Energy

November 25, 2017 draft

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Introduction

Energy is essential to the University's ability to carry out its mission. The largest part of the University's emissions come from the energy used to power, heat, and cool its buildings. With a population of 40,000, occupying 15 million square feet of building space on 133 acres, Boston University's campuses are essentially a city within a city.

The University's direct emissions from energy

Background and historical emissions

Emissions from energy use are categorized according to the GHG Protocol in scope 1 and scope 2. Scope 1 emissions come from natural gas, oil, gasoline, and diesel burned on campus. Emissions associated with the generation of electricity and steam used by the University are considered Scope 2 emissions. Boston University has reported its scope 1 and 2 emissions for the CRC and BUMC campuses since fiscal year[1] 2006. As shown by graph 1, between FY 2006 and FY 2016 overall emissions have decreased by about 25%. In FY 2016 BU's combined scope 1 and 2 emissions, net of carbon sinks, totaled 121,984 metric ton of carbon dioxide equivalent (MTCO_2e) for the two campuses.

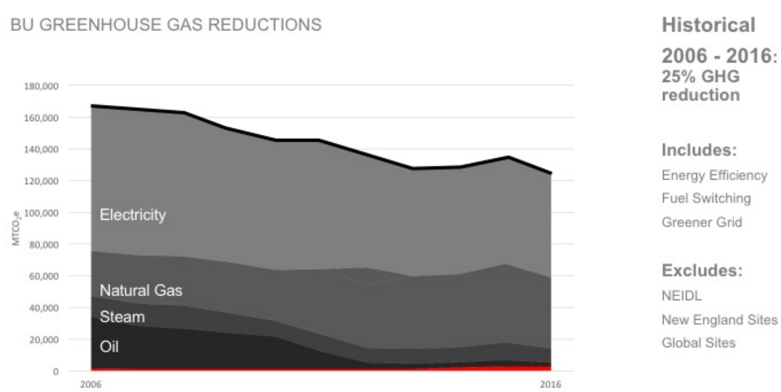

Figure 1. Boston University Greenhouse Gas Emissions: historical data

Over the last decade the University was able to achieve emission reduction while the campus grew by 14%. As shown in graph 2, three factors determined emission reductions. First, demand for energy dropped thanks to energy efficiency investments led by BU's Facilities Management & Planning. Second, the University converted to cleaner burning fuels for heating and cooling buildings: natural gas replaced oil which today only provides 3% of BU's energy needs, down from 24% in 2006. Third and last, a large dent in emissions came from the electrical grid in the Northeast, which has become significantly greener as generation of electricity moves from coal to natural gas and renewables.

[1] This means that emissions follow the fiscal year cycle and that emissions for 2006 combine emissions from the second half of 2005 and the first half of 2006.

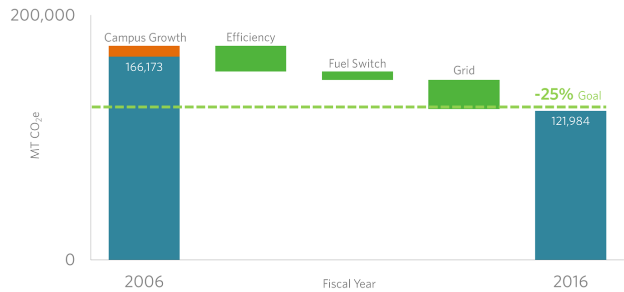

Figure 2. Campus growth and emission reductions from FY 2006 to FY 2016.

New FY 2016 baseline

Using the Climate Action Plan as an opportunity to construct a more complete emissions inventory a new FY 2016 baseline was constructed. For the first time the baseline captures emissions from facilities beyond the campuses, and now includes the NEIDL, BU's share of the MGHPCC[2], Tanglewood and Sargent properties.

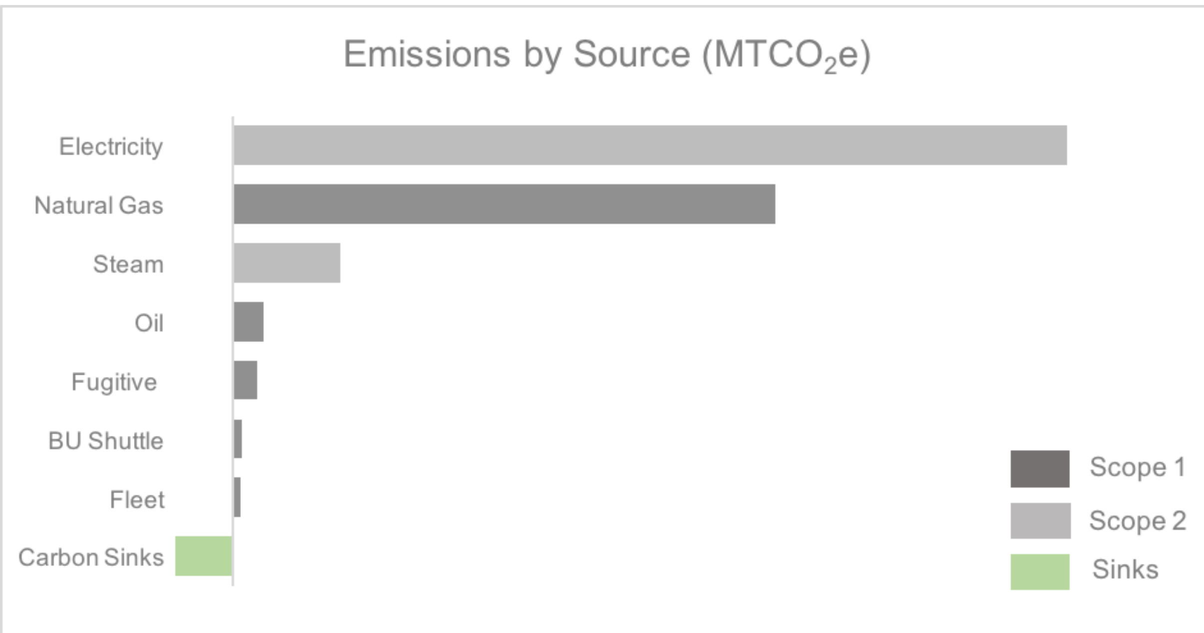

Figure 3. Emissions by Source for FY 2016.

[2] MGHPCC is the Massachusetts Green High-Performing Computing Center, a world-class high performance computing center located in Holyoke, MA. Boston University is a partner of the MGHPCC along with other universities, industry partners, and the Massachusetts state government.

	SCOPE 1	SCOPE 2	TOTAL MTCO$_2$e
FACILITIES			
CRC	46,600	51,500	98,000
BUMC	800	23,300	24,100
MGHPCC		800	800
Tanglewood	100	100	200
NEIDL	300	2,400	2,700
Carbon Sinks			-4,700
FLEET	700		700
BU SHUTTLE (BUS)	800		800
CRC & BUMC FUGITIVE EMISSIONS	2,100		2,100
TOTAL (CO$_2$e)	51,400	78,100	**124,700**

Table 1. Breakdown of GHG emissions from BU in FY 2016.

Boston University owns property in four areas regionally. The Charles River Campus is the hub for undergraduate activity, spans an area of 75 ha (183 acres), and is dominated by buildings and roads with patches of landscaping and gardens. The BU Medical School is in a very densely developed area, spanning 29 ha (71 acres) with limited vegetation. The Sargent Center for Outdoor Education in Hancock, NH is a property owned by the University and leased to Nature's Classroom. Sargent Center includes several buildings and fields, but is dominated by large stature forest spanning an area of 288 ha (712 acres). Finally the BU Tanglewood Institute in Lenox, MA is a 26 ha (64 acre) property run by the College of Fine Arts with the land comprised of a near equal mix of buildings, fields, and forest patches. Building from a faculty analysis described in detail in Hardiman et al. (2017), we estimate the net biological flux for these regional BU properties to be an annual update of 3.7 Mg C ha-1 (4,650 tonnes of CO_2). This net biological update offsets nearly 4% of the Universities Scope 1 and 2 emissions.

Recommendations

The new baseline excludes satellite campuses that BU operates through Global Programs in Washington D.C., Los Angeles, London (UK), Geneva (CH), Sydney (AUS). Despite best efforts there is no system in place to retrieve energy consumption for these locations. In the future the Task Force recommends establishing reliable data collection systems for satellite campuses managed by Global Programs, especially those owned and occupied by BU.

Climate Action Strategy: three scenarios

Context setting

The Task Force envisioned three different scenarios to reduce emissions and put the University on a carbon neutrality path:

- BU Good achieves 80% GHG emission reduction by 2050, which lags behind the goal established by the City of Boston.
- BU Better achieves 100% GHG abatement by 2050, which matches the City's goal.
- BU Bold is the most aggressive scenario in which the University achieves 100% GHG abatement by 2040, a whole decade earlier than BU Better and the City of Boston, and putting BU at parity with multiple universities (GWU, NYU, and Syracuse) as leaders in this area.

As described in more detail below, The Task Force recommends the pursuit of Net Zero Direct Emissions by 2040 "BU Bold," the most ambitious scenario. This will provide local and national leadership as well as significant institutional benefits. Furthermore, the Task Force agrees that locking in emissions reductions in the first few years [2018-2025] will generate significant environmental and economic benefits and put the university on a strong path toward meeting our target. The plot below shows emissions reductions over time under the Bold scenario (the bold green line), with other institutions and their stated emissions goals provided by way of comparison.

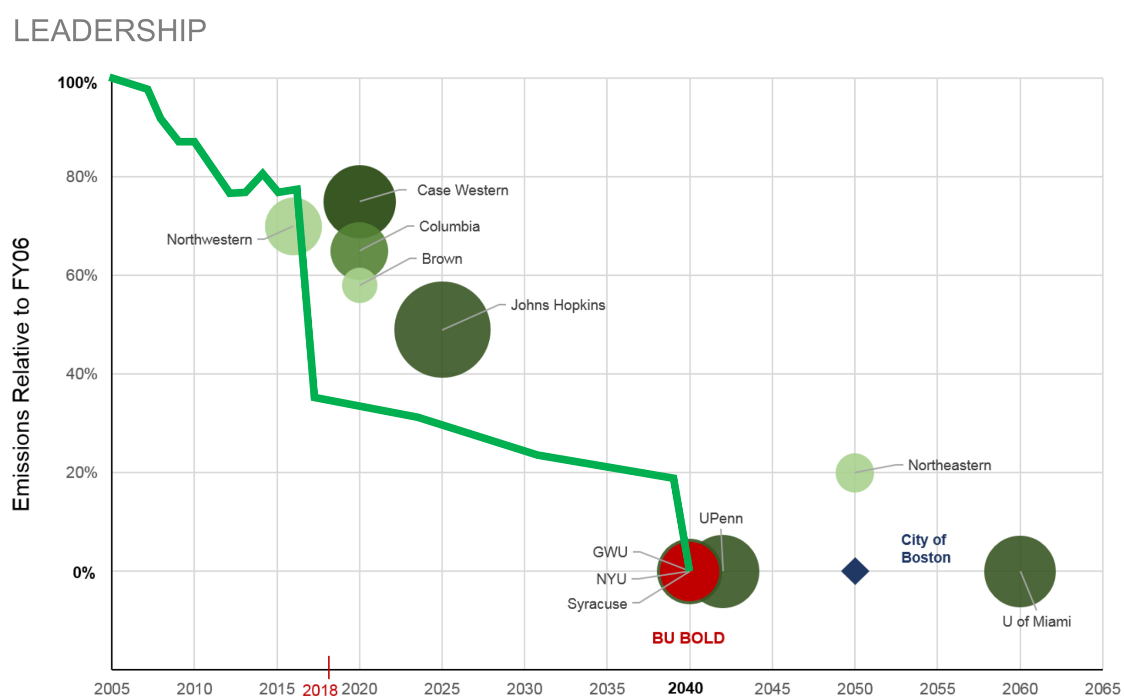

Figure 4. Emission abatement curve over time under the Bold scenario

The 3 emissions reduction scenarios Good, Better, and Bold have many similar features, but provide different levels of how aggressive BU chooses to be in reducing its carbon emissions in terms of magnitude and timing.

The Task Force provides the necessary steps to achieve emission abatement goals. Some elements are recurrent but differ across scenarios in scope and speed. The two pillars at the heart of each strategy are energy efficiency projects to reduce demand, and the purchase of renewable energy. Other actions to reduce emissions in later years include the electrification of fossil fuel systems and the purchase of offset. Below is a brief description of each.

Investing in building energy efficiency is critical to optimize operations in a way that reduces energy use and simplifies monitoring and maintenance, which enables staff to identify further saving opportunities. Energy efficiency initiatives will reduce emissions by 17-31%. Holding down energy consumption in new buildings and major renovations through high performance building design, LEED certification, and EUI targets will help keep us on track as the campus grows. This shift to higher performing buildings is the first concrete action the University can take to reduce emissions on campus and show the seriousness of its commitment.

A large portion, almost half, of the University's emissions will be reduced by procuring renewable energy from a large-scale project outside New England. This is the single action that can immediately abate a large portion of BU's emissions. The Energy Working Group has been working with a renewable energy broker to identify the right project based on criteria developed by the Group. To learn about the selection process and criteria for choosing the project see the section "How & Why the BU CAP Chooses Renewable Projects."

Despite the limited options for rooftop solar on campus, the potential for on-campus renewables is equivalent to about 1% of the electric load. While this is a small number, the presence of photovoltaic system on campus provide great research and education opportunities and a statement to the living-learning laboratory commitment. Moreover, on-campus solar would provide the ability to more carefully study peak-loads and explore the effect of demand-response on the University's energy bill.

All scenarios assume that the New England grid will reduce in carbon intensity at an annual rate of 1.25%. Today, the average generation mix for ISO New England is composed of 51% natural gas, 33% nuclear, 4% hydro, 3% coal, 2% wind, and 7% of other sources. In the last ten years, the switch from coal to natural gas made the grid approximately 40% greener.

Climate Action Scenarios	**BU Good**	**BU Better**	**BU Bold**
Goal (GHG reduction in %)	80% by 2050	100% by 2050	100% by 2040
Matching city's goal?	Falling short	Aligned with City of Boston	Ahead of City of Boston
Cumulative Emissions released ($MTCO_2e$)	2,200,000	1,500,000	1,000,000
Cumulative Emission cut ($MTCO_2e$)	2,100,000	2,800,000	3,300,000
GHG reduction from energy efficiency	17% by 2048	31% by 2042	31% by 2032
Energy efficiency – new construction	Site EUI assumed 110 kBtu/sf Site EUI Goal 40 kBtu/sf	Site EUI assumed 90 kBtu/sf Site EUI Goal 40 kBtu/sf	
Renewable energy	50% 2018-2030 100% after 2030	100% in 2018 onward	
Electrification	None	With natural replacement of old equipment	
On campus renewables	None	Provide on buildings identified, and for new construction and renovations in the near term	
Offsets	Between actual reductions and goal		
Grid intensity	Assumed to be a decrease in carbon intensity of 1.25% /year		

Campus Growth	Assumed at 0.75% / year
New Construction	LEED Gold Certified with an average site EUI of 40 kBtu/sf/yr
Grid intensity	Assuming a decrease in carbon intensity of 1.25% /year

Table 2. The three scenarios and their elements.

BU Good

In the BU Good scenario, the University would achieve an 80% GHG reduction by 2050, which is falling short of the City of Boston's commitment of zero direct emissions by mid-century. To get there, the University enters in to a power purchase agreement (PPA) equivalent to 50% of BU's electric load for the first decade or so (2018-2030) and then to 100% of the electric load after 2030. In addition to the PPA, the University increases its energy efficiency investments accounting for 17% of GHG emissions reduction by 2050 and limiting the Site Energy Use Intensity (EUI) in new construction to an average of 40 kBtu/sf/year.

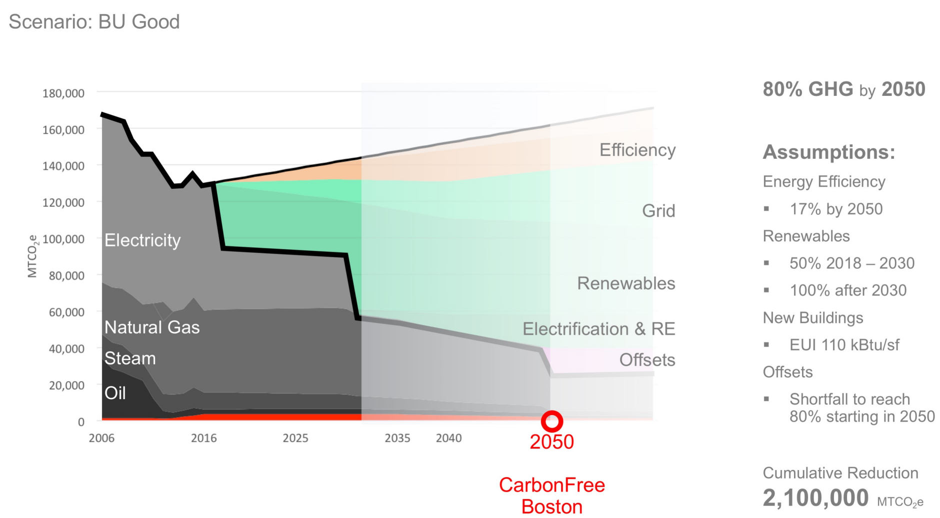

Figure 5. Abatement Curve for 80% Net Emission Reduction by 2050 (BU Good).

Energy efficiency projects selected for the Good strategy are the most straightforward, having higher returns, and have been the focus of energy efficiency efforts for the last 5 years. They include lighting projects (conversion to LED's and adding web based controls), optimizing HVAC systems in buildings with existing modern computer building automation systems (referred to as direct digital control, DDC), and upgrading HVAC control equipment and operating specifications at 6 of BU Medical Campus main lab buildings, since it provides a very focused opportunity with large impact. Since the Good strategy is focused on meeting a 2050 carbon objective, projects are implemented over a 30 year time period. The Good strategy requires doubling of the past 5 years energy efficiency expenditure rate, and requires the lowest increase in staff and overall budget. Under the BU Good scenario there would not be any electrification of fossil fuel systems used for heating.

BU Better

Under the BU Better scenario, the University would join the City of Boston in aiming at carbon neutrality by 2050. To achieve an additional annual GHG cut of 25,000 MTCO2e by 2050, BU needs to procure a large PPA for renewable energy that covers 100% of the University's electric load. Within a year, this one-time transaction would cut almost half of the University's total emissions. It is an immediate, large impact step that is relatively easy to achieve compared to energy efficiency projects which will take time to implement and require a continuous effort. Likely, two PPA waves will be needed, where the first PPA contract covers emissions from electricity for the years 2018-2030 while the second one would cover emissions from electricity from 2030 to 2050.

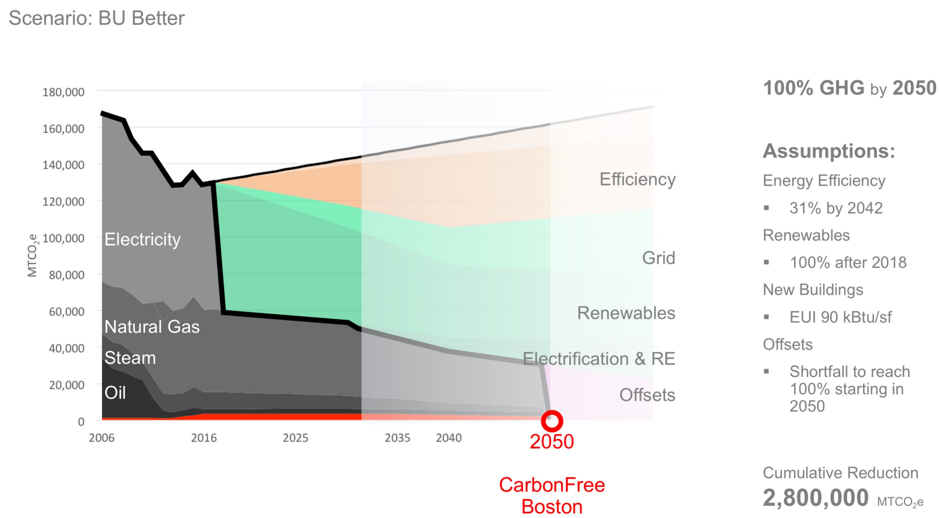

Figure 6. Abatement Curve for Net Neutral Direct Emissions by 2050 (BU Better).

From an energy efficiency perspective, on top of projects described in BU Good, a third, more extensive set of projects has to take place over a 24 year timeline. These energy efficiency projects involve a greater level of effort due to project complexity as well as a large number of smaller buildings that have individual roof-top-units and individual boiler controls that require additional technology to be better tied into the actual thermal conditions of the building (primarily in the dorms and older brownstone offices). Another major energy efficiency area of opportunity is to convert the original pneumatic control systems employed in many of the original CRC buildings (including Mugar Library, the GSU, and CAS) to modern computer based control. Implementing a modern computer based building automation system enables greater ability to customize control sequences and airflow to how the building is actually used. These retrofit projects are complex, but can be implemented fairly quickly by using wireless control technology that has been developed. Energy consumption also needs to be limited in how the campus grows, so for new construction and major renovations, the Site Energy Use Intensity (EUI) will need to average 40 kBtu/sf/year.

Besides a large scale PPA and energy efficiency projects, BU Better also foresees onsite renewables and the electrification of fossil fuel systems with the natural replacement of outdated equipment.

BU Bold

The BU Bold scenario aims at achieving carbon neutrality by 2040, ten years sooner than the City of Boston. To get there, the BU Bold pathway entails the same actions described in BU Better but with energy efficiency implemented over a significantly shorter time period. The PPA strategy would be identical, with the University entering a PPA for the purchase of renewables equivalent to 100% of BU's electric load.

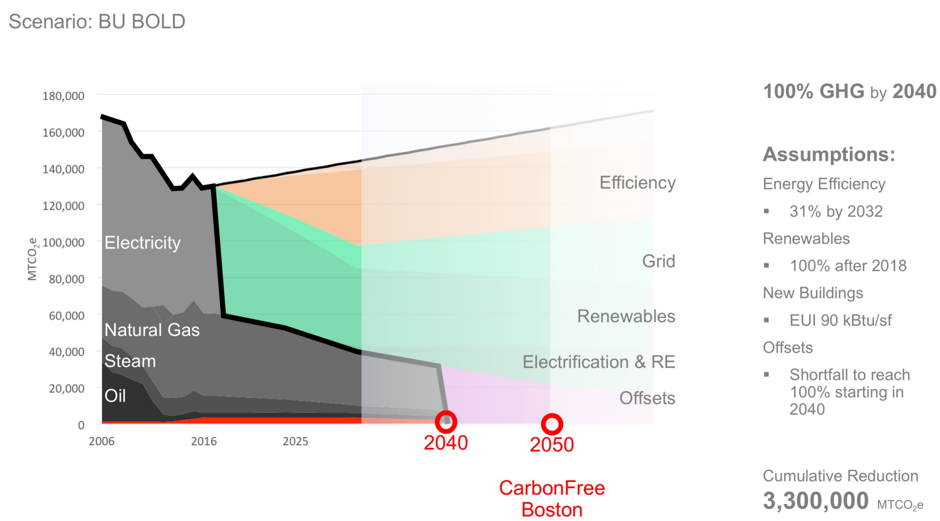

Figure 7. Abatement Curve for Net Neutral Direct Emissions by 2040 (BU Bold).

Energy efficiency projects under this scenario are the same as BU Better. However they are based on an accelerated time period (14 years) in order to reduce BU's electrical demand quickly to correspond to the expected timeline for purchase of renewable electricity contracts. Implementation over an accelerated time period does entail a greater investment in terms of not only the direct project costs but also in further increased staffing levels. Moreover, an accelerated schedule implies experimenting in the next few years with pilot programs to electrify fossil fuel systems currently utilized on campus.

Recommendation: Net Zero Direct Emissions by 2040 "BU Bold"

Although ambitious, the Task Force feels confident that achieving Net Zero Direct Emissions by 2040 through BU Bold is a realistic strategy that would place the University in a leadership role locally and nationally, and that would provide the greatest opportunities for sustained environmental benefits. A scenario (BU Good) in which we lag the commitments already made by the City of Boston and multiple urban universities would not demonstrate leadership or spur innovation. Ideally, we are helping to demonstrate to the City and our peers how various strategies can be used to achieve carbon neutrality. The strategies employed in BU Bold are no different from those in BU Better, but require additional resources to meet an accelerated timeline. While BU Bold requires a large institutional commitment from a managerial and budgetary perspective, the economics looks promising; as described below, many of our strategies have a long-term payback through energy cost savings. In fact, BU Bold is projected to have greater net cost savings than either of the other two options. Moreover, an accelerated period is important to reduce BU's impact on the climate, since there is a substantial advantage to reducing emissions as quickly as possible, and there would be numerous ancillary benefits. BU Bold is achievable using currently available strategies, which we expand upon in the following sections. Future changes from a technological, political, and economical perspective will make BU Bold a reasonable commitment.

Climate Action Strategies

This section describes in greater detail the role that energy efficiency, renewables, and offsets will play in achieving carbon neutrality.

Energy Efficiency

Achieving greater energy efficiency in our existing buildings is a foundation for Boston University to develop a plan to meet its climate commitments. Energy efficiency projects will not only reduce BU's demand for energy and its carbon emissions, but will generate significant financial savings that pay for these projects, as well as other aspects of the Climate Action Plan over time. Three energy efficiency scenarios are proposed that have different levels of project scope, timing, and investment level for the Charles River and Medical campuses. These energy efficiency projects are estimated to reduce our current carbon emissions by 17 to 31%, reduce energy expenditures by 20 to 33%, achieve financial returns on the order of 9 to 10%, and require an investment of $88-170 million over a 30 year period.

The projects included in the 3 energy efficiency scenarios focus on efficient lighting and HVAC controls due to the large impact and attractive economics these projects offer relative to other options. Estimates of implementation costs and savings were developed by a team of engineering students as part of a directed project course led by an engineering faculty member, in collaboration with BU Facilities staff and outside experts (including several BU alumni) [1]. The estimates are based on detailed studies of current building operating data, engineering plans, available contractor estimates for different projects that were scaled to other buildings, detailed calculations for over 30 buildings, and is also based on the results achieved from BU's past 5 years of energy efficiency projects that reduced BU energy use by 10%. This analysis serves only as a preliminary budget estimate of what the potential project costs and savings will be, but was developed conservatively in terms of underestimating energy savings and over-estimating project costs. To refine these estimates, a more extensive effort would need to be conducted based on specific contractor estimates for BU's 300-plus buildings that occupy nearly 15 million square feet.

The performance of the three scenarios in terms of carbon and energy use reduction, cost, and financial savings of these scenarios are summarized in Figure 8. Our analysis indicates that BU can reduce its carbon emissions by 17% (Good) and 31% (Better and Bold), while achieving energy expenditure reductions by 20% (Good) and 33% (Better and Bold). The internal rate of return for these projects is estimated to range between 9-10%, and would generate net cumulative savings between $32 and $135 million over a 30 year period. Of note, the total net savings are greatest within the BU Bold plan, with a comparable internal rate of return to BU Better. These savings would not only pay for the cost of these projects (including additional staff, direct project costs, interest, and maintenance), but would generate recurring savings that can be used to fund other aspects of the Climate Action Plan (purchase of sustainable electricity, capital expenditures for electrification and efficient new buildings, and purchase of offsets). To achieve these results, BU would need to invest between $88 and $170 million, with maximum annual expenditures to between $4 and $8 million per year, and an additional 4 to 9 facilities staff to develop, manage, and monitor the performance of these projects. As anticipated, BU Bold would require the most significant upfront investment and expansion of facilities staff, but would yield the greatest net savings.

GHG Scenarios (Year reduction)	EE $ savings	EE GHG Savings	EE period (yr) of time	Total Invest[1] / Invest/yr[2] (millions)	Add. Staff	Total Net Savings[1] / Savings/yr[3] (millions)	30 yr IRR %[1]
Good (2050 80%)	20%	17%	30	$88 / $2.0	4	$32.5 / $8.0	9.1%
- Lighting & Controls (79 bldgs)							
- Existing BAS optimization (19 bldgs)							
- BUMC Labs: (6 bldgs)							
Better (2050 100%) All Good Projects, plus:	33%	31%	24	$149 / $4.1	7	$88 / $13.5	10.1%
- Conversion to Digital Control							
- RTU & Dorm HVAC Control (59-79 bldgs)							
BU Bold (2040 100%) All projects of Better, but accelerated (59-79 bldgs)	33%	31%	14	$170 / $7.5	9	$135 / $13.5	9.9%

1) Incl. staff and maintenance 2) Avg over EE period, incl staff 3) Avg after EE period

Figure 8. Overview of BU Energy Efficiency Strategies: impact and implementation costs

Financial considerations and project details for Energy Efficiency

The annual and cumulative financials (cash flow) for the Bold strategy are illustrated in Figures 9 and 10. Project cost expenditures are $7.5 million per year over the 14 year period (including staffing, interest, and direct project costs), and will generate net annual savings of nearly $13.5 million per year after the 14 year period. Cumulative net savings achieves a breakeven in year 16, and at the end of 30 years, results in $135 million net savings which provide funds for the other aspects of the Climate Action Plan (purchase of sustainable electricity, capital cost to electrify the campus, and purchase of offsets).

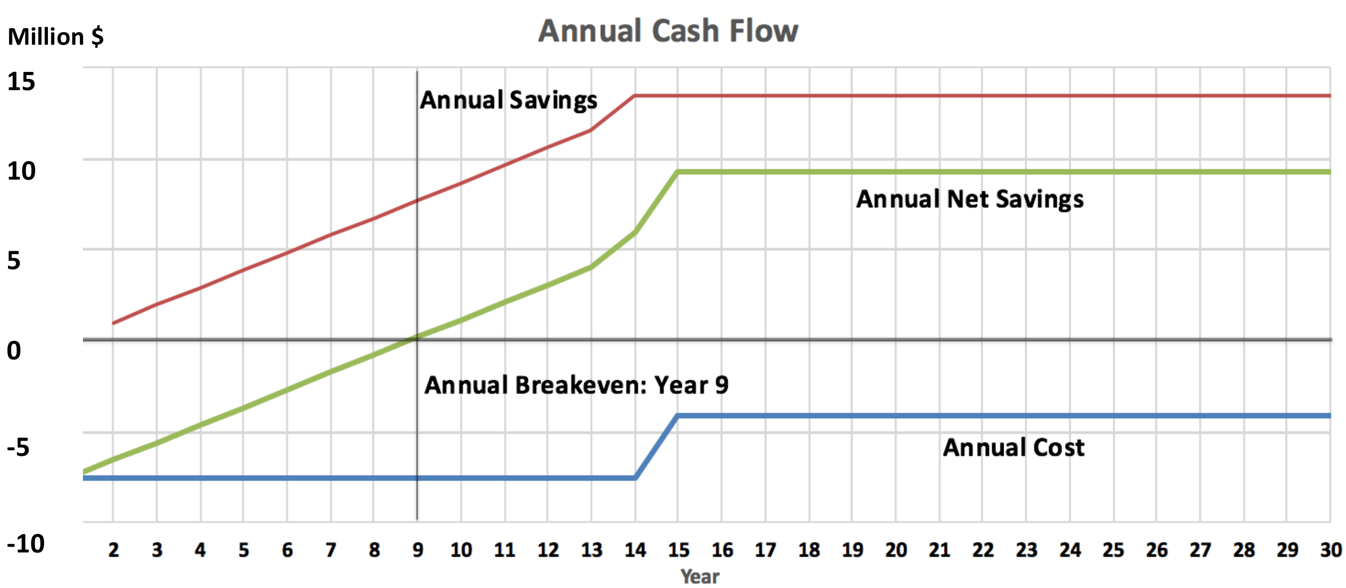

Figure 9. Annual financial analysis of Bold strategy

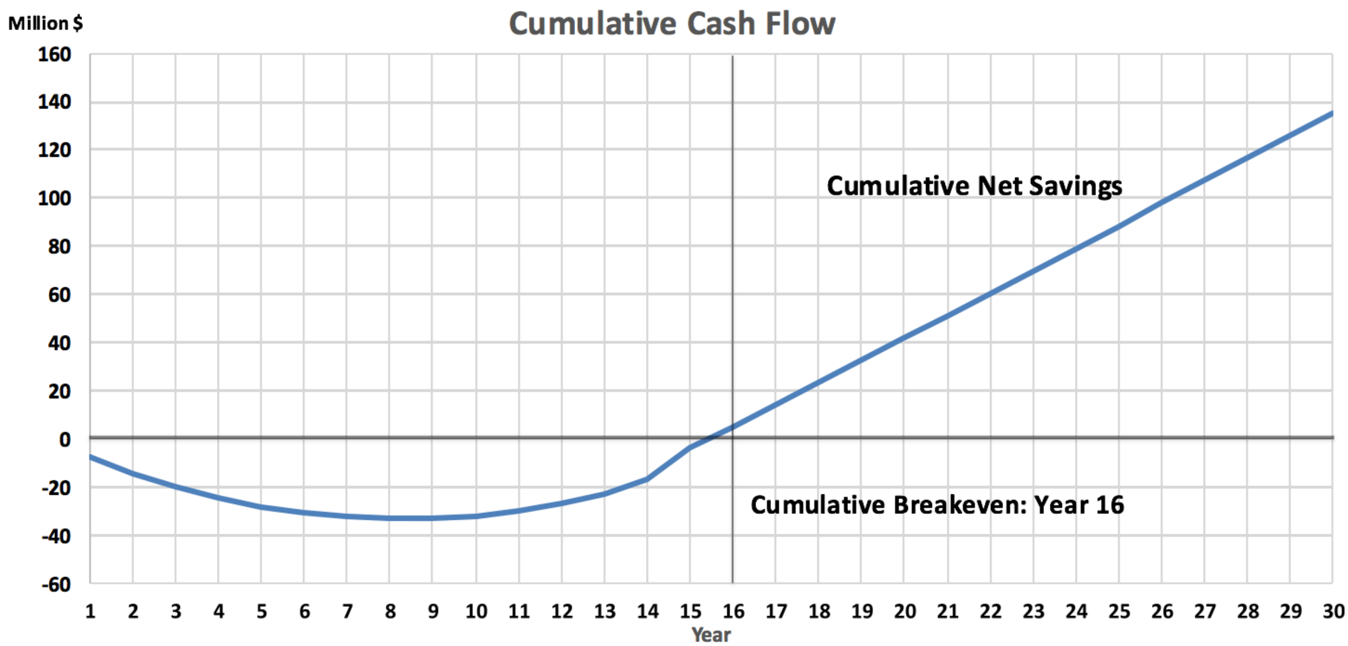

Figure 10. Cumulative Financial Analysis of Bold Strategy

A comparison of the annual and cumulative savings of the 3 scenarios are shown in Figures 11 and 12. The aggressive implementation rate of the Bold strategy results in significant savings well before 2050 compared to the other two strategies, and nearly double the cumulative savings in comparison to the Better strategy. The decline in annual net savings for the Better and Good strategies occurs due to inclusion of maintenance costs for the equipment installed. While the Bold strategy is completed in year 15, the added staff would be available to implement the electrification strategy.

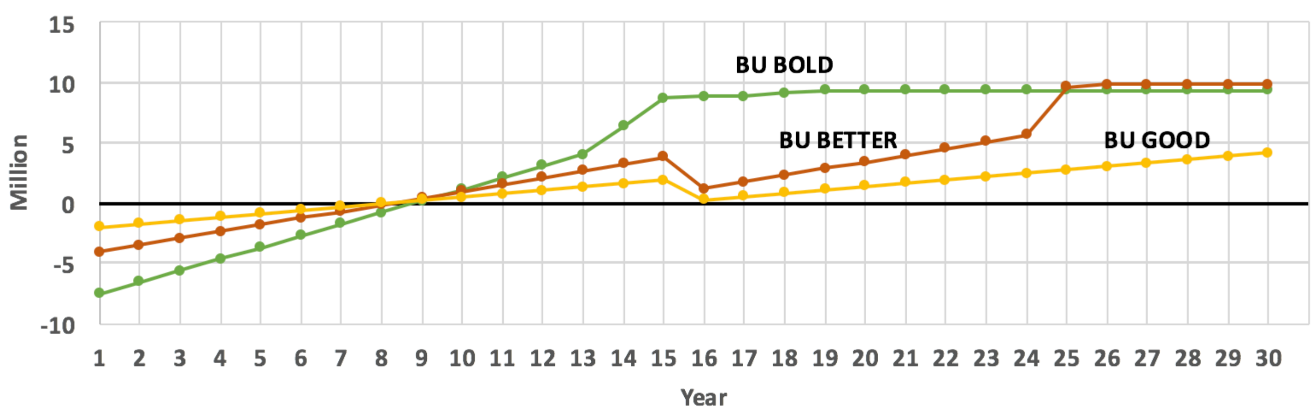

Figure 11. Comparison of Net Annual Savings for the Good, Better, Bold Strategies

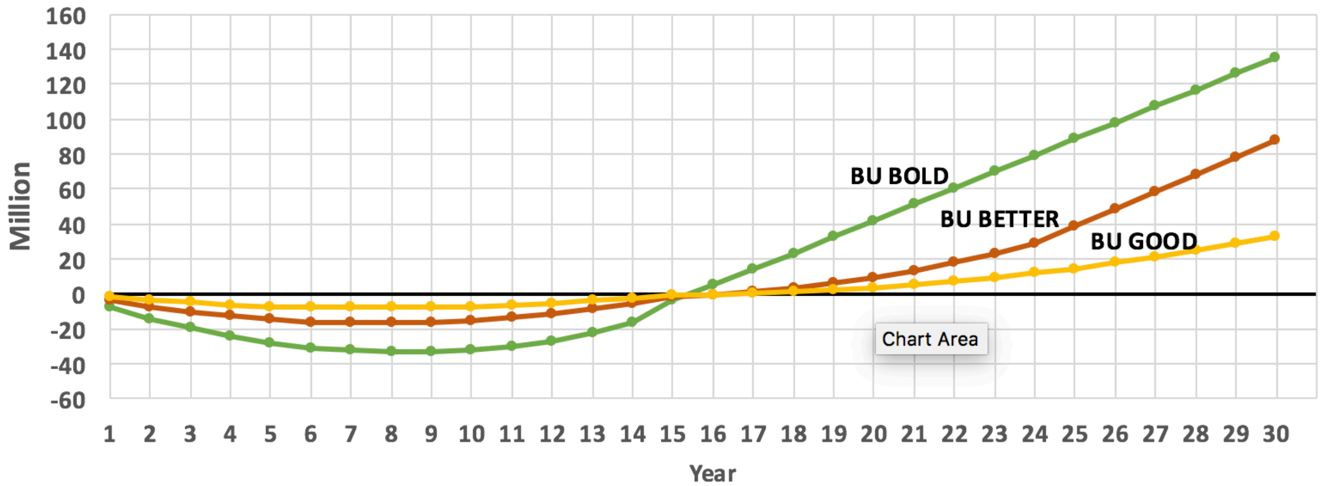

Figure 12. Comparison of the Net Cumulative Savings for the Good, Better, Bold Strategies

How & Why the BU CAP Chooses Renewable Projects

Projected Emissions Reductions

We are seeking a project that will have the greatest impact on emissions reductions. GHG emissions reductions will be greater in markets where more fossil fuels are used to generate electricity. Scientifically, it doesn't matter where reductions come from. Carbon dioxide is well-mixed globally, so reductions from any one place are equivalent to reductions from any other place. Through the efforts of the Regional Greenhouse Gas Initiative, ISO New England has already become one of the greenest power grids in the country. It is dominated by natural gas and nuclear power, with hydro, wind, coal, and "other" making up the rest. There may be other criteria that favor one location over another such as jobs and air quality. Considering these facts caused us to look for power grids with greater fossil fuel emissions, grids dominated by coal for current and projected generation.

At any one time, the actual mix of energy sources are a function of the demand, which is often a function of local environmental and economic conditions. Demand varies during the day, seasonally, and over longer periods of time as a function of how many people are in a region, what kinds of businesses operate there, and technological and policy changes that improve end use efficiency. Some power plants provide the base load for a region, others come on line when demand increases and peaks. It is important for the University to choose a project not by the average annual emissions on a particular grid, but by the actual marginal emissions generated on the grid at the times when renewable sources are most likely to be producing. We are therefore, seeking projects where the anticipated emissions from fossil fuels will be greatest on that grid – at the time the renewable energy is being produced, and thus the highest differential of marginal emissions.

Because we are not generating our own electricity, we must find sources of renewable energy, purchase it, and account for the difference between emissions from renewables and those that are emitted on the grid at the time the renewable power is being generated. This is necessary because transmission limitations on the grid do not allow us to receive "green electrons" directly from other parts of the national grid. Our demand will be satisfied by renewable energy produced elsewhere in the country.

Renewable Energy Certificates

We use an accounting device known as a renewable energy certificate (REC) to keep track of renewable energy transactions, and the RECs are then retired. One REC is generated for every megawatt hour of electricity and are considered a verification that we have purchased a certain amount of renewable energy. By retiring the credit, no one else can also claim credit for the same renewable energy, thus avoiding double-counting. For the University to have confidence that double-counting is avoided the RECs will be Green-e Certified. This third-party certification will be provided through Green‑e Energy, an independent certification and verification program for renewable energy. It is a voluntary consumer-protection program that certifies renewable energy options offered by utilities and marketers in the voluntary renewable energy market.

Additionality
This means the project will generate new renewable energy that would not otherwise have been generated. The concept of additionality can be complex. We have focused on the simplest and clearest definition – the University's contractual commitment and strong credit rating enable the project developer to obtain the financing necessary to build the project. Without the University's commitment, the project would not move forward. Additionality is an absolute requirement for any project in which we participate, because it is the only way that the University can know that its net demand for electricity is generating fewer GHG emissions than would otherwise occur. Additionality can be determined with sufficient due diligence during the project selection process.

Projected Environmental and Health Co-Benefits
All large-scale energy engineering projects have environmental impacts from the construction process and through operations. During the due diligence process for project selection, we will seek projects that minimize their construction and operational impacts and maximize any potential health benefits.

Education & Research Opportunities
Access to both real-time data and the physical project sites for research and educational purposes are a requirement for project selection. Since the renewable energy project will likely be a considerable distance from campus, web-cams will also be required during construction and ongoing operations of the project. We want the Climate Action Plan to be transparent, and we also want the actions undertaken as part of it to provide both educational benefits and opportunities for faculty and student research.

Project Economics
Project economics will be evaluated based on the Net Present Value per megawatt-hour. The PPA will be implemented through a Contract for Differences where the University will be obligated to purchase the electricity at a fixed rate per megawatt-hour over a specified period. Since the electricity in the grid cannot be delivered directly to the University, the electricity will be sold at the hub where the renewable energy is being generated at the wholesale market price at the time of generation. The difference between the purchase and sale prices will generate a monthly bill or a check for the University.

The price of renewable energy projects in any part of the US grid varies widely due to many factors. Whether new transmission capacity needs to be added, the demand for new renewable energy, the availability of technology, the credit-worthiness of the developer, the availability of capital for projects, and the assessment of how the energy market is likely to evolve all influence the prices that can be negotiated for renewable power. Prices vary geographically in different parts of the grid fairly substantially, with the New England region having high prices compared to other parts of the grid.

On Campus Renewables

In 2015 a helioscopic assessment was conducted by Zapotec Energy to determine the feasibility for solar photovoltaic (PV) installation on the Charles River and Medical Campuses. Carried out on a total of 80 buildings, the analysis identified 16 locations that matched the following criteria: system economics, site & environmental issues, electrical feasibility, structural feasibility, visibility, and research and educational benefits. Solar energy produced by PV systems from the top 16 buildings of the list represent about 1% of BU's total of today's electricity needs.

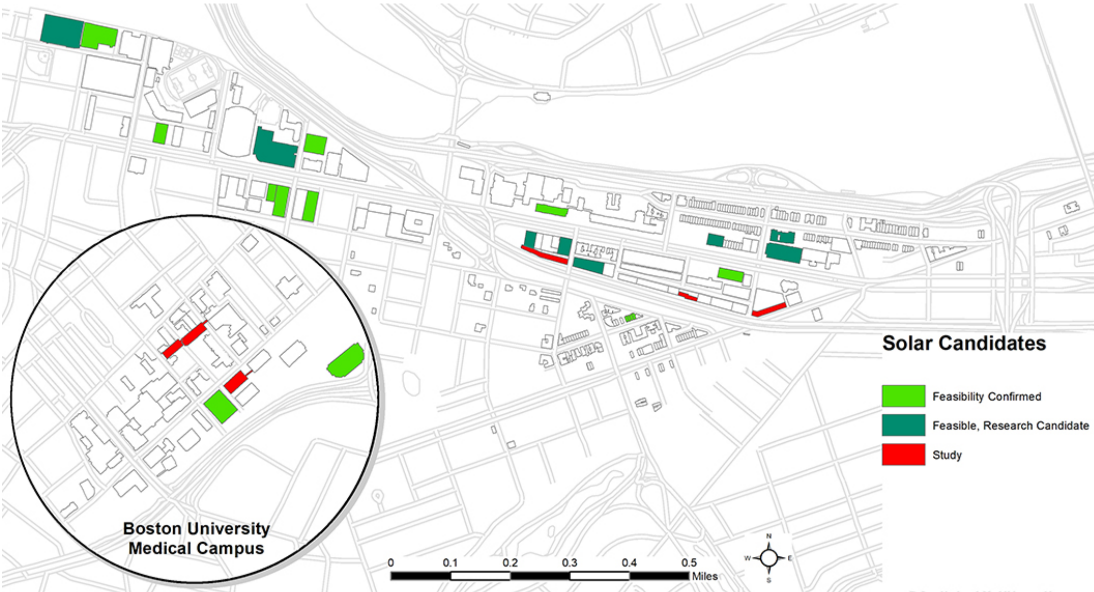

Figure 13. Candidates for solar photovoltaic installation.

Name / Description	Street Address	System Size	Generation	
Charles River Campus		[kW]	[kWh/yr]	
Track & Tennis Center-South	100 Ashford St	297	378,900	
FM&P (NE and NW Roofs)	120 Ashford St	298	372,000	
FM&P (South Façade)	120 Ashford St	3	2,800	
FitRec	915 Commonwealth Ave	175	221,900	
Administrative Offices	25 Buick St	171	207,000	
Global Programs	888 Commonwealth Ave	129	157,000	
Marketing & Communications	985 Commonwealth Ave	89	110,000	
Offices	910 Commonwealth Ave	64	85,000	
CILSE	610 Commonwealth Ave	69	83,214	
Offices	900 Commonwealth Ave	146	194,000	
Hariri Building	1 Silber Way	48	59,000	
School of Theology	745 - 755 Commonwealth Ave	35	43,400	
EPIC	750 Commonwealth Ave	32	40,100	
Earth House +	1A, 3, 5, & 7 Buswell St	33	42,320	
EPIC South Façade	750 Commonwealth Ave	Study		
Engineering Building South Façade	15 St. Mary's Street	Study		
Engineering Research Building Façade	44 Cummington Mall	Study		
Metcalf Science Center South Facades	590 Commonwealth Ave	Study		
Medical Campus				
Parking Garage	610 Albany Street	530	305,600	*
Parking Garage	710 Albany Street	450	259,400	*
CABR	700 Albany Street	Study		
School of Medicine	72 E. Concord	Study		
Evans Building	85 E. Concord	Study		
Total		1,590	1,996,634	

Figure 14. Candidates for solar photovoltaic installation by kWh per year.
* BU's share of 50/50 split with BMC

Two different strategies are outlined here for considering renewable energy generation on campus:

1) A traditional Power Purchase Agreement (PPA) where the University does not own the renewable energy assets, just agrees to purchase the power generated for a fixed rate over a fixed period of time, or
2) The University builds, owns, and maintains the renewable energy asset. If the University were to build, its own systems, the economics of the project would rely more heavily on the ability for the project to reduce the building's energy and demand charges which are outlined in the box below.

Demand Charge Reductions

Local generation of electricity from solar cells or wind turbines can reduce carbon emissions and electricity bills. Both reductions go beyond the quantity of electricity generated. Carbon emissions are reduced by reducing the need to turn on the most expensive generating plants, which often have the highest emission rates. In Massachusetts, PV reduced carbon emissions by about 1 percent below the average amount of carbon emitted per kilowatt-hour (kWh) produced.

With regard to dollar savings, the cost per kWh is only one component of the monthly electricity bill. The monthly bill also includes charges for transmission, distribution and demand; these charges can be reduced significantly if consumption is offset by generation at critical points in time. If electricity generated by PV can reduce net consumption during periods of peak demand, peak demand charges will be reduced. Peak demand charges often can account for 25-50 percent of the monthly bill. And there is strong reason to believe that PV can reduce peak consumption. In Massachusetts, capacity utilization rates for rooftop PV are correlated with warm sunny days, which are correlated with high levels of demand.

To calculate the savings associated with installing PV and evaluate the economic attractiveness of installing PV, we calculate the return on investment for installing PV on the roofs for ten buildings on the BU Charles River Campus. These buildings are chosen based on the availability of data. Specifically, for these buildings we have information on the design and cost of installing photovoltaics on the building and the quantity of electricity consumed at fifteen-minute intervals since 2010.

For each building, we compile fifteen-minute information on the quantity of electricity consumed and use this information to reproduce the monthly electricity bill, which includes charges for the electricity consumed and it transmission and distribution. This result is used as the baseline level of consumption and cost that is used to evaluate potential savings that are generated by installing photovoltaic systems

Calculating the amount of energy and money saved proceeds in three steps. In the first step, we calculate the potential reduction in electricity consumption that would be generated by installing PV. To do so, we calculate fifteen-minute information on the quantity of electricity that would have been generated had PV been installed on the roof as described by Zapotec Energy, Inc. This firm produced building specific information on the type and capacity of photovoltaic systems that could be installed on each of the sixteen buildings. These technical specifications are combined with hourly observations for solar insolation and weather to drive the PV module of the System Advisor Model that is compiled by the National Renewable Energy Laboratory. This module calculates the quantity of electricity that would have been generated given the observed conditions. Summing this generation produces the monthly and annual reductions in electricity that these building would have to purchase from the grid.

In the next step, we translate the reduction in purchases to reductions on monthly electricity bills. To do so, the simulated values for the hourly generation of electricity generated by PV are subtracted from the observed rates of electricity consumption, and these lower rates of consumption are used to recalculate the monthly bill for electricity. The difference between the observed bill and the bill based on lower level of consumption represent the savings generated by PV.

In the third step, we calculate the return on investment for PV by comparing monthly savings generated by PV to the up-front cost of the PV system, which are obtained from the analysis performed by Zapotec Energy. For each building, we have about seven years of simulated savings generated by PV. These monthly savings vary based on rates of sunshine, rates at which buildings consume energy, and changes in electricity rates. For each, we will quantify the variation and use this information to forecast future rates of savings. Savings will be converted to current dollars and compared to the cost of installing PV. This comparison will be used to compute various financial measures (e.g., NPV, IRR, payback, and profitability index) that are typically used in investment decision making. We expect that these will vary by building because buildings differ in the timing and rate of consumption and generation and these differences will affect transmission and distribution charges, which constitute a large part of the monthly bill. Furthermore, these building specific return measures explicitly account for uncertainty because savings (due to the reduction in net consumption) vary over time.

	Monthly Savings				**Investment requirement**	**NPV**	**IRR**	**Payback period**	**Profitability Index**
Building	kWh	(%)	($)	(%)	(2016 $)	(2016 $)			(NPV/$ invested)
595 Commonwealth Ave									
610 Commonwealth Ave									
750 Commonwealth Ave									
100 Ashford St									

Figure 15. Economic analysis model for peak load shaving.

Recommendations

For the 24 buildings identified, and for new construction and renovations, the Task Force recommends the University pursue the development of on-site renewable energy resources in the near term for the following reasons: visibility, education, research, and to reduce demand for power provided by the grid when the end of the first large scale PPA contract expires. At present, only four of these buildings have the type of meters necessary to provide the pulse data to calculate the demand charges and are tabulated in Figure 15. To understand the economics and inform decisions about the most cost-effective strategies for renewable energy on these buildings, the Task Force recommends building level meters with pulse outputs be installed by 2020. The complexity of utility rate structures and how they are assigned to building meters contributes to the economics of renewable energy and varies by building meter rate tariff, so the economics of these projects needs to be evaluated on a case by case basis to determine whether it is most cost effective to install the solar project through a PPA contract connecting to the grid "in front of the meter", supply the building directly through a PPA "behind the meter," or own the renewable energy asset directly. In any case, the RECs need not be retained in the short term, as the University's greenhouse gas reductions are accounted for in the large scale PPA. The option to buy out any on campus renewable energy projects should be provided for in PPA contracts to give the University the flexibility to connect the renewable energy resources to the building's electrical system to reduce demand for grid power when the large scale PPA contract comes to a close.

Subsequent to the initial recommendations in September, the Energy Working Group met on November 20th to finalize the recommendations. Figures 13 and 14 have been revisited to reflect the consensus. These recommendations now include two more buildings on the Medical Campus and 6 more on the Charles River Campus to be included for additional study. The Energy Working Group emphasized the importance of including projects with improved public visibility so the following facades were added to the list for further study: 590 and 750 Commonwealth Ave, 15 St. Mary's Street, and 44 Cummington Mall.

Carbon Offsets

The Climate Action Plan foresees the need to purchase carbon offsets to close the gap between actual and net zero emissions. Under the BU Better scenario the purchase of offsets would begin around 2050 whereas it would begin in 2040 under the BU Bold scenario.

A greenhouse gas (GHG) or "carbon" offset is a unit of carbon dioxide-equivalent (CO_2e) that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere. These offset credits, measured in metric tons, are an alternative to direct reductions for meeting GHG targets in a cap-and-trade system. Purchasing certified carbon offsets and retiring them enable organizations to reduce their GHG emissions indirectly. For Boston University, this will be necessary when other means of reductions have been exhausted.

Current Landscape for Offsets

Many businesses and organizations currently buy GHG offsets to help meet voluntary commitments to reduce their GHG emissions.

Several credible organizations currently verify, validate, and certify offsets. These include the Verified Carbon Standard (VCS), The Gold Standard, Climate Action Reserve, and American Carbon Registry. VCS manages the carbon benefits as well as the non-carbon benefits, the latter through the Climate Community and Biodiversity Alliance, which insures offset project minimize negative local environmental and social impacts. Overall, the best guidance for evaluating offset programs was developed by the World Resources Institute, where key criteria include:

1. Real: GHG emission reductions come from specific and identifiable actions involving specific carbon projects.
2. Additional: Benefits must be above and beyond "business as usual." Additionality is ultimately a subjective judgment. Approaches attempt to ensure that additional projects are able to get credits while weeding out those that would occur in the absence of the incentive provided by the carbon market.
3. Permanent: Emission reductions are long-lasting and irreversible.
4. Enforceable: Credits should be backed by standards and tracking systems that define their creation and ownership in a transparent manner.
5. Quantifiable: Emission reductions can be accurately and conservatively measured.
6. Verifiable: Proof that emissions have actually occurred and been accurately measured.

The University has not purchased carbon offsets to date. However, in 2014 BU sold carbon credits that were generated from reductions in campus energy consumption achieved in 2012. These credits were sold to General Motors through the Chevrolet Campus Clean Energy Campaign to retire carbon reductions across America for the benefit of the climate. After meeting an additionality test, the process required *sustainability*@BU to have these reductions validated and verified by DNV-GL and the Verified Carbon Standard (VCS). The funds received were invested in BU's Sustainability Revolving Loan Fund.

In the fall of 2017, Boston University expects to announce an agreement with Soli Points to provide a carbon credit program through 23 retail dining and convenience store locations. It targets BU students, faculty, and staff who can access the program for free.

Soli acquires validated and numerically quantified tons of carbon offsets and credits as sold in regulated markets to create Points under its patent (US 8,527,335). Soli makes carbon purchases directly from Cap & Trade auctions such as are conducted by the Regional Greenhouse Gas Initiative (RGGI) and the Western

Climate Initiative, as well as jointly with The Adirondack Council. Acquired carbon tons are retired from use as allowances for utilities to generate emissions above desired thresholds, and, in the process, fractionalized into redeemable coupon points in 2-pound denominations.

As the Soli Points scheme is established, the Task Force recommends an evaluation of the program to quantify its impact on carbon emissions.

Recommendations

The Task Force recognizes that the landscape for offsets in 2040 will be dramatically different than the current one. Today, the cost of carbon offsets at auctions has varied widely in the regulated cap and trade markets: based on recent California and RGGI markets, credible, compliance-grade certified offsets in the can range from \$3 to \$10 per MTCO2e.

By 2040, there may well be regulations, a carbon charge or tax, or other policies requiring organizations to reduce emissions. There may also be new mechanisms for the University to credibly achieve carbon neutrality in addition to those noted above. As the Climate Action Plan evolves over time, credible alternatives should be considered as options.

Appendix

Energy Efficiency Project Description

The cost and savings estimates for the 6 primary energy efficiency project areas used to develop the Good, Better and Bold strategies are listed in Table 3. These projects focus on LED lighting and appropriate controls, as well as HVAC optimization of airflow and implementation of controls. Funds are also included for Measurement and Verification (M&V) to implement widespread real-time metering of individual major buildings (62 across both CRC and BUMC), and implement a software system to monitor and identify trends that reveal operating problems. Additional measurement of individual building energy use is critical to being able to identify energy efficiency opportunities as well as monitor performance. Table 3 also indicates the number of buildings that each area is implemented in, which relates to the staffing level that would be required to implement these projects. From past projects, major HVAC related controls projects require on the order of 2 years to develop, execute, and verify for each building, while lighting projects can be implemented on a quicker tempo.

Cost and savings estimates in this table were developed by the engineering project team [1], and then the cost increased to ensure a conservative estimate to account for project complexity. Cost estimates do not include possible utility rebates since they change over time and are not known until a detailed project estimate is developed by approved contractors. However, based on recent past projects, the cost is likely to be reduced by 0.5 to 1.5 year payback level, although it is expected that lighting project rebates will be phased out over the next 2 years.

Many of these project areas focus on implementing better HVAC controls and re-optimizing airflow setting for the HVAC systems used in buildings. These opportunities were identified by computing the high cost of supplying air in both buildings that use return air, called economizer systems, typically used in office buildings, and 100% outside air systems, typically used in laboratory buildings. Even with the reduction in natural gas prices and the significant switch from oil to natural gas throughout BU, the price of air supply is high since it includes the cost to heat, cool, and transport air throughout buildings. Our calculations [2] show that economizer systems provide air at \$3.29 per cubic foot per minute, lab air costs \$4.44/cfm, and lab air on the

BUMC costs $7.82/cfm due to the high cost of district steam [1]. These high airflow costs provide the rationale for focusing on whole building optimization projects, as well as the fact that HVAC systems account for 40-60% of building energy use and GHG emissions. Well-designed HVAC control systems can also increase thermal comfort in buildings and enhance productivity of faculty, staff, and students, an important ancillary benefit of these measures.

Project	Direct Project Cost*	Annual Savings	Payback	No. of Buildings
Good				
Metering, M & V, Monitoring	$2,500,000			62
LED Lighting & Controls	$16,500,000	$3,300,000	5.0	79
Existing BAS Optimization	$10,120,000	$2,024,000	5.0	19
BUMC Lab HVAC Opt.	$17,940,000	$2,990,000	6.0	6
Better & Bold				
Conversion to Digital Controls	$19,482,000	$3,044,000	6.4	34
RTU's (Rooftop Unit) Controls	$13,000,000	$2,000,000	6.5	33
Dorms (HVAC Controls)	$1,275,000	$213,000	6.0	20
Totals	$80,840,000	$13,500,000	6.0	

*Not including maintenance costs, staff, expedited costs for accelerated schedule, or utility incentives

Table 3. Energy Efficiency Project Details

Over the past 5 years, there have been a number of lighting and DDC HVAC optimization projects in both office/classroom and lab buildings, which confirms both the expected savings and costs for these proposed projects [3]. Estimates for the BUMC HVAC project for 6 lab buildings is based on a detailed study of the current control system and current airflow schedule, in consultation both with BUMC facilities and BU EH&S staff, and considering the substantial savings that have been achieved to date (such as in building X). One significant driver of cost savings for the BUMC projects is the very high cost of district steam purchased from Veolia, which costs $3 per therm of heat, which is nearly 3 times the fuel cost that would be needed for on-site boilers. However, BUMC EE projects remain financially attractive even if local steam boilers were installed. (Note, the BUMC analysis does not include an analysis of energy efficiency opportunities for the NEIDL due to time limitations.)

Another major energy efficiency area is to convert the pneumatic control systems employed in many of the original CRC buildings (including Mugar Library, the GSU, and CAS buildings) to modern computer based control. Implementing a modern computer based building automation system enables greater ability to customize control sequences and airflow to how the building is actually used. These retrofit projects are complex, but can be implemented fairly quickly by using wireless control technology that has been developed. Estimates for this project area were based on information obtained from a major building automation vendor, and consideration of the schedules and airflows currently being used in a number of these buildings. For example, in Mugar Library, optimizing HVAC airflow and adding DDC controls is estimated to reduce HVAC energy costs by 57% of the $400,000 dollars spent per year. A list of buildings that still incorporate pneumatic controls was developed by BU FM&P staff, and corresponds to roughly 2 million square feet of building area.

Estimates for savings from roof-top-units (typically used on smaller buildings that do not employ central air handlers and building controls) were develop without a comprehensive engineering based estimate nor a detailed list of units deployed. Savings estimates were based on observed typical building airflow levels and cost of economizer air supplied since its similar to the cost of running RTUs. Similarly, the estimate for dorm boiler control was only based on observations in brownstones, and student reports of over-heating in a number of the larger older dorms. Improvements of the estimates in these two areas can be obtained through staff and contractor work.

A more detailed breakout of the costs and savings potential for the 3 scenarios is presented in table 3. This table indicates the additional operational and project staff estimated to be required to implement each of these strategies over the indicated time period. On the right side of the table, the cost for these additional staff is listed, as well as the annual maintenance cost that should be accrued for these energy efficiency systems. Typically, control technology is expected to have a 20 year life, so an appropriate level of funding is estimated to ensure these systems can be maintained (4% of installed cost per year). The last column of the table gives the average number of building projects that must be completed per year, and relates to how the staffing level was estimated. Note, some of the required additional staff is general operating staff (such as for M&V, building automation, HVAC engineering staff), while other required staff would be needed to run projects. Staffing levels are based on the need to deal with the particularly complex level of details that are involved in HVAC projects, which many times include review by EH&S staff for lab buildings, coordinating schedules, ensuring design standards are implemented, etc.

Scenarios GHG (year reduction)	EE $ savings	EE GHG Savings	EE time (yr)	No. staff		Total Invest (million)	Invest/yr[2] (million)	30 yr IRR & Net sav	No. bldgs/yr
Good (2050 80%)	20%	17%	30	4	project[1]	$47	$1.6	9.1%	1-2
- Lighting (LED/controls)					staff [1]	$12	$0.4		
(79 buildings)					maint[2]	$29	$1.9		
- Existing BAS Optimization					total[3]	$88		$32.5	
(19 buildings)									
- BUMC Labs									
(6 buildings)									
Better (2050 100%)	33%	31%	24	7	project[1]	$81	$3.4	10.1%	3 to 4
All projects of Good, and:					staff [1]	$20	$0.7		
- Conversion to Digital Controls					maint[2]	$48	$3.2		
- RTU & Dorm HVAC Controls					total[3]	$149		$88	
(79 buildings total)									
BU Bold (2040 100%)	33%	31%	14	9	project[1]	$93	$6.6	10%	4 to 6
- All projects of Better, but accelerated					staff [1]	$21	$0.9		
(79 buildings total)					maint[2]	$56	$3.7		
					total[3]	$170		$135	

1) Over EE period 2) Maint. @ 4% of investment 3) Over 30 years

Table 4. Financial and Operational Details of BU Energy Efficiency Strategies

To get a sense of the financials for these different strategies, the internal rate of return was calculated for each strategy, total investment required (including direct project cost, staffing, and maintenance), as well as the cumulative net savings for a 30 year period (see table 4). While the Better and Bold strategy require greater investment levels, they also result in a high a high return rate (~9%) since these projects are accelerated and generate savings over a longer period of time. These two strategies also generate a much greater total net savings levels ($80 and $129 million at the end of 30 years).