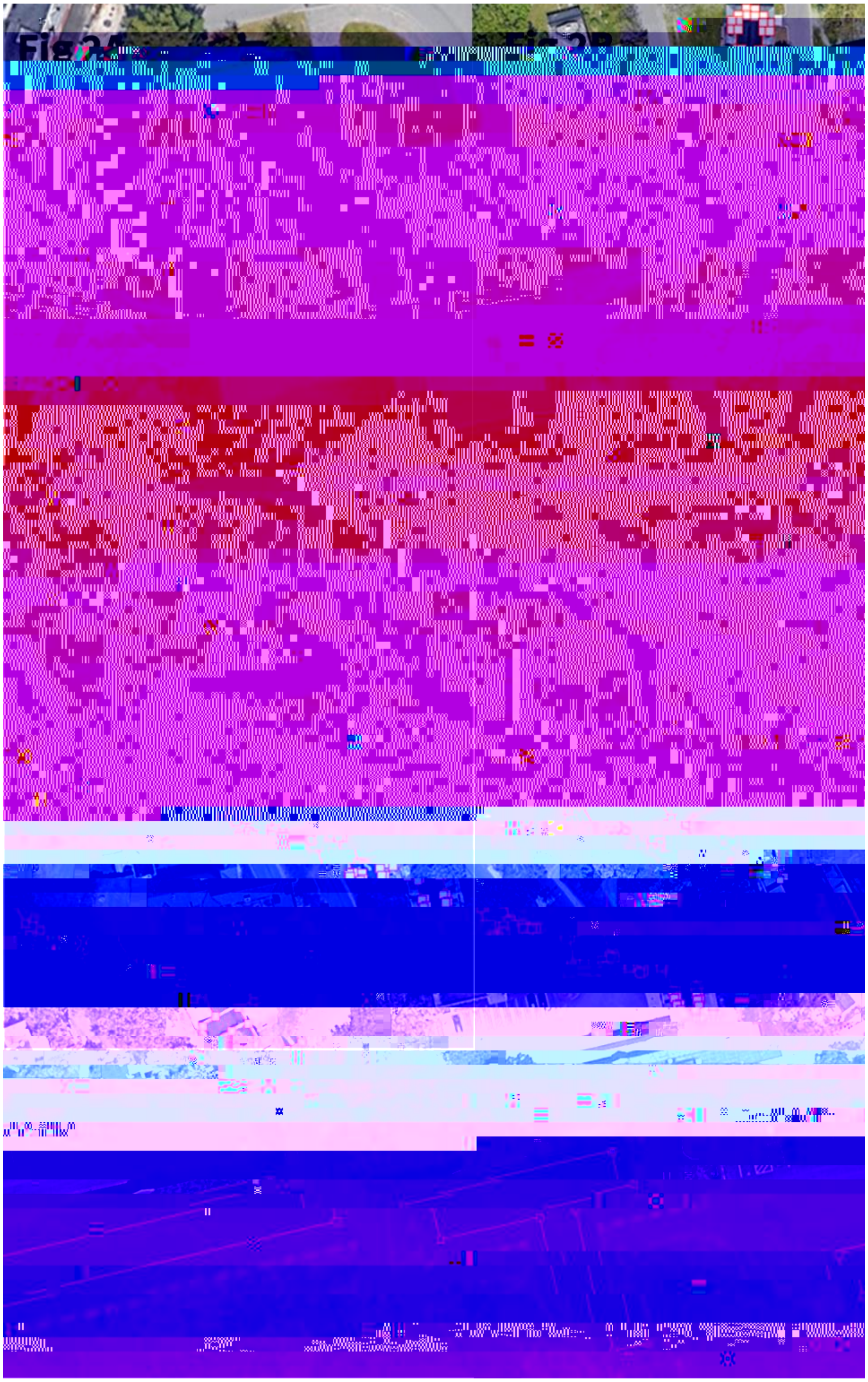

Figure 2: **Medieros**, Figure 2A. **CLFX**, Figure 2B. **Fitzaga**, Figure 2C. **Williams**, **Welsh**, **Roncalli**, Figure 2D. **Kostka**, Figure 2E. And **Cheverus**, Figure 2F. All surface area calculations and energy estimates were done on the PV Watts database.

Energy Estimates & Analysis

Using data pulled from the National Weather Service and PVWatts Database, along with the DaftLogic Google Maps Area Calculator Tool, a concrete amount of data was obtained which helped in answering how much energy would be produced and how much money would BC save per year. As seen in Table 1, the "Surface Area", which was calculated with the DaftLogic software, was used to determine the number of panels possible based on the size of the panels (given by the column under "Square Footage per Panel"). Once this was determined, the surface area was imported into the PVWatts Database, which uses the national laboratory from the Department of Energy's Office of Energy Efficiency and Renewable Energy (NREL) to determine the size of the system (given in kWh) depending on variables such as: Tilt (30 degrees), Direction (south), System Loss (20.5%), Array Type (Fixed), Rate (.165 USD/kWh) and the subsequent output of the system (given in kWh/year). This data was then used to determine an estimated annual value in USD that the university would save by implementing solar panels. Once the Annual System Output was calculated for, the top three buildings were chosen for financial analysis.

Financial Estimates & Analysis

To provide a full financial analysis of the viability of installing solar on upper campus dorms at Boston College, data was collected from Bruce Dixon in the Office of Sustainability, the National Renewable Energy Laboratory (NREL), and EnergySage. Boston College's current electricity rate and projected consumption data were then used to calculate the electricity costs for BC in a single year. Then the cost savings were calculated by subtracting the value of projected energy production from a proposed installation from the university's annual cost of electricity on the upper and middle campus. In order to extrapolate these savings over the warranted period for solar systems, an electricity cost growth rate was used in a future value formula to estimate the compounded savings the university could amass after 25 years. The SMART solar incentive was then added to the price calculations in Excel, which then produced the cost savings projections of the solar system proposal. Total installation cost was calculated by applying the assessed price per watt of a system between 100 and 500 kW to the proposed system size. This was then applied to the cost savings to establish an expected ROI. The most viable (non-debt) financing options were then analyzed for their payback period and long-term value by extrapolating when accumulated cost savings would break even with initial installation cost. These included PPA and outright ownership.

Social Aspect

The social aspect of this study is largely important in determining student opinion on qualitative manner, as a multifaceted comparative study that compares climate, overall solar energy potential, and administration and student opinions on the implementation of solar energy on these different university campuses. This analysis is located primarily in the discussion section of this report.

Results

Building and System

Based on Table 1 and 2, BC's solar applicability is possible. The three largest Dorms by surface area, CLXF, Fitzaga, and Medieros (all boasting over 6000ft^2 of usable roof space) have an annual system output of 281,836 kWh/year, 215,061kWh/year, and 127,709 kWh/year, respectively. They also have an estimated value of over 100,000 USD in savings per year when the annual system output is multiplied by the electricity rate that Boston College pays for currently for its electricity. The next biggest Dorms, Williams, Welch, and Roncalli, which are all identical floor plans and building design, have over 5000 ft^2 in surface area, creating an annual system output of 97,707 kWh/year and savings of nearly 50,000 USD per year. The final two dorms, Cheverus and Kostka, have surface areas of 5115 ft^2 and 4320 ft^2, respectively, with Cheverus having a potential output of 96,379 kWh/year and an estimated savings of 15,902 USD and Kosta having a potential output of 80,581 kWh/year and annual savings of 13297 USD.

Dorm	Surface Area (ft^2)	Square Footage per Panel	Angle + Direction	# of Panels	System Size (kWh)	Annual System Output (kWh/year)	Electricity Rate ($/kWh)	Estimated Savings per Year (USD)
CLXF	15510	19.25	30 + South	806	212.3	281836	.165	46502

Table 1: Upper campus undergraduate residential dormitories with flat roof surface areas (ft^2) and optimal angles and direction for maximum solar capture throughout the day. Includes the number of solar panels that would fit on a given surface area, the system size in kWh, its output dependent on solar radiation and size, and the potential value of solar generation given in USD. Calculated using the PV Watts database.

Month	**Open Sky (%)**	**Solar Radiation (kWh/ft^2/day)**
January	0.31	0.320
February	0.32	0.415
March	0.43	0.457
April	0.45	0.514
May	0.47	0.530
June	0.42	0.539
July	0.51	0.574
August	0.51	0.562
September	0.47	0.510
October	0.4	0.385
November	0.44	0.300
December	0.33	0.278

Table 2: 12-month cycle of the percentage of **Open Sky** (defined by how much cloud cover on average for the month) determined from the National Weather Forecast System's 5-year record of Boston, MA. **Solar Radiation** levels were compiled based on the PVWatt Database which uses the NREL Department of Energy database to determine radiative levels. Records the amount of

25 years, the cost savings would total $2,576,499.75. However, given that electricity rates rise at an average annual rate of 3.5%, this can be extrapolated to the projected cost savings (EnergySage). Also, adding the SMART incentive increases the value of electricity produced to $0.18 per kWh for a 470-kW system in 2020, saving a total of $112,735.14 for each of the first three years (EnergySage). At a 3.5% growth rate, the value of the electricity produced by the solar system then compounds annually, saving the university a total of $4,223,104.99 over 25 years. The cost of installation based on $2.44 per watt would be $1,148,020 up-

Figure 4 shows a comparison of the two financing options over 25 years and the annual cost savings they would return.

Figure 4: Bar graph depicting the compared annual cost savings projection of a Power Purchase Agreement (PPA) and Up-

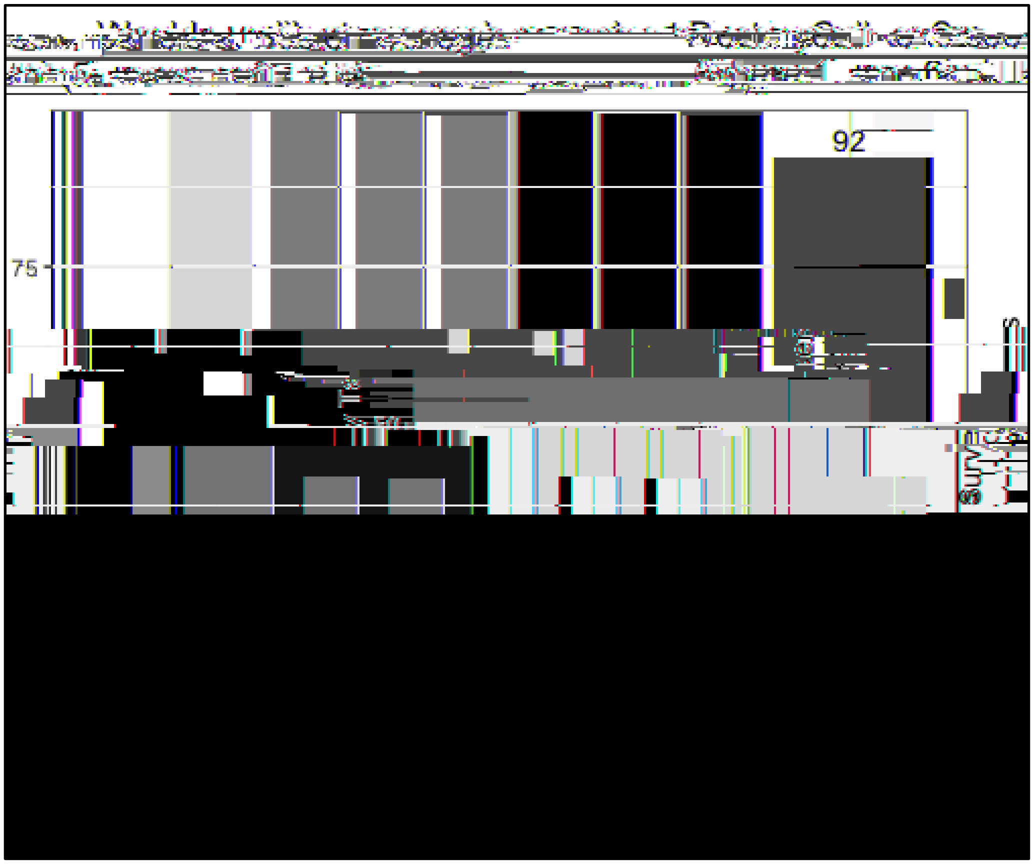

Figure 6: **Histogram for responses of 103 Boston College students to Question 2 of Survey** (Appendix A): Would you like to see solar panels at Boston College? (where 1 is not at all, and 5 is yes, definitely)

Figure 7 is a histogram of survey responses from Question 3, how important is it for you to physically see these solar panels? In this question, the rank of 1 meant not important and 5 was very important. As seen in this histogram, answers varied across the board. The mode is rank 1, so most survey respondents believe that it is not important to physically see solar panels on campus. However, the next highest group of answers is rank 5, very important to see these solar panels. Therefore, while the mode is located at rank 1, the median and mean are likely somewhere closer to the rank of 3, showing that it is neither truly important or not important to see solar panels on Boston College's campus. This means that visually students do not mind if they see them or not; instead, it is more important that students know that they are there and being used for energy (as seen in the results of Figure 6), whether or not students can physically see them or not.

Figure 7: **Histogram for responses of 103 Boston College students to Question 3 of Survey** (Appendix A): How important is it for you to physically see these solar panels? (where 1 is not important, and 5 is very important)

Figure 8 is a histogram of the survey responses for question 4, do you think the use of solar panels to decarbonize energy on campus would attract more potential students? In this question, 1 is not at all and 5 is yes, definitely. The survey results, as shown by the histogram, are skewed to the left, such that 5 has 64 responses, and this number decreases linearly from the rank of 5 to 1. In this histogram, 1 (not at all) only has 1 response. A simple percentage calculation shows that 62.1% of survey respondents believe that yes, solar panels will definitely attract more students, and 95.1% of survey respondents are at least neutral to the idea that the implementation of solar panels will attract more potential students for Boston College.

Looking at the data collected in Table's 1 and 2, it is clear that the amount of kWh energy produced is significant enough to provide enough of an incentive for Boston College. The amount of energy produced is able to power over 60 homes for an entire year (the average home American home requires 10,524 kWh of electricity per year (US Energy Information Administration)). The results also show that the surface area directly correlates to the amount of energy that the system outputs, as increased rooftop area allows for greater radiative absorption by more solar panels. Additionally, when compared to the amount of oil needed to produce one kWh of electricity on Boston College's campus, which ranges between .08 gallons and .10 gallons of oil, solar is much efficient in the long run, especially considering its relatively infinite source. This is because it takes over 100,000 gallons of oil per year to power middle campus alone, and when you look at Boston College as a whole, that amount jumps to nearly 250,000 gallons of oil a year; adding 4.2

and liability would fall to the third party that is supplying the PPA. However, this involves forgoing ownership of the infrastructure itself, and forgoing most of the savings by purchasing the electricity from the third-party for a discount. Ultimately, up-front investment and ownership would be the most efficient and profitable option for Boston College. They would maintain control and operation of the system in the event that needs change. Additionally, the profits would be approximately $3,075,085 over 25 years, which is $2,110,460 or 319% more than if through a PPA.

It is true that ownership would mean saddling the school with the entire installation cost of $1,148,020. The full payback period would be 9.6 years before seeing a return on investment. At the same time, fundraising has been used as an effective tool by other non-profit organizations looking to go solar (Resnick). Using the fundraising infrastructure BC has to its advantage, a "Sponsor a Panel" campaign could be launched to cover a portion or, depending on the success, a majority of the up-front costs. This would significantly r

random selection of survey respondents, that solar panels have the potential to attract prospective students

solar panels have a negative, positive, or neutral effect on applicants, such information would be useful to administrators to include when performing a cost-benefit analysis of a potential solar system. A positive or even neutral correlation may provide evidence against the assumption that photovoltaics would ruin the visual appeal of the Chestnut Hill campus. Instead, administrators could turn their attention to the environmental, financial, and public perception benefits that our research details.

Appendix A

References