A Comprehensive Study on the Economic and Social Effects of Integrating Solar Energy into Boston College's Energy Infrastructure

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Abstract

This project analyzed the feasibility of, best location of, and process by which, solar panels have the potential to be installed on Boston College's campus. By working with sustainability and energy management professionals both on campus and in the private sector, we were able to collect the necessary data and information to complete this report. Based on our research, the most probably buildings on campus to install solar panels would be O'Neill Library and Conte Forum. This proposal looked into the energy demand of these two buildings, the estimated savings over the course of a year, and the potential ways to finance the project. If all goes well, within a few years, Boston College could implement solar panels ultimately reducing its carbon footprint and saving on energy costs.

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I. Introduction

Directly, Boston College doesn't produce its own solar power or participate in a solar energy co-op system of any kind. Although it sources its energy from a mix of different sources and is generally sustainable, we wanted to look into whether solar panels would be a good choice the campus. With this proposal we intend to outline the strategic benefits of integrating solar panels into Boston College's energy infrastructure from a qualitative and quantitative position. When defining our proposal and determining the recommendation we are going to make to Boston College's administration, we initially believed that vertical solar windows would be most effective in reducing Boston College's carbon footprint. Upon doing research on the topic, we found that although vertical solar is applicable in some cases, the technology at this point in time is quite costly and thus not cost efficient. According to Moore's law, technological advancements will accelerate exponentially, however the time frame in which we would recommend integrating vertical solar is too short to see the full effect of such technology. After pivoting from our initial approach, we conducted research on additional forms of renewable energies, particularly wind vanes and solar panels. We felt that wind vanes were too intrusive and unsightly to integrate into Boston College's gothic architectural style, so we turned our focus towards traditional rooftop solar panels. With this conclusion, we decided to ask was was the best place or way to implement solar panels on Boston College's campus. We explored the best possible systems off campus and buildings on campus to determine what the best way was. We determined the most efficient building based on its location, roof structure, aesthetic appeal, location, and energy demand throughout the year. With this question, we decided to ask; what was the best method of implementing solar panels at BC? What are the best places, if any, to install solar panels on campus? What are the cost savings produced from using solar panels? How should Boston College pay for this project?

Implementing a green revolving fund into Boston College offers a creative solution to paying for a solar project. The Sustainable Endowment Institution, who is responsible for creating the Billion Dollar Green Challenge, thoroughly outlines green revolving funds and how to properly implement them into institutions on their website. Green revolving funds directly assist universities in achieving significant reductions in operating expenses and greenhouse gas emissions. These are called "revolving" funds because the funds loan capital to individual sustainability projects, which then repay the loan in full through savings in utilities budgets. In doing so, this generates existing funds for future projects and pays for itself entirely. Green revolving funds have been incredibly successful. According to the Sustainable Endowment Institute, the 52 existing green revolving funds that were examined had an average annual return on investment of 28 percent, an average payback period of 3.5 years, and had not once reported a loss on a project (Green Billion). Green revolving funds are, in part, so successful because of their malleability. These funds can be carefully tailored to best cater to the specific needs and structure of any institution, maximizing impacts for any institution that properly implements one. This opportunity for customization across institutions is evident through Boston University and Harvard University's own implementation of green revolving funds. As the case studies indicate, these green revolving funds are both incredibly successful even though they are structured entirely differently.

One article that we found particularly helpful was a study done on the benefits of rooftop solar in South Korea. In this study, the researcher, Hong Taehoon, utilized a GIS (Geographic Information System) based approach to map areas with ideal sunlight for development of solar energy infrastructure. The GIS map he created clearly illustrates areas in which rooftop photovoltaic energy generation would be most efficient, and areas where hydroelectric, geothermal, or alternative energy sources are more efficient than solar (A GIS (Geographic Information System)-Based Optimization Model for Estimating the Electricity Generation of the Rooftop PV (Photovoltaic) System). We utilized a similar approach to determining which buildings on Boston College's campus, but instead of collecting data on the best areas to implement solar panels, we instead identified buildings on campus with the largest energy footprint.

While we strongly believe in integrating solar panels into Boston College's energy infrastructure, we also know that there are many challenges, both administrative and financial. We thought it was important to research potential barriers that we might face in order to address them in our proposal to Boston College's administration. We consulted an article from the International Journal of Energy Research, published by Hayat, Muhammad Bahar et al. This article on the challenges of solar implementation illustrates significant barriers to scalable solar adoption and implementation, however Hayat's conclusions are flawed as he is viewing solar energy generation from a macro scale. He talks about solar as a means to solve large problems (i.e water treatment, agriculture, etc.), therefore we felt that it was a strong case for a smaller scale, regional approach to solar energy integration. We believe that the integration of solar energy on Boston College's campus will be feasible on a significantly smaller scale, such as the adoption of solar panels on only one or two buildings on campus.

II. Methods

Survey Distribution

We used two main data sets for our analysis. Firstly, we obtained energy usage data from Boston College. This data was collected by Charlie via Bruce Dixon, and is the monthly energy consumption of O'Neill Library and Conte Forum. This information was the most recent total dataset that was available based on our needs. Secondly, we collected survey responses using Qualtrics market research software to determine the sentiment of installing solar energy infrastructure on campus. To collect this data, we had to apply for an exemption to the Institutional Review Board because our collection of data involved human subjects. Once we completed the application and were approved, we began collecting responses. To collect responses, we circulated our survey through our friends and colleagues at Boston College, including faculty, students, and local Chestnut Hill residents. We also posted our survey on Facebook and asked members in the Boston College Class of 2019 Facebook group to complete our survey. The survey was anonymous, therefore we cannot tell how many responses came from that posting. Participants included 40 males and 46 females. Although we intended to record responses of different affiliations with Boston College, the majority of our respondents were students, and only one participant was a faculty member. No Chestnut Hill residents participated in our survey. Participation in this study was on a voluntary basis, and participants did not receive any compensation for responding to our survey.

Data Collection

Our data collection process consisted of us consulting with the Energy Manager here at Boston College, John MacDonald, and the Sustainability and Energy Management Specialist, Bruce Dixon. We first met with John to ask him a couple of question regarding our project. We inquired whether or not solar panels on campus were possible, what the potential cost of them might be, and if there was a cheaper alternative. He told us that if we were interested in installing solar panels on campus, it might actually be cheaper to take an energy reduction route due to the initial upfront costs. Without subsidies or a method of paying for the upfront cost, solar panels would not be feasible on campus. He suggested the Power Purchasing Agreement (PPA) which is the traditional and most practical way of installing them. In this method, the upfront cost would be covered from an outside body and the user, Boston College, would pay a fixed flat rate using the energy until the solar panel installation was paid off.

After discussing the possibility of installing solar panels on campus, we moved onto the best possible location for them. He suggested that the most feasible place on campus would be buildings that had large flat roofs, little interference from trees or other buildings, a south facing position, a constant energy demand throughout the year, and would be out of sight and not interfere with the gothic architecture style of Boston College. Using this criteria, John suggested the most practical locations to install solar panels on campus would be either O'Neill Library or Conte Forum. He also spoke about how the there were a good amount of other smaller places that would be possible for solar panels such as Newton Campus, Higgins Hall (as the science buildings generally have the highest electricity demand), and the campus dormitories. Unfortunately, because of the seasonality of these buildings and there being relatively little demand throughout the summer, it would make more sense for solar panels to be installed on buildings where there is a general base layer of demand throughout the year. The idea behind the base layer would be for the solar panels to take the load off throughout the heavier months and reduce the overall cost throughout the year.

After speaking with John, we determined that the best places to install solar panels on campus would be O'Neill Library and Conte Forum, we determined that we should gather the correct energy consumption data on those buildings. To do this, we reached out to Bruce Dixon, the Sustainability and Energy Management Specialist here at Boston College. We spoke to Bruce about our proposal to install solar panels here on campus in addition to our discussion with John MacDonald about the best possible locations. After speaking with him, Bruce gave us the 2018 electricity consumption for O'Neill Library and Conte Forum. This data was monthly and detailed how much energy was used in each building throughout the year.

Conte Forum	Assume extra cost				O'Neill Library				
Date		Consumption	Units		Date		Consumption	Units	Notes
1/1/2018	1/31/2018	381830	kWh		1/1/2018	1/31/2018	324457	kWh	
2/1/2018	2/28/2018	332723	kWh		2/1/2018	2/28/2018	310274	kWh	
3/1/2018	3/31/2018	175564	kWh		3/1/2018	3/31/2018	323043	kWh	
4/1/2018	4/30/2018	137621	kWh		4/1/2018	4/30/2018	306634	kWh	Estimate because of a communication loss.
5/1/2018	5/31/2018	143247	kWh		5/1/2018	5/31/2018	370897	kWh	
6/1/2018	6/30/2018	133521	kWh		6/1/2018	6/30/2018	344366	kWh	
7/1/2018	7/31/2018	422522	kWh		7/1/2018	7/31/2018	381262	kWh	
8/1/2018	8/31/2018	965330	kWh		8/1/2018	8/31/2018	410186	kWh	
9/1/2018	9/30/2018	290806	kWh		9/1/2018	9/30/2018	411886	kWh	
10/1/2018	10/31/2018	207706	kWh		10/1/2018	10/31/2018	382197	kWh	
11/1/2018	11/30/2018	174509	kWh		11/1/2018	11/30/2018	331636	kWh	
12/1/2018	12/31/2018	159345	kWh		12/1/2018	12/31/2018	315028	kWh	

Table 1:The energy demand of O’Neill Library and Conte Forum throughout 2018.

Now that we had the energy consumption data by kilowatt hour for O’Neill and Conte Forum, we had to figure out the total cost of the energy. From looking at local energy prices throughout the Chestnut Hill and Newton areas we found that the pricing of electricity and the cost structure varied significantly based on the household or business and the plan that was being used. As electricity generally consisted of both variable and fixed costs, we wanted to look at the total cost of electricity and then the average cost of kWh from what used. Looking at both the kWh per fixed price and the kWk per variable cost, the cost electricity from November 2018 until April 2018 throughout the state of massachusetts ranged from $0.1091 --$0.15995 per kWh (National Grid). As such, we took the average of the variable and fixed data which all ended up being priced at $0.133.

Electricity pricing	Residential ($)	Commercial ($)
Fixed		
11/18-4/19	$13.718	$13.166
Variable		
11/18	$0.11599	$0.11165
12/18	$0.13255	$0.13227
1/19	$0.15802	$0.15341
2/19	$0.15995	$0.15647
3/19	$0.12658	$0.12215
4/19	$0.11631	$0.1091
Average	$0.1349	$0.130842

Table 2: Energy cost range per kWh in Massachusetts from November 2018 to April 2019.

Survey Design

The survey consisted of 7 questions, 3 of which were demographic and 4 were related to the information we intended to collect. Demographic questions included gender, age, and affiliation with Boston College. The fourth question was a likert scale (from 1 = "least impact," to 10 = "significant impact") to gauge the perceived impact on Boston College's Gothic architectural style by solar energy infrastructure. The question immediately following this asked respondents to expand qualitatively on their reason for their grade on the likert scale, in which participants could type any response they wished. The following question asked respondents to name any buildings on Boston College's campus, if any, that they felt would be a good place to integrate solar energy infrastructure in the form of solar panels. The majority of buildings on Boston College's campus were named, from the most recognizable buildings like Gasson Hall and St. Ignatius Chapel, to lesser known buildings such as the Cadigan Alumni Center and St. Clements Hall. The final question of the survey asked respondents if they would support an initiative to implement solar energy infrastructure onto Boston College's campus. Respondents could answer "yes," "maybe," or "no." In total, we collected 86 responses to our survey. We felt that this was an appropriate amount of responses to determine the general sentiment about solar energy infrastructure at Boston College.

III. Results

Survey Results

The demographic of participants was largely balanced in relation to their gender, with respondents skewing slightly more female than male. There were 46 female respondents, and 40 male respondents. The age of respondents was heavily skewed towards the 18-25 years old range, with only one respondent above the age of 25. We were not surprised by the skewing of data because the majority of our respondents were students at Boston College. For future studies, it would be important to survey more participants that fall into the under 18 age range and 25 and older age range. Similar to the prior question, we were not surprised to see that the majority of our respondents were students at Boston College given their age. It would be interesting to survey more faculty and community members to gauge interest in renewable energy infrastructure from a different perspective than a student.

Next, we asked respondents to grade how much of an effect installing solar panels on Boston College’s campus will have on Boston College’s iconic gothic architectural style on a likert scale from 1 to 10. (1 = least impact, 10 = significant impact). The average score was 4.45, suggesting that respondents held a largely neutral stance regarding the perceived impact on Boston College’s gothic architectural style, with a slight skew towards not having that much of an effect. This lead us to believe that the Boston College community believes it is feasible to implement solar panels into Boston College’s energy infrastructure without significantly altering Boston College’s gothic architectural style.

Many of the responses to the qualitative question following the likert scale stated that solar panels would indeed have an impact on Boston College’s aesthetic charm. However the responses were largely positive in that they believed solar panels could add to the gothic architecture, or at the least not detract from it if they were hidden or integrated in a way that they were not intrusive. One respondent noted that there are particular buildings on campus like O’Neill Library and Carney Hall in which the installation of solar panels would add to the aesthetics of the building. The same respondent also noted that it would make more sense from a design perspective to use solar panels as an aesthetic enhancements to stereotypically unattractive buildings on campus. Attaching solar panels to Gasson, for example, would face backlash from the Boston College community as Gasson is easily the most recognizable building at Boston College. Many respondents also noted that the green shingles on top of some buildings at Boston College are iconic, and that installing solar panels on top of them would detract from the aesthetic charm of Boston College. A significant amount of respondents noted that a strategic place to place solar panels would be on buildings with flat roofs, particularly O'Neill Library, McElroy Dining Hall, or Conte Forum.

The following question asked respondents to suggest buildings on campus, if any, that they would like to see solar panels on. Building on the insights from the prior question, the least suggested buildings were Gasson Hall, Bapst Library, and St. Ignatius Chapel. The buildings that respondents believed would benefit from solar panels are O'Neill Library (56 votes), the Fish Field House (55 votes), McElroy Dining Hall (51 votes), Walsh Hall (51 votes), and the Reservoir Apartments (50 votes). These buildings are known as the either the most depressed looking (Walsh Hall and McElroy Dining Hall) or modern looking (O'Neill Library and Reservoir Apartments) buildings on campus. Other buildings that received significant votes from respondents were the dormitories on Newton Campus, the new Connell Recreation Complex, Rubenstein Hall, the dormitories on College Road, and the Gonzaga dormitory.

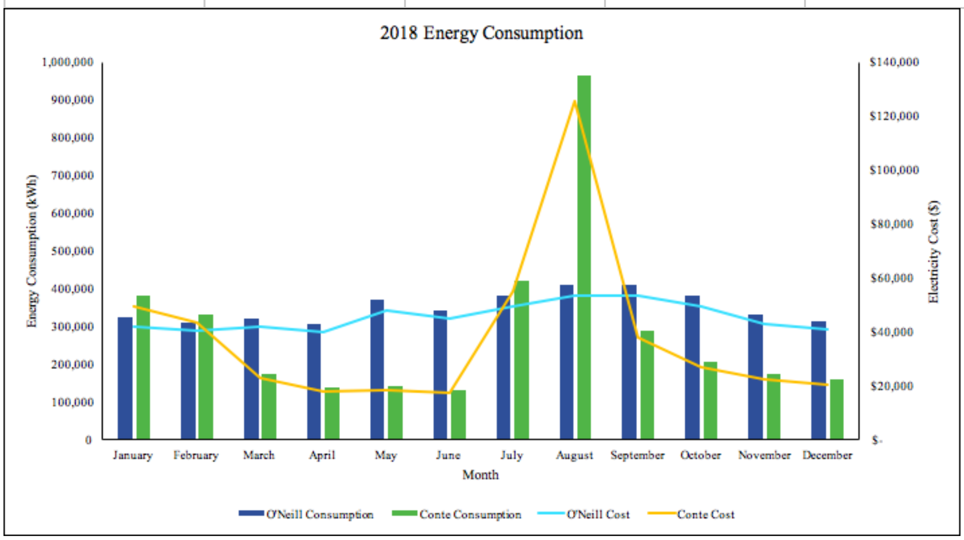
Calculations

As we determined what each of the two buildings' energy demand was and the price that Boston College would pay, we calculated the ultimate cost per month throughout both buildings.

Table 3: Calculates the energy cost for O'Neill Library and Conte Forum throughout 2018.

		Average Cost:	$0.133 / kWh	
	O'Neill	Conte	O'Neill	Conte
Month	Consumption (kWh)	Consumption (kWH)	Cost ($)	Cost ($)
January	324457	381830	$42,179.41	$49,637.90
February	310274	332723	$40,335.62	$43,253.99

March	323043	175564	$41,995.59	$22,823.32
April	306634	137621	$39,862.42	$17,890.73
May	370897	143247	$48,216.61	$18,622.11
June	344366	133521	$44,767.58	$17,357.73
July	381262	422522	$49,564.06	$54,927.86
August	410186	965330	$53,324.18	$125,492.90
September	411886	290806	$53,545.18	$37,804.78
October	382197	207706	$49,685.61	$27,001.78
November	331636	174509	$43,112.68	$22,686.17
December	315028	159345	$40,953.64	$20,714.85
Average:	322357.9167		$41,906.53	



Graph 2: Depicts the 2018 energy consumption against estimated cost per building

With our monthly cost of electricity estimates throughout 2018 we decided to compute how much money and energy could be saved with solar power implementation.We started by looking at the amount of solar energy available each month. Because Massachusetts is located in the Northeastern United States, the sun isn't out everyday of the weak and the UV index isn't as high as states in the south or west such as Florida or Arizona. In the state of Massachusetts and specifically the Newton and Brighton areas, there is only so much available sunlight throughout the day which greatly fluctuates based on the position of the sun and season. In the case of

Massachusetts, in comparison to other states, it ranks number 45/50 in terms of state sunshine rank, it averages around 2,600 annual hours of sunlight throughout the year, and it has around 98 clear days annually. In terms of total peak sunshine, there is on average 4.27 hours per day throughout the peak of the summer and 2.99 hours in the peak of the winter. On average that is 3.84 hours of sunshine throughout the year (Turbine Generator). Because of Massachusetts' relatively cloudy days, intaking a large amount of solar energy consistently throughout the year is difficult. Because of this difficulty, constructing and positioning the solar panels in the correct manner such that the photovoltaic cells are the most efficient is essential to being productive. As such, positioning the solar panels south facing and enough so that they, as it travels across the sky throughout the year, are able to intake on average the most sun is key to a successful installation.

In the town of Newton, which we assumed had very similar if not the same amount of sunlight available on average throughout the year as Boston College, we determined the available monthly solar energy available per kilowatt by square meter per day. These figures were based on actual solar panel production from 5 kWh residential solar panel systems. Granted, this is different than what our proposed system on campus would be but given the weather figures it seemed to be the reliable comparison to use (Decision Data). From this data, we made assumptions based on electricity price and ultimately came down potential savings estimates based on the price of electricity for the given month.

Solar Power Savings by Month in Newton

A 5kW system will save someone in Newton up to $124.33 on an average month. That's significant given the average Massachusetts power bill of $119.26 per month. Here's a monthly breakdown:

Month	Available kW / m2 / day	Max savings / month
Jan	3.42	$95.73
Feb	4.34	$110.59
Mar	4.80	$134.40
Apr	5.10	$138.14
May	5.03	$140.63
Jun	5.03	$136.28
Jul	5.46	$152.73
Aug	5.43	$152.00
Sep	5.13	$138.86
Oct	4.18	$116.87
Nov	3.29	$88.97
Dec	3.10	$86.71

Table 4: Available kWh / m^2 / day in Newton

Using the available kilowatts of solar energy per day, we scheduled out each month, multiplied by the monthly energy demand of each building and came to potential savings for each month.

Table 5: Details the potential savings per month in O'Neill and Conte Forum

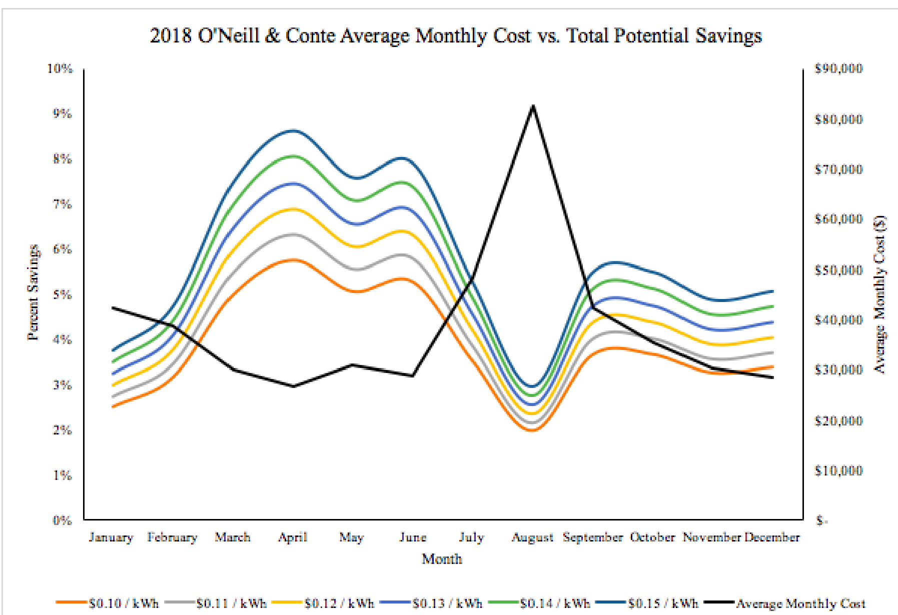
Month	kW / m^2 Available per Day	Days per month	kW / m^2 Available per Month	Production (100 m^2)	Savings	O'Neill New Cost	Conte New Cost
January	3.42	31	106.02	10602	$1,590.30	$37,344.54	$44,229.30
February	4.34	28	121.52	12152	$1,822.80	$35,410.08	$38,103.96
March	4.8	31	148.8	14880	$2,232.00	$36,533.16	$18,835.68
April	5.1	30	153	15300	$2,295.00	$34,501.08	$14,219.52
May	5.03	31	155.93	15593	$2,338.95	$42,168.69	$14,850.69
June	5.03	30	150.9	15090	$2,263.50	$39,060.42	$13,759.02
July	5.46	31	169.26	16926	$2,538.90	$43,212.54	$48,163.74
August	5.43	30	162.9	16290	$2,443.50	$46,778.82	$113,396.10
September	5.13	30	153.9	15390	$2,308.50	$47,117.82	$32,588.22
October	4.18	31	129.58	12958	$1,943.70	$43,919.94	$22,981.02
November	3.29	30	98.7	9870	$1,480.50	$38,315.82	$19,460.58
December	3.1	31	96.1	9610	$1,441.50	$36,361.86	$17,679.90

With these estimated savings, we then concluded the percentage of savings for each buildings. The percentage of electricity savings per month was determined on a range of electricity costs ranging from $0.10 per kilowatt hour to $0.15 per kilowatt hour. We applied these cost ranges to the average of the two building total energy prices per month to come to a range of potential monthly savings.

Month	Average Monthly Cost	$0.10 / kWh	$0.11 / kWh	$0.12 / kWh	$0.13 / kWh	$0.14 / kWh	$0.15 / kWh
January	$42,377.22	2.50%	2.75%	3.00%	3.25%	3.50%	3.75%
February	$38,579.82	3.15%	3.46%	3.78%	4.09%	4.41%	4.72%
March	$29,916.42	4.97%	5.47%	5.97%	6.47%	6.96%	7.46%
April	$26,655.30	5.74%	6.31%	6.89%	7.46%	8.04%	8.61%
May	$30,848.64	5.05%	5.56%	6.07%	6.57%	7.08%	7.58%
June	$28,673.22	5.26%	5.79%	6.32%	6.84%	7.37%	7.89%
July	$48,227.04	3.51%	3.86%	4.21%	4.56%	4.91%	5.26%
August	$82,530.96	1.97%	2.17%	2.37%	2.57%	2.76%	2.96%
September	$42,161.52	3.65%	4.02%	4.38%	4.75%	5.11%	5.48%
October	$35,394.18	3.66%	4.03%	4.39%	4.76%	5.13%	5.49%
November	$30,368.70	3.25%	3.58%	3.90%	4.23%	4.55%	4.88%
December	$28,462.38	3.38%	3.71%	4.05%	4.39%	4.73%	5.06%

Table 6: This table calculates the potential range of savings per month if the solar plan is implemented

We then constructed a line graph that plotted the estimated monthly cost savings against the average monthly cost to power O'Neill Library and Conte Forum.



Graph 3: Depicts

The average electricity cost per month for Conte and O'Neill against the savings range per month

From this data and the subsequent graphs, we came to the conclusion that based on a electricity price range of $0.10 to $0.15 per kWh, and the monthly energy demand in 2018, the potential savings range for the year could be from 2.17% to 8.61%.

IV. Discussion

To us, these findings seem a little low however the estimates are heavily based on assumptions for electricity cost, productivity of solar panel, weather patterns throughout the year, and type of panel Although we found that the potential savings were 2.17%-8.61%, we truly believe that the savings could be far greater given the type of project installed. Our assumptions were based off of the productivity of a residential 5 kWh solar panel system and how it would apply to a potentially commercial type property such as Boston College. Because of this assumption, we believe that the kWh solar power generated could be far greater than what was estimated.

Since we discovered the potential savings and student body opinion on solar panels on campus, we answered what the best and most way to implement solar panels on campus was. Additionally, we also figured out what the best place on campus would be to instal the solar panels. Given O'Neill and Conte Forum's flat roof structure, base energy demand throughout the year, and location on campus, these two buildings would be the best places to install solar panels. However, the question of how to pay for the solar panels comes to question.

Typically, the most popular way to finance solar panels since 2007 has been the Power Purchase Agreement (PPA). This system is a financial agreement where a developer arranges for the design, permitting, financing, and installation of a solar energy system on a customer's property with little to no cost. Once the solar power is generated, the developer sells the power to the host customer at a fixed rate that is typically lower than the local utility rate. This lower electricity price serves to offset the customer's purchase of electricity from the grid while the developer receives income from the electricity sales in addition to tax credits. This agreement lasts anywhere from 10-25 years and the developer remains responsible for the operation and maintenance of the system for the duration of the agreement (Solar Energy Industries Association).

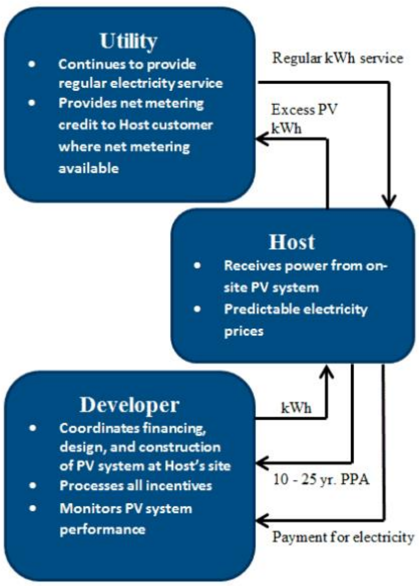


Exhibit 5: A diagram of a PPA solar model

With this model, there is little to no upfront cost associated with the installation reducing the need for large upfront investments. However, in the case that Boston College doesn't want to be in debt to the developer for the subsequent time period, there are also other ways to install the solar panels. One way to do the installation, and invest in other green initiatives on campus, would be the development of a green revolving fund such as the one Harvard has.

Case Study

The following section explores how Boston College can pay for the implementation of solar panels into its campus through the creation of a system called the green revolving fund. The section is broken up into eight specific subsections. The first section is titled "About the Sustainable Endowment Institute" and identifies a non-profit organization that has developed the

the green revolving fund. The second section is titled "About the Billion Dollar Green Challenge" and highlights the specific challenge created by the Sustainable Endowment Institute in order to efficiently spread its green revolving fund model to institutions across the country. The third section is titled "Overview of Green Revolving Funds" and provides a general framework of what the fund is, how it works at a surface level, and why it is so successful if implemented correctly. The fourth section is titled "Details: Sources of Seed Funding, How Institutions Repay Loans, and Who Manages Funds" and really delves deeper into the technicalities of how green revolving funds work and the variety of nuances that institutions must consider in order to be successfully implemented. The fifth section is titled "Benefits of Green Revolving Funds" and specifically highlights the proven benefits of creating a green revolving fund. The sixth section is titled "Benefits of Joining the Billion Dollar Green Challenge" and explores the additional benefits of creating a green revolving fund through a commitment to the Billion Dollar Green Challenge. The seventh and eight sections, respectively titled "Boston University's Green Revolving Fund: A Case Study" and "Harvard University's Green Revolving Fund: A Case Study", highlight two very different yet successful approaches to implementing green revolving funds at other Boston-based universities. The primary purpose of these two specific case studies is to highlight just how easy it is for institutions to tailor the green revolving fund to meet their specific needs without compromising the fund's success.

About the Sustainable Endowment Institute

The Sustainable Endowment Institute, which was founded in 2005 as a special project by Rockefeller Philanthropy Advisors, is a Cambridge-based non-profit that has pioneered research and education to advance sustainability in campus operations and endowment practices in universities across the country. The Sustainable Endowment Institute, in collaboration with 16 partner organizations that include the American College & University Presidents Climate Commitment and Association for the Advancement of Sustainability in Higher Education, launched a ground-breaking project to assist universities across the country in achieving significant energy savings through the use of an innovative financial model (Green Billion). This project is the Billion Dollar Green Challenge and was first launched by the Sustainable Endowment Institute and its partners in October of 2011.

About the Billion Dollar Green Challenge

The Billion Dollar Green Challenge was formed as a mechanism to challenge colleges, universities, and other organizations across the country to invest a combined total of one billion dollars in self-managed revolving funds that finance improvements in reductions in energy usage and costs. More than 50 colleges and universities across the country have pledged their commitment to the Billion Dollar Green Challenge since its inception in 2011 by implementing unique, carefully-tailored green revolving funds to their respective institutions. These institutions vary across whether or not they are public or private and the size of their campus and endowments. They include but are not limited to Arizona State University, Boston University, College of William and Mary, Dartmouth College, Emory University, Georgia Tech, Harvard University, Princeton University, Stanford University, UCLA, University of Maine, University of Minnesota, University of New Hampshire, University of New England, and University of Utah. According to the Sustainable Endowment Institution, 58 institutions have committed a total of $122 million to date (Green Billion).

Overview of Green Revolving Funds

Green revolving funds directly assist universities in achieving significant reductions in operating expenses and greenhouse gas emissions. The Sustainable Endowment Institute has proven this model is successful, as indicated by data collected from 52 already-implemented green revolving funds. Conservative estimates demonstrate that these existing green revolving funds consistently earn a 20+ percent annual return on investment (ROI) with a median annual ROI of 28 percent. Established funds have reported annual ROI’s ranging from Georgia Tech’s 20 percent to Boston University’s 59 percent (Green Billion). Perhaps more importantly, however, is the fact that the Sustainable Endowment Institute has reported that these 52 existing revolving funds have not once recorded losses. The Sustainable Endowment Institute also reports that, according to this same data set, the median project payback period is 3.5 years (Green Billion). This means that, on average, projects pay for themselves completely in 3.5 years and actually generate excess profits from that point onwards.

The Sustainable Endowment Institute first developed green revolving funds to address urgently needed yet capital-intensive energy efficiency upgrades on campuses while facing steep budget cuts. The Sustainable Endowment Institute argues that these are called “revolving funds” because the funds loan capital to individual sustainability projects, which then repay the loan with savings created in that respective institution's utilities budget (Green Billion). This generates existing funds for future projects while simultaneously paying for itself completely. The Billion Dollar Green Challenge defines green revolving funds with two specific criteria. First, the fund must finance measures to reduce resource use or carbon emissions. Secondly, the fund must revolve. This means that savings attributed to reduced operating costs must be used to repay the up-front investment back to the green revolving fund for future projects (Green Billion).

Details: Sources of Seed Funding, How Institutions Repay Loans, and Who Manages Funds

According to the Sustainable Endowment Institute, green revolving funds can secure seed funding through a variety of manners. These manners can be used individually or paired with each other to minimize impacts across the institution. Administrative budgets are most commonly used to start green revolving funds and can take on various forms which include (but are not limited to) Facilities, an existing campus Sustainability Office, or even through voluntary payroll reductions from campus employees. The student body can also serve as a way for green revolving funds to gain seed funding. This type of funding is minimal and rarely exceeds $100 thousand, but could be implemented by dedicating a marginal (say $10 per student each semester) amount of tuition per student to the fund. Donations from alumni or foundations could also be used as a method of securing seed funding. Additionally, universities with large endowments could allocate a small portion of that endowment as a seed investment to create a green revolving fund. The endowment could either donate the capital or implement it as a loan to be repaid in the same manner that projects replenish existing funds. Utility rebates can also be leveraged to start green revolving funds (Green Billion). Again, it is critical to understand that these various methods of securing seed funding for green revolving funds can and should be paired with each other. This allows for increased customization so that institutions can tailor this model to be most effective.

The Sustainable Endowment Institute outlines two specific methods in which institutions commonly repay loans to green revolving funds. The first method in which institutions commonly repay loans to green revolving funds is the Loan Model. This model is useful when project proponents have direct control over their budget and thus can independently repay their loan. The Loan Model is especially useful in scenarios where departments or schools within a institution directly control their own utility budgets. The second method in which institutions commonly repay loans to green revolving funds is the Accounting Model. Here, repayment to the green revolving fund is handled by a centrally-managed budget where the savings were generated. Here, the centrally-managed budget comes from the institution's entire budget rather than a budget that exists within a specific school or department.

A final note on these two methods to repay loans to green revolving funds is the opportunity for institutions to charge interest on their loans. This opportunity can be implemented to both the Loan Model and Accounting Model. It is primarily used to increase the speed in which a particular institution can grow its green revolving fund. The math behind this opportunity is straightforward: institutions that charge higher interest rates on loans yield greater returns and grow their green revolving fund by a larger rate. As reported by the Sustainable Endowment Institute, only five universities currently charge interest on loans. These interest rates range from the University of Colorado at Boulder's 1 percent to the University of Minnesota's 5.5 percent (Green Billion). The caveat with charging interest rates on loans, of course, is that payback periods would likely increase as projects must generate a greater amount of capital to repay the loan in full plus interest.

Fund administration varies widely across institutions. However, the vast majority of institutions that have implemented green revolving funds use committees to review and approve project proposals. Although the majority of institutions use committees to manage their green revolving funds, the manner of who serves on these committees varies across institutions. Some combination of administrators, staff, students, faculty, alumni, and external consultants can all make up these committees (Green Billion). A major benefit of having a large committee is that it allows for a diverse set of opinions to scrutinize project proposals, which can further improve impacts of implemented projects and greatly reduce risks in failure of proposed projects. However, a major drawback of having large committees is that they can be incredibly complex and quickly become too complicated to effectively manage a green revolving fund. Size and makeup of committees should be considered by institutions before the implementation of a green revolving fund, which can be easily tailored to best fit that institution's structure and needs.

Benefits of Green Revolving Funds

The Sustainable Endowment Institution identifies six primary benefits for institutions that implement green revolving funds. First and foremost, green revolving funds can transform expenses into investments. Presently, most institutions still consider investments in sustainability as expenses or opportunities to avoid costs. The “revolving” aspect of these funds emphasizes that energy and other efficiency projects make the institution money over time and are actually investments into building the funding of future financial health for that institution. A second benefit of implementing green revolving funds is that they can institutionalize a mechanism for funding efficiency. The existence of these funds provides a perpetual source of funding for that institution and the existence of a dedicated fund, rather than multiple one-off investments, is that cost-saving efficiency projects will more likely be funded in the future. A third benefit of the implementation of green revolving funds is their ability to streamline the internal loan process for an institution. The existence of a dedicated fund makes it easier for facilities staff to access capital for a particular project than to navigate more complex funding structures each time they want to acquire capital from the institution they work for. A fourth benefit of the implementation of green revolving funds is the opportunity for institutions to easier implement performance tracking for projects. The existence of a green revolving fund provides a centralized database of cost savings and energy data because committees will have specific information regarding each project proposal and its success. This centralized database will then provide the institution with opportunities to benchmark current project proposals both to historic projects and, perhaps more importantly, cost savings and energy data of other institutions that have also implemented green revolving funds. A fifth benefit of the implementation of green revolving funds is the opportunity for an institution to actually instill sustainability as a core value. In this day and age, sustainability is becoming more and more of a measurement for institutions to compete with each other. Establishing a green revolving fund is significant in proving that the institution is actually committed to sustainability and provides stronger data to back up that claim. A sixth and final benefit of implementing a green revolving fund is that institutions can seize new fundraising opportunities. The existence of a green revolving fund on campus for an institution provides another incredibly appealing medium for donors to give back while simultaneously providing a unique, hands-on educational opportunity for students (Green Billion).

Benefits of Joining the Billion Dollar Green Challenge

Furthermore, the Sustainable Endowment Institute highlights three major benefits for institutions that join the Billion Dollar Green Challenge by implementing green revolving funds. First and foremost, joining the Billion Dollar Green Challenge means institutions benefit from consulting throughout the lifetime of the fund. Institutions gain access to expertise and knowledge regarding forming the fund, managing the fund, and reviewing project proposals within the fund. It also directly connects participating institutions to an engaged network and bevy of resources through both expert supporting staff and other participating institutions. This access to consulting throughout the lifetime of the fund is important because of how tailored each green revolving fund can be. The institution can easier figure out how to best implement the fund. A second benefit of joining the Billion Dollar Green Challenge is the access to project tracking, identification, and organization. The Sustainable Endowment Institute has created the Green Revolving Investment Tracking System (GRITS), which is a web-based project management platform used by over 400 institutions. GRITS provides institutions access to a massive database and allows institutions to track progress across specific projects while comparing it to the success of other existing projects within the database. A third and final benefit of joining the Billion Dollar Green Challenge is the recognition of leadership and positive media attention. Institutions that join the challenge become a part of that network and get included in press releases that highlight successes of the green revolving fund. This is important because sustainability is increasingly becoming a measurement for institutions to compete upon and this magnitude of positive exposure can have an incredible influence on perception of the institution (Green Billion). In conclusion, institutions can still develop their own green revolving funds without actually committing to the Billion Dollar Green Challenge. However, choosing not to do so would exclude that institution from the three benefits listed above and any other existing benefits. There is no fee to join the Billion Dollar Green Challenge as of 2018, and institutions may withdraw at any point in time (Green Billion).

Boston University's Green Revolving Fund: A Case Study

Boston University is a private university with a full-time student enrollment of 23,500 students. As of June 30th, 2009, the university had an endowment of $919 million (Flynn, 2011 pg. 2). The university's green revolving fund was created in 2008 with $1 million in seed funding provided by an administrative budget (Flynn, pg. 2). Because Boston University's green revolving fund was designed for simplicity, it sits at a fixed budget of $1 million and does not charge interest on loans (Flynn, pg. 2). The university's committee to advise the management of the green revolving fund is made up of four working groups that include administrators, faculty, students, and staff (Flynn, pg. 3). Project proposals are reviewed on a case-by-case basis but favor potential projects with payback periods of less than 1.5 years (Flynn, pg. 4).

Boston University's green revolving fund has been quite successful. Since its inception, the fund has produced an average payback period of 1.97 years, an average cost-savings of $70,782 per project or $424,696 per year across all projects, and an average return on investment of 57 percent including utilities incentives (Flynn, pg. 4). Furthermore, these projects have contributed to an annual energy savings of 2,546,000 kWh for the university (Flynn, pg. 2). Boston University has noted two key takeaways as to why their carefully-tailored green revolving fund has been so successful. First and foremost, the fund's straightforward structure has been critical to its success. Because of the simplicity of this green revolving fund, it can operate efficiently without adding any additional work for other university staff and administrators while simultaneously getting projects approved in an efficient manner (Flynn, pg. 9). Secondly, Boston University attributes the success of their green revolving fund through their success in promoting sustainability on campus and online. Boston University's website, "Sustainability @BU", has been critical in raising awareness towards current campus projects and has inspired numerous additional project proposals (Flynn, pg. 9). The success of Boston University's program highlights one unique, tailored approach and how successful the university's green revolving fund has been thus far.

Harvard University's Green Revolving Fund: A Case Study

Harvard University is a private university with a full-time student enrollment of 19,207 (Foley, 2011, pg. 2). As of June 30th, 2009, Harvard University had an endowment of $26 billion (Foley, pg. 2). The university's green revolving fund, referred to as the "Green Loan Fund", was originally funded in 1992 with a $1.5 million commitment from the offices of the President and Provost and has since evolved into a $12 million program (Foley, pg. 5). The Green Loan Fund is managed by a review committee made up from a wide variety of stakeholders across campus, including but not limited to students, administrators, and staff throughout various departments across campus. This large committee composition is used for two primary reasons: to allow proposed projects to be scrutinized from multiple diverse viewpoints and to help spread knowledge of the fund's existence to many departments across campus (Foley, pg. 5). Since 2007, the Green Loan Fund has incorporated a 3 percent interest rate in order to further grow the size of the fund. Loan criteria indicates that, for a project to be approved, the project must result in a direct reduction of costs and environmental impacts for the university with a simple payback period of less than five years, based upon cost savings (Foley, pg. 6). Funds are available on a first-come, first-served basis. However, projects that prioritize reducing greenhouse gas emissions are given preference.

Harvard's Green Loan Fund has been unbelievably successful and remains a textbook example of how successful green revolving funds can be if implemented correctly. The Green Loan Fund has an average payback period of 3 years, an average return on investment of 29.9 percent per project, and a total annual cost savings of $4.8 million for the university (Foley, pg. 8). Furthermore, the Green Loan Fund has funded over 200 projects cumulatively total more than $16 million since its inception (Foley, pg. 8). Harvard's Office of Sustainability has identified three carefully-tailored aspects of the Green Loan Fund that are responsible for its massive success. First and foremost, designated staff must support the fund and advocate for project proposals from the campus community. This engages a wider variety of students and departments by ensuring that their proposals are heard out. Secondly, Harvard's Office of Sustainability has identified that the committee responsible for reviewing proposals must have many stakeholders and represent various constituencies. Finally, the Office of Sustainability reiterates that it is imperative that projects must be thoroughly reviewed and carefully implemented. This holds especially true in the stages of calculating performance and cost savings, so to maximize the Green Loan Fund's average return on investment and minimize its average payback period (Foley, pg. 10).

V. Recommendations

Based on the culmination of our market research, literature review, analysis of Boston College's energy infrastructure, and the various funding options for this proposal, we believe that implementing solar panels on top of Conte Forum and or O'Neill Library are not only viable, but necessary. Our market research indicated that students believed integrating solar panels into Boston College's energy infrastructure would not have a large effect on the gothic architectural style should the panels be placed appropriately. The buildings that respondents indicated would have the least impact on Boston College's aesthetic charm were O'Neill Library and Conte Forum. Coincidentally, these buildings have the highest energy footprint at Boston College and would benefit most from a solar panel program as well. O'Neill Library and Conte Forum use the most energy out of all of the buildings on Boston College campus, and such would benefit from an influx of solar energy as a supplemental energy source. Vargas et al. note in their case study about the integration of solar energy infrastructure in Seville, Spain, that solar energy alone is not sufficient to power the city. Solar energy is better used as a supplemental energy source to support the electricity needs of the city. Boston College could benefit from an adaptation of Seville's energy infrastructure on a smaller scale, and use solar energy as a supplemental energy source for the buildings with the largest energy demand. While implementing solar panels on campus will be cost efficient in the long run, we have also researched case studies of alternative funding options for solar infrastructure from Boston and Harvard University.

Upon thoroughly exploring green revolving funds and their success at Boston and Harvard University, we believe that there is sufficient evidence that Boston College could fund this project through implementing a green revolving fund of its own. With an endowment of $2.6 Billion, Boston College could easily allocate a small portion (say, $1 Million) to create a green revolving fund. The creation of the green revolving fund would provide capital for Boston College to implement solar projects across campus and would pay for itself in cost reductions on energy use, while simultaneously reducing the university's carbon footprint. Furthermore, this fund would be self-replenishing and fund future sustainability projects. A critical takeaway from the Boston and Harvard University case studies is just how easily institutions can carefully tailor their green revolving funds to best fit their respective structures and needs. Green revolving funds are proven to be successful at institutions across the country (and right in Boston), highly customizable across institutions, and cheap to implement compared to Boston College's massive endowment.

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Appendices

Table 1:The energy demand of O'Neill Library and Conte Forum throughout 2018.

Conte Forum	**Assume extra cost**				**O'Neill Library**				
Date		Consumption	Units		Date		Consumption	Units	Notes
1/1/2018	1/31/2018	381830	kWh		1/1/2018	1/31/2018	324457	kWh	
2/1/2018	2/28/2018	332723	kWh		2/1/2018	2/28/2018	310274	kWh	
3/1/2018	3/31/2018	175564	kWh		3/1/2018	3/31/2018	323043	kWh	
4/1/2018	4/30/2018	137621	kWh		4/1/2018	4/30/2018	306634	kWh	Estimate because of a communication loss.
5/1/2018	5/31/2018	143247	kWh		5/1/2018	5/31/2018	370897	kWh	
6/1/2018	6/30/2018	133521	kWh		6/1/2018	6/30/2018	344366	kWh	

7/1/2018	7/31/2018	422522	kWh		7/1/2018	7/31/2018	381262	kWh	
8/1/2018	8/31/2018	965330	kWh		8/1/2018	8/31/2018	410186	kWh	
9/1/2018	9/30/2018	290806	kWh		9/1/2018	9/30/2018	411886	kWh	
10/1/2018	10/31/2018	207706	kWh		10/1/2018	10/31/2018	382197	kWh	
11/1/2018	11/30/2018	174509	kWh		11/1/2018	11/30/2018	331636	kWh	
12/1/2018	12/31/2018	159345	kWh		12/1/2018	12/31/2018	315028	kWh	

Table 2: Energy cost range per kWh in Massachusetts from November 2018 to April 2019

Electricity pricing	Residential ($)	Commercial ($)
Fixed		
11/18-4/19	$13.718	$13.166
Variable		
11/18	$0.11599	$0.11165
12/18	$0.13255	$0.13227
1/19	$0.15802	$0.15341
2/19	$0.15995	$0.15647
3/19	$0.12658	$0.12215
4/19	$0.11631	$0.1091
Average	$0.1349	$0.130842

Table 3: Calculates the energy cost for O’Neill Library and Conte Forum throughout 2018.

		Average Cost:	$0.133 / kWh	
	O'Neill	Conte	O'Neill	Conte
Month	Consumption (kWh)	Consumption (kWH)	Cost ($)	Cost ($)
January	324457	381830	$42,179.41	$49,637.90
February	310274	332723	$40,335.62	$43,253.99
March	323043	175564	$41,995.59	$22,823.32

April	306634	137621	$39,862.42	$17,890.73
May	370897	143247	$48,216.61	$18,622.11
June	344366	133521	$44,767.58	$17,357.73
July	381262	422522	$49,564.06	$54,927.86
August	410186	965330	$53,324.18	$125,492.90
September	411886	290806	$53,545.18	$37,804.78
October	382197	207706	$49,685.61	$27,001.78
November	331636	174509	$43,112.68	$22,686.17
December	315028	159345	$40,953.64	$20,714.85
Average:	322357.9167		$41,906.53	

Solar Power Savings by Month in Newton

A 5kW system will save someone in Newton up to $124.33 on an average month. That's significant given the average Massachusetts power bill of $119.26 per month. Here's a monthly breakdown:

Month	Available kW / m2 / day	Max savings / month
Jan	3.42	$95.73
Feb	4.34	$110.59
Mar	4.80	$134.40
Apr	5.10	$138.14
May	5.03	$140.63
Jun	5.03	$136.28
Jul	5.46	$152.73
Aug	5.43	$152.00
Sep	5.13	$138.86
Oct	4.18	$116.87
Nov	3.29	$88.97
Dec	3.10	$86.71

Table 4: Available kW / m^2 / day in Newton, MA

Table 5: Details the potential savings per month in O'Neill and Conte Forum

Month	kW / m^2 Available per Day	Days per month	kW / m^2 Available per Month	Production (100 m^2)	Savings	O'Neill New Cost	Conte New Cost
January	3.42	31	106.02	10602	$1,590.30	$37,344.54	$44,229.30
February	4.34	28	121.52	12152	$1,822.80	$35,410.08	$38,103.96

March	4.8	31	148.8	14880	$2,232.00	$36,533.16	$18,835.68
April	5.1	30	153	15300	$2,295.00	$34,501.08	$14,219.52
May	5.03	31	155.93	15593	$2,338.95	$42,168.69	$14,850.69
June	5.03	30	150.9	15090	$2,263.50	$39,060.42	$13,759.02
July	5.46	31	169.26	16926	$2,538.90	$43,212.54	$48,163.74
August	5.43	30	162.9	16290	$2,443.50	$46,778.82	$113,396.10
September	5.13	30	153.9	15390	$2,308.50	$47,117.82	$32,588.22
October	4.18	31	129.58	12958	$1,943.70	$43,919.94	$22,981.02
November	3.29	30	98.7	9870	$1,480.50	$38,315.82	$19,460.58
December	3.1	31	96.1	9610	$1,441.50	$36,361.86	$17,679.90

Month	Average Monthly Cost	$0.10 / kWh	$0.11 / kWh	$0.12 / kWh	$0.13 / kWh	$0.14 / kWh	$0.15 / kWh
January	$42,377.22	2.50%	2.75%	3.00%	3.25%	3.50%	3.75%
February	$38,579.82	3.15%	3.46%	3.78%	4.09%	4.41%	4.72%
March	$29,916.42	4.97%	5.47%	5.97%	6.47%	6.96%	7.46%
April	$26,655.30	5.74%	6.31%	6.89%	7.46%	8.04%	8.61%
May	$30,848.64	5.05%	5.56%	6.07%	6.57%	7.08%	7.58%
June	$28,673.22	5.26%	5.79%	6.32%	6.84%	7.37%	7.89%
July	$48,227.04	3.51%	3.86%	4.21%	4.56%	4.91%	5.26%
August	$82,530.96	1.97%	2.17%	2.37%	2.57%	2.76%	2.96%
September	$42,161.52	3.65%	4.02%	4.38%	4.75%	5.11%	5.48%
October	$35,394.18	3.66%	4.03%	4.39%	4.76%	5.13%	5.49%
November	$30,368.70	3.25%	3.58%	3.90%	4.23%	4.55%	4.88%

December	$28,462.38	3.38%	3.71%	4.05%	4.39%	4.73%	5.06%

Table 6: This table calculates the potential range of savings per month if the solar plan is implemented

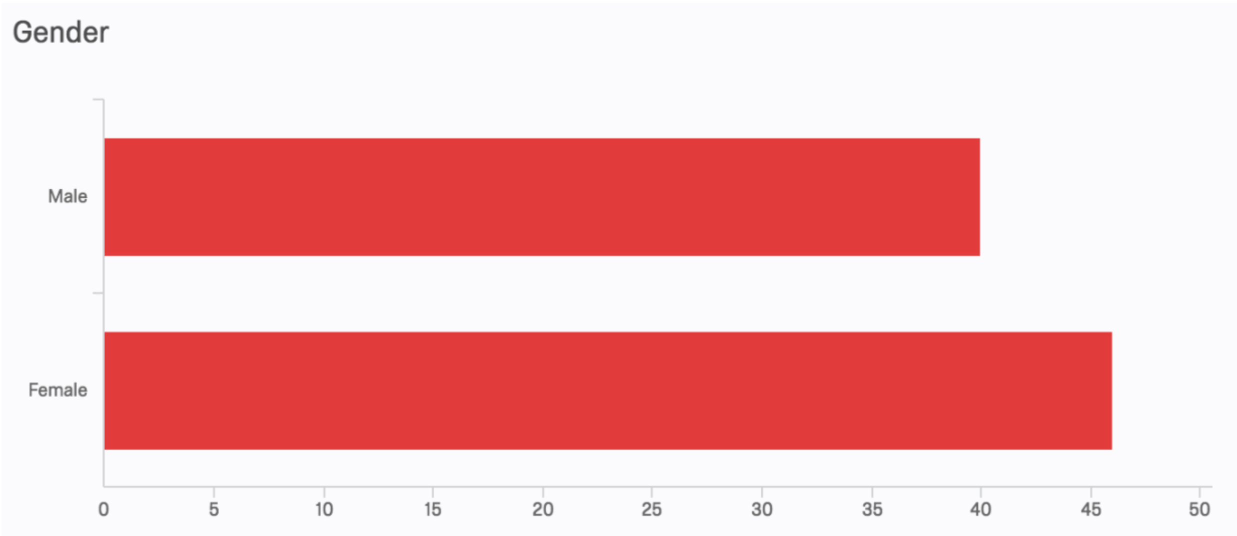

Exhibit 1: The gender distribution of our survey respondents

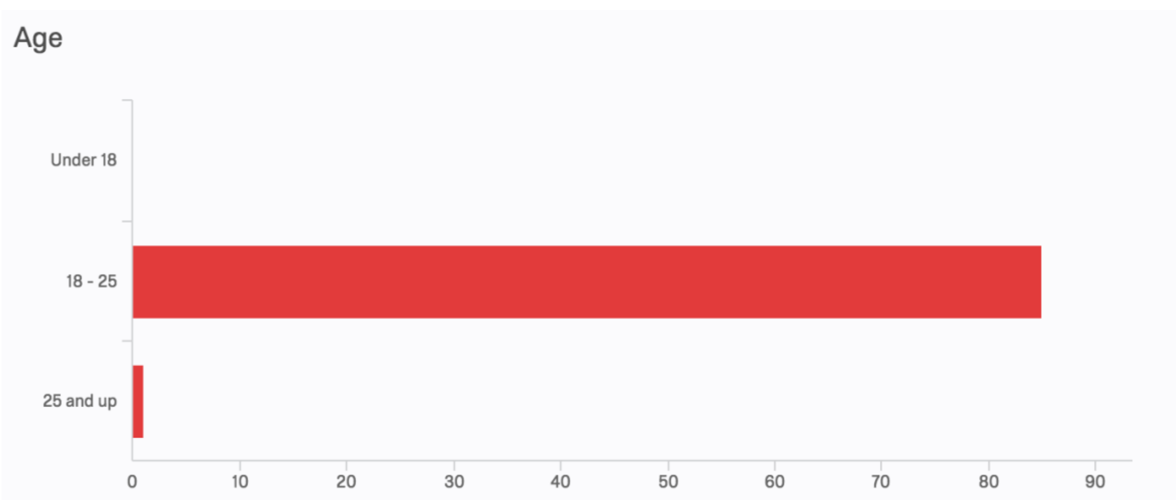

Exhibit 2: The age range of our survey participants

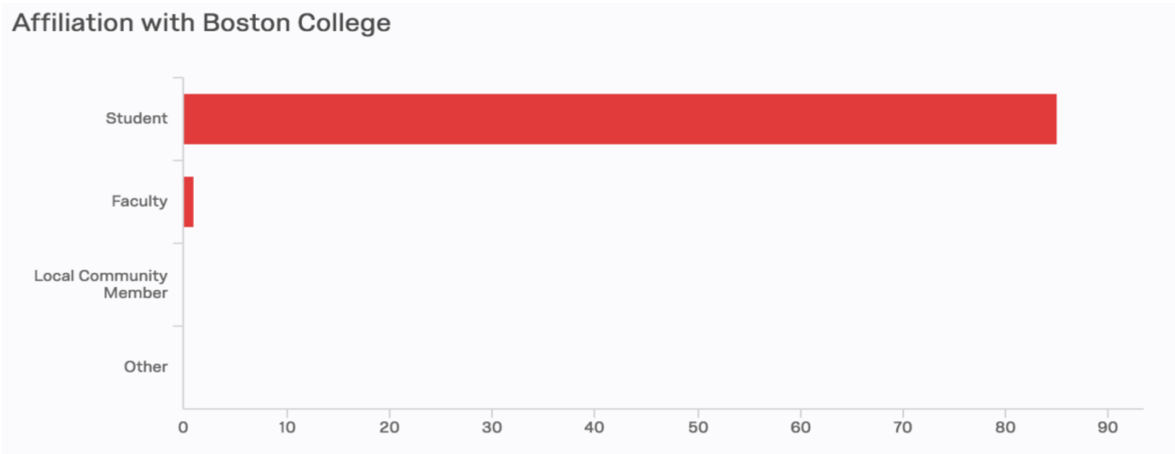

Exhibit 3: The respondents affiliation to Boston College.

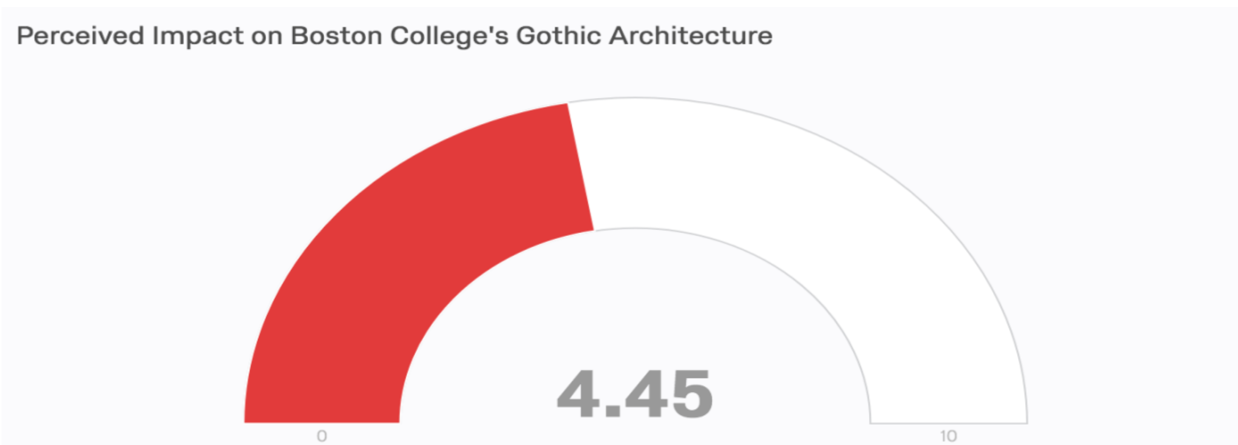

Exhibit 4: The perceived impact on Boston College's Gothic Architecture.

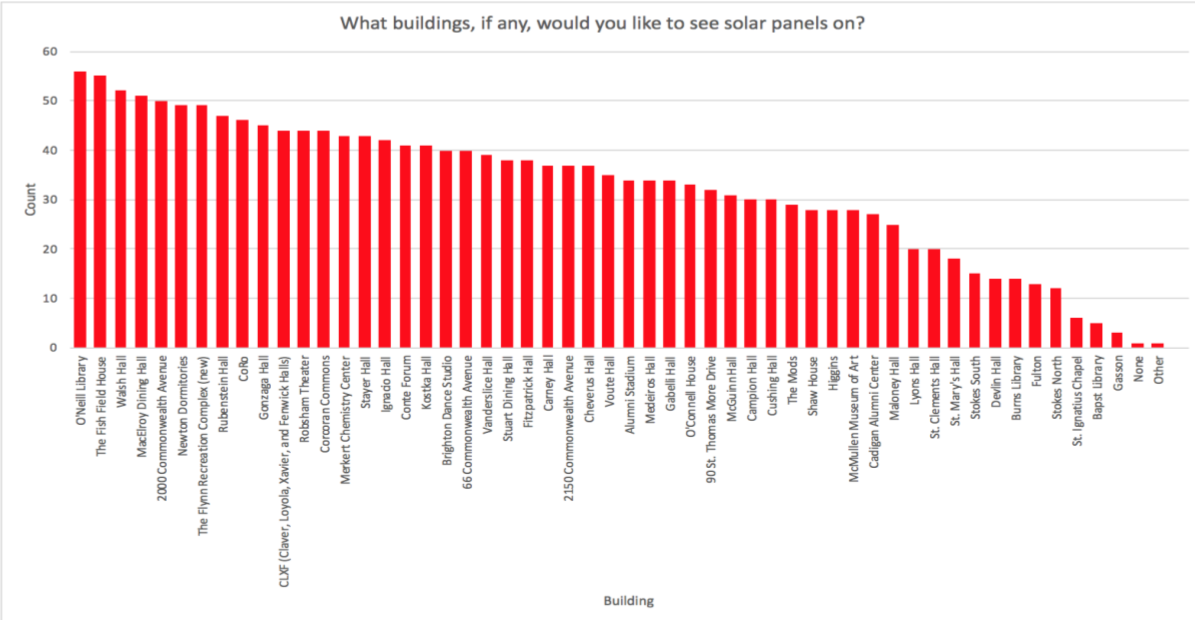

Exhibit 5: Details the desired buildings on campus that survey respondents would like to see solar panels on.

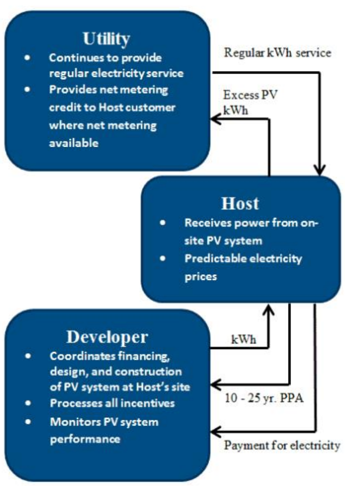

Exhibit 6: Depicts a PPA model structure

Cost of Solar Panels in Newton, MA

The figures below show the total cost of solar power in Newton and the estimated payback or break-even period. The numbers below assumes you want to buy the system outright. You can also get a loan, lease the system, or set up a "power purchase agreement" (PPA). Learn more about payment options.

Residential 5 kW system	Commercial 50 kW system
Estimated system cost: $20,950	Estimated system cost: $193,500
(-) Federal tax credit: 30% with no maximum	(-) Federal tax credit: 30% with no maximum
Final cost after tax credits: $14,665	Final cost after tax credits: $135,450
Est. energy savings per year: $1,492	Est. energy savings per year: $14,919
Time to recover costs: 9 years 10 months	Time to recover costs: 9 years 1 month
30-year savings: $30,095	30-year savings: $312,135

Exhibit 7: Average cost estimates and savings for solar panels in Newton, MA.