Duke University Carbon Policy on the Road to 2024:

Policy Proposals

Report Completed by a Duke University Bass Connections in Energy Team
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Table of Contents

Executive Summary

The goal of our Bass Connections in Energy Team (henceforth "the Team") was to research ways to measure and influence both individual and institutional change to reduce Duke University's carbon footprint in pursuit of the university's 2024 climate neutrality commitment. Throughout the 2016-2017 academic year, the Team developed energy reports for departments and researched potential carbon pricing programs. After studying existing examples and models, and by interviewing different stakeholders, the Team shifted its focus to broad carbon policies. The Team, therefore, recommends a range of different strategies to reduce overall carbon footprint at Duke.

Rationale for Project

Duke University has pledged to be carbon neutral by 2024. The recommendations in this report aim to reduce the University's reliance on offsets come 2024 while also allowing Duke to serve as a sustainability leader. The recommendations fall into four distinct, but related, categories. They furnish a set of tools that Duke University can use to reduce its carbon footprint and establish itself as a climate leader among peer institutions.

1. Campus-Wide Education

The rationale for Campus-Wide Education schemes is to get broad support for sustainable policy from all levels of the Duke community. This will involve students, as well as faculty and staff.

Student Engagement I – Build a "Energy at Duke" webpage on Sustainable Duke's website

The Team recommends building a page on Sustainable Duke's website that outlines Duke University's energy systems and other energy efficiency initiatives. This will help increase transparency, and can serve as a resource for other institutions interested in reducing their carbon footprint. Increasing transparency can also help establish Duke as a sustainability leader, as a lack of transparency has been a criticism of the University during the last year.

Student Engagement II – Educate Duke Students on Sustainability and Allow Feedback

Duke should hold open forums on energy and sustainability policy, as well as create publicly-visible energy dashboards. This will help educate students and improve transparency between the university and an increasingly-engaged student body.

Staff Engagement – Expand Leading for Environmental Sustainability Staff Training Workshops

Sustainable Duke should expand educational programming to include content on both carbon reduction at the departmental level and Duke's current energy efficiency projects. This will help keep staff engaged in emissions reductions, and may be a useful preliminary step to increase engagement before more administratively intensive policies.

2. Targeted Education

The goal for targeted education is to give decision-makers on campus relevant energy information to position them to influence energy consumption.

Targeted Education I –Create and Distribute Departmental Energy Reports

Sustainable Duke should generate departmental energy reports which will include information such as energy usage by energy source (chilled water, electricity, and steam), and the department's energy usage as compared to other departments. This information will be used to inform future decision-making processes about energy-related retrofits and investments. It will also increase consideration for energy consumption and its associated emissions within each department.

Targeted Education II – Post Building and Departmental Energy Consumption Leaderboards on the Sustainable Duke Website

Sustainable Duke should publish leaderboards of energy consumption per square foot at the building and departmental level. Through these reports, departments and building occupants will be able to see where they stand among their peers, and spur friendly competition. This will also foster interdepartmental collaboration.

Targeted Education III –Create an Energy Efficiency Retrofit Guidebook

Sustainable Duke and Facilities should collaborate to create an energy efficiency retrofit guidebook for departments, to be housed on the Sustainable Duke website. This guidebook should provide information about energy efficiency retrofits and how they can benefit a building. It should also detail the process for investigating the potential of and funding options for a retrofit.

3. Pricing Carbon

Through pricing programs, Duke University can send a price signal to departments and schools to help reduce carbon emissions on the margin. This is especially relevant for decision-makers who have pecuniary responsibilities.

Pricing I – Shadow Pricing

Duke should incorporate a shadow price in financial forecasting, especially in the planning and design of new or improved infrastructure. A shadow price is not a fee, but an added accounting cost of offsets in the forecasting process that helps reorient financial incentives towards options that have a smaller carbon footprint. Offsets will invariably be purchased in 2024, so shadow price will save the University and individual departments money in the long term.

Pricing II – Charge for Emissions

Eventually, Duke should consider charging schools or departments based on their carbon footprint. There are many variations on a carbon charge, and peer institutions like Yale (as well as corporations like Microsoft) have implemented a carbon charge policy with some success. The price of carbon should be set to the average cost of offsets, to send a price signal and fund offsets. The policy can be implemented in different ways, including revenue-collecting and revenue-neutral models.

4. Building Improvement

These recommendations target new construction and investments in existing infrastructure and helps Duke take action to reduce future anticipated emissions, thereby lowering the number of carbon offsets needed. It promotes methods to replenish the energy fund

Construction I – Increase Funding Allocated to Energy Efficiency Projects

Duke should increase the amount of funding allocated to on-campus energy efficiency projects to ensure buildings are maximizing energy efficiency and minimizing energy consumption. By increasing the allocation from the Provost and establishing a revolving fund, Duke will benefit in a number of ways.

Construction II – Provide Support to Enable Full Compliance with Sustainable Building Guidelines

The Sustainable Building Policy adopted by the Board of Trustees in 2015 requires new construction and major renovation projects to achieve at least 30% energy performance improvement over baseline design. Thes guideline has not once been met. Support, revision, and enforcement of the guideline would ensure carbon efficient construction and renovation projects.

Conclusion and Next Steps

By implementing the tools outlined in this report through campus-wide education, targeted education, pricing carbon, and building improvement, Duke can further drive a wedge in on-campus emissions, reducing the number of offsets that will need to be purchased while also collecting revenue to put towards offsets. Many of the recommendations outlined in this report require high-level political support and institutional change at Duke University. Therefore, the Campus Sustainability Committee should take up this issue and task a subcommittee with further developing and implementing the recommendations outlined beginning in the 2017-2018 academic year.

Introduction

Prior to the start of the 2016-2017 school year, a Bass Connections in Energy team (henceforth known as “the Team”) was assembled and tasked with creating departmental energy reports and designing a carbon pricing program for Duke’s campus. The Team has spent the past year formulating recommendations and procedures for how to reduce energy consumption on campus through education and carbon pricing. Over the course of the year, the Team has extensively examined Duke’s energy-related infrastructure, policies, and procedures. A deeper level of understanding about these issues was obtained through interviews with Duke University personnel who are responsible for the development and execution of energy-related procedures at various levels such as new construction, facilities maintenance, and finance. In addition to learning about on-campus systems, the Team’s recommendations are also a result of examining initiatives at external organizations aimed at reducing energy-related emissions. The most in-depth look at an external organization came in the form of a multi-day trip to Yale University to examine its carbon charge program and interview associated stakeholders.

Building on all of the lessons learned during the past year, the Team has assembled a set of recommendations that Duke University can feasibly implement to reduce on-campus energy consumption and associated emissions. After detailing the background and overview for targeting emissions reductions at Duke, this report will consider the specifics of each recommendation, the rationale behind them, how they could be implemented, and what the expected outcomes are. These recommendations are divided into four main sections: campus-wide education to better inform the Duke community about energy and carbon issues, targeted education focusing on delivering more reliable energy information to influential decision-makers on campus, pricing carbon, and building improvement.

Background

Carbon Policy

As the world continues to feel the effects of climate change and scientists warn of the dangers of the planet warming 2° Celsius above pre-industrial levels, carbon pricing programs have grown in popularity as a means of reducing emissions. The goal of a carbon pricing policy is to decrease emissions by requiring emitting entities to pay for, or internalize, the damage they inflict upon society. These negative externalities are costs borne by the public that result from carbon emissions that include, but are not limited to, adverse effects on agricultural productivity, increased health care costs, and property damage arising from flooding. A policy that prices carbon seeks to transfer these costs away from the public and attribute them instead to the polluters, who have the ability to influence change. Carbon pricing is a free-market environmental approach that provides an economic signal in the form of a price on emissions. Polluters then can choose the best option for themselves, whether that be reducing emissions, cease emitting activities altogether, or simply paying the fee. In addition to reducing emissions, carbon pricing leads to new, lower-emitting sources of economic growth.[1] Importantly, every emitter faces the same price, creating incentives for emission reductions at the lowest cost among all possible options.

Carbon pricing programs typically come in one of two forms: an emission trading system (ETS) or a carbon tax. An ETS, also known as a cap-and-trade system, sets a maximum amount of emissions for a jurisdiction and allows emitting entities to buy and sell emission allowances among themselves. An ETS sets a fixed amount of emissions, and then the price of emissions is determined by the trading market. In contrast, a carbon tax sets the price of emissions in the form of a tax, but the emission reduction is determined by how strongly the tax influences emitting entities. Choosing

[1] The World Bank, "Pricing Carbon," World Bank, 2017, http://www.worldbank.org/en/programs/pricing-carbon#CarbonPricing.

between a cap-and-trade and a tax depends on economic and political factors.[2] The decision will be influenced by the goals of the program and the context in which it is implemented.

Carbon pricing programs have been and continue to be employed by organizations around the world, including entire countries, sub-national cities and states, corporations, and academic institutions. Successful examples among the latter two, sometimes referred to as "internal carbon pricing" because they are internal to a single entity, include Microsoft and British Petroleum (BP). Microsoft imposed carbon fees on its internal departments and uses this money to support efficiency and renewable energy projects.[3] BP implemented an internal carbon trading program in 1999, which aimed to reduce emissions by over 10% by 2010.[4] A success story among sub-national jurisdictions comes from British Columbia, which has seen emissions drop by 5-15% after the implementation of a carbon tax in 2008.[5] These programs show that placing a monetary value on the cost of carbon tangibly reduces carbon impact. A carbon pricing program would have a similar effect at Duke, and this report explores how an effective program can fit within the institutional framework of the University.

Why Duke?

Duke University pledged to be carbon neutral by 2024.[6] This means that by 2024, Duke aims to reduce or offset emissions from energy use and employee commuting and air travel to zero. Since the 2007 implementation of the Climate Action Plan to guide emissions reductions for campus, Duke's

[2] Ibid.
[3] Tamara "TJ" DiCaprio, *Making an Impact with Microsoft's Carbon Fee: Inspiring a virtuous cycle of environmental investment and action*, report,. March 2015, https://www.microsoft.com/about/csr/environment/carbon/.
[4] Mark Akhurst, Jeff Morgheim, and Rachel Lewis, "Greenhouse gas emissions trading in BP," *Energy Policy* 31, no. 7 (2003): 657-63. doi:10.1016/s0301-4215(02)00150-7.
[5] Brian C. Murray and Nicholas Rivers, *British Columbia's Revenue-Neutral Carbon Tax: A Review of the Latest 'Grand Experiment' in Environmental Policy*, NI WP 15-04, Duke University and University of Ottawa, Durham, NC, 2015, https://nicholasinstitute.duke.edu/sites/default/files/publications/ni_wp_15-04_full.pdf.
[6] Sustainable Duke, *Growing Green - Becoming a Carbon Neutral Campus: Duke University Climate Action Plan,* issue brief, October 2009, http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf.

emissions dropped 23% through 2016.[7] Duke will not be able reduce campus emissions to zero by 2024, meaning the University will need to buy carbon offsets to account for remaining emissions by 2024. By implementing a carbon pricing program in addition to the other recommendations outlined in this report, Duke will be able to further reduce on-campus emissions, reducing the number of offsets the University will need to purchase in 2024. Moreover, Duke can ensure that when offsets purchases do occur, the price paid is consistent with the internal cost incurred to reduce emissions. This minimizes the total cost of meeting the pledge. Meanwhile, other educational institutions have shown increasing interest in carbon policies, with Yale, Princeton, and UC Berkeley among those peer universities that have already implemented them or are planning to.[8] This growing support, combined with a desire to reduce on-campus emissions as much as possible to limit the number of offsets purchases necessary to be carbon neutral by 2024, suggests that such policies have potential for success at Duke.

Approach

The recommendations laid out in this report are broken into four different categories: campus-wide education, targeted education, pricing carbon, and infrastructure improvement. The categories are divided this way due to varying target audiences and avenues for change. While delineated, the categories of recommendations should not be looked at independently, but rather are a set of tools that when used together, can effectively reduce on-campus emissions in a variety of different ways. The brief rationale for each categories of recommendations is as follows:

1. Campus-wide Education: The goal of campus-wide education is to provide more opportunities for students and faculty to learn about energy consumption at Duke and allow

[7] Sustainable Duke, "2016 Progress Report," Sustainability Strategic Plan | Sustainable Duke, 2016, https://sustainability.duke.edu/ssp2016/.
[8] Jim Shelton, "As interest grows, Yale Carbon Charge leads the way in studying carbon pricing," Yale News, March 29, 2017, http://news.yale.edu/2017/03/29/interest-grows-yale-carbon-charge-leads-way-studying-carbon-pricing.

opportunities for students to become involved in energy-related projects on campus. By increasing knowledge and participation among the Duke community regarding energy decisions, Duke can expand its campus culture of sustainability and enhance grassroots-level support for higher-level policy change at the University.

2. Targeted Education: Targeted education will consist mostly of energy reporting, which seeks to create easy-to-read, one-page energy reports that will be delivered to influencers within each department, such as building managers or deans. By improving the transparency and readability of energy consumption reporting and delivering them to people that can help influence change within departments, the grassroots support garnered in campus-wide education can be paired with higher-level capacity and support within departments to create more avenues for collaboration.

3. Pricing Carbon: The educational approach to energy consumption will likely not be enough to drive a major wedge into on-campus emissions. Setting a price on carbon and taxing emissions from departments accordingly, however, will send a price signal to departments, incentivizing emissions reductions investments where education alone might not be a sufficient driver.

4. Building Improvement: By making changes to and enforcing existing procedures for infrastructure investments on campus, Duke can expand the availability of energy efficiency retrofits and incentivize investments into more efficient buildings, reducing the amount of money the University will need to pay for offsets in the future.

Category 1: Campus-wide Education

The purpose of developing and expanding campus-wide education is to raise awareness about energy issues in an attempt to build support for energy-reduction on campus. In addition to informing the Duke community about how individual behavior can impact energy consumption and associated emissions, building grassroots support will encourage students, staff, and faculty to advocate for policy changes related to energy consumption. By building support, Duke can garner advocates and supporters for policy changes related to energy consumption. Through increasing the availability of transparent energy-related, Duke can promote energy knowledge, which studies suggest will reduce energy consumption more than a price signal alone.[9]

1.1 Student Engagement

By educating students about energy issues at Duke, the University can build more grassroots support for progressive energy policies and procedures on campus. Additionally, educating students about energy consumption on campus will likely decrease their individual consumption.[10]

1.1.1 Build an "Energy and Sustainability at Duke" Page on the Sustainable Duke Website

The Bass Connections team proposes assembling a page on the Sustainable Duke website dedicated to information about Duke University's energy systems and associated sustainability measures. This page should include information about how the University generates, purchases, distributes, and charges for energy services on campus. It will include information about how power is billed on campus. Additionally, this page will have information about Duke's outlook on energy and how it makes the decisions it does about energy.

[9] Katrina Jessoe and David Rapson, *Knowledge is (Less) Power: Experimental Evidence from Residential Energy Use*, NBER Working Paper No. 18344. National Bureau of Economic Research.
[10] Ibid.

Rationale

This website aims to increase the transparency of the energy systems at Duke and serve as a resource for other institutions investigating strategies for mitigating campus emissions. As the Team researched energy networks at Duke, the Bass Connections team learned about the complexities of the energy system at Duke. It took many months of research and interviews to gain a comprehensive understanding of how energy is purchased, distributed, and billed on campus. By increasing understanding about the energy network, this page can also serve as a resource for research teams at Duke and other universities. For future research teams at Duke, it will save them the months it took the Team to discover and synthesize this information. For future research teams at Duke and elsewhere, it will provide information about campus energy structures that will enable them to know what to look for. This will help them attain a similar level of understanding about their on-campus energy system in a shorter amount of time. Additionally, increasing the transparency about energy on campus would help Duke's image, as limited energy-related information has been one of the primary criticisms of the University surrounding the Combined Heat and Power (CHP) plant during the last year.

1.1.2 Educate Students about Duke University's Energy Systems and Allow Feedback

Duke should hold open forums on Duke's Climate Action Plan and organizing regular campus tours to show how Duke's electricity and power systems works. Additionally, the Team recommends providing an electrical dashboard in each of the buildings to let students know how much energy they consume in real time (like the one in Figure 1 below). The University should also create channels for student feedback on institutional or departmental energy reduction initiatives. This can include open discussions, town halls, or even online messageboards.

Figure 1: Electricity Consumption Dashboard in Environment Hall

Rationale

Based on the interest students have demonstrated about energy issues on campus (for example, support and opposition regarding the proposed CHP plant), it is important to let students know their opinions are important to carbon reduction projects. By educating them first, it will improve transparency and promote areas of mutual understanding between student groups and Duke administration.

1.2 Staff Engagement

By educating and engaging more staff members about energy consumption, Duke can further create a campus culture of sustainability that permeates the classroom.

1.2.1 Expand Leading for Environmental Sustainability Staff Training Workshops

Sustainable Duke has a program for staff called Leading for Environmental Sustainability, which educates staff about sustainable office practices. While the training touches on energy use, it is

more focused on recycling and other environmental practices.[11] The training also focuses on educating the staff members about the Green Grant Fund application and the Green Workplace Certification. This training should be expanded to include information on carbon policy, or a new, parallel training can be developed.

The Team proposes expanding educational programs to include carbon reduction and energy efficiency resources. These educational programs can take many forms, from informational posters to formal trainings. For example, Sustainable Duke's Leading for Environmental Sustainability Workshops can be expanded to include carbon reduction policy. A scheme like this could also pair department heads with representatives from Facilities Maintenance Department (FMD, or "Facilities") who can give them a better idea of what projects their department can undertake. The program can be implemented for all staff, or only certain key stakeholders (like department heads or Facilities managers). Regardless of what model is used, the program should allow operations-facing personnel to understand how their department can reduce their emissions as well as the ways Duke is moving towards its carbon-neutrality goal.

Rationale

Staff engagement is important to a comprehensive engagement strategy for carbon policy. Personal space usage accounts for significant energy consumption in departments. An emissions-awareness program or training can help prioritize reducing carbon emissions among staff and create a culture of sustainable practices including recycling, installing light sensors and wisely using electrical devices.

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[11] "Duke Green Workplace Certification," Sustainability: Duke Green Workplace Certification, accessed April 20, 2017, http://sustainability.duke.edu/action/certifications/greenworkplace/.

Category 2: Targeted Education

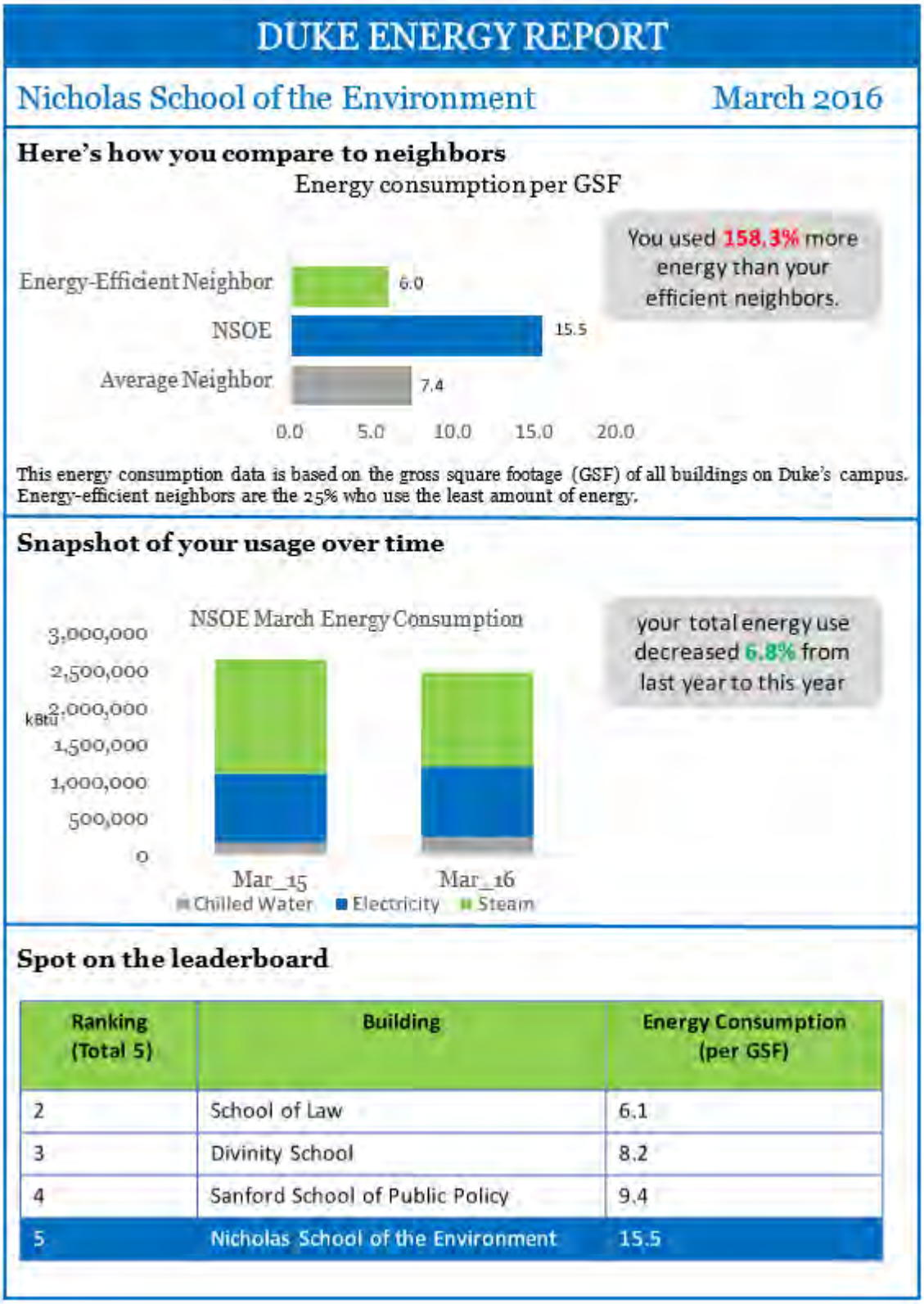
While the information and education strategy outlined above is geared at promoting a campus culture of knowledge and awareness surrounding energy issues, this category is geared more towards informing high-level decision-makers within different units on campus about their energy consumption. Delivering targeted, concise energy reports and creating a guidebook for energy efficiency retrofits will make it simpler for building managers and deans to understand their building's energy use and act to reduce it. Duke ought to make this information as accessible and simple as possible because these administrators have busy schedules.

Currently, departments are given energy usage data based on space classification by Facilities in an excel file, which shows them the amount of energy the buildings they occupy consumed in the time-period in question. The bill is then split per the proportion of space they are allocated in each building, and then totaled for each department. Financial managers for each school or department read this data and raise concerns if numbers deviate from previous months a significant margin.[12]

Proposal 2.1: Create and Distribute Departmental Energy Reports

Sustainable Duke and FMD should generate departmental energy reports to be sent regularly to financial managers and/or building managers of departments. These reports will include information such as energy usage by energy source (chilled water, electricity, and steam), and the department's energy usage as compared to other departments. Energy usage levels (in consumption per square foot) by department will also be published online as a leaderboard on platforms such as the Sustainable Duke website. As a part of this recommendation, Sustainable Duke ought to hire an intern to be responsible for generating these reports and an annual summary report of energy consumption on campus. A sample energy report is below:

[12] Interview with Duke University Energy Manager, Casey Collins, interview by author, March 24, 2017.



Ranking (Total 5)	Building	Energy Consumption (per GSF)
2	School of Law	6.1
3	Divinity School	8.2
4	Sanford School of Public Policy	9.4
5	Nicholas School of the Environment	15.5

Rationale

These reports will help Duke better inform administrators at the departmental level about their department's energy usage levels. This information will be used to inform future decision-making

processes about energy-related retrofits and investments. It is also meant to increase the amount of thought put towards energy consumption and its associated emissions within each department. While current reports are distributed, they are dense and rather inaccessible since they are simply a spreadsheet of numbers.[13] The report shown above is a simpler, easier-to-read version. This type of reporting will be relatively easy, as it requires only a different representation of existing information that is already sent to departments. Additionally, since the Team has already developed samples of these reports, the only work required will be modifying the template with the appropriate information for each department on a regular basis. The reports are modelled after home energy reports created and distributed to utility customers by Opower. Based on studies conducted by Opower to test the effectiveness of this type of reporting, it discovered electricity usage reductions by 1.5-2.5% in the two years immediately following implementation.[14]

To facilitate the process of creating and distributing energy reports, Sustainable Duke should hire an intern to do the reports and the annual yearly report. The intern should also be tasked with evaluating the progress of the project, soliciting feedback from stakeholders on campus such as Facilities, unit heads, students, etc. They can track actual progress in the context of the guidelines in this report and assess modifications that need to be made according to their findings. These interns can be one of the important links of communication to help spread accurate energy-related knowledge and to ensure the sustainment of the project. By evaluating the project as it goes, the interns will be able to assess and recommend necessary adjustments accordingly.

Hiring an intern to ensure the sustainment of the energy reports will be of medium difficulty, as it requires funding and oversight from Sustainable Duke. However, it is in line with Sustainable Duke's work already being done to track and implement the Climate Action Plan. This will be vital

[13] An example can be provided upon request to Jason Elliott (jason.elliott@duke.edu).

[14] M. Sami Khawaja and James Stewart, "Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs," Cadmus Group, accessed April 25, 2017, http://www.cadmusgroup.com/papers-reports/long-run-savings-cost-effectiveness-home-energy-report-programs/.

to the long-term success of the project to assess its progress and adjust based on lessons learned and steps taken each year.

Proposal 2.2: Post Building and Departmental Energy Consumption Leaderboards on the Sustainable Duke Website

Sustainable Duke should publish leaderboards of energy consumption per square foot at the building and departmental level. Spreadsheets distributed to finance managers within each department show the consumption per square foot total for each building a department occupies space in, plus the amount allocated to that department. Posting this information only requires translating existing information to a web page; since Sustainable Duke is revamping its website by the end of 2017, now is an appropriate time to implement this recommendation.

Rationale

By publishing departmental and building-level energy consumption information, departments and building occupants will be able to see where they stand among their peers, and spur friendly competition. Based on a trip to Yale to interview implementers of its carbon charge program, the Team discovered that releasing information about how departments and buildings compare in terms of energy consumption fostered collaboration. A building manager in one department told members of the Team that when leaderboard information was released, they could see which buildings were reducing energy consumption more than others, which led some building managers to call one another and inquire about what strategies they were implementing.[15] Publishing this information is likely to similarly give department heads and building managers opportunities to identify peers doing well in reducing energy consumption, and establish contacts to exchange ideas.

[15] Interviews with Carbon Policy Implementers at Yale, interview by author, November 11, 2016.

Proposal 2.3: Create an Energy Efficiency Retrofit Guidebook

Sustainable Duke and Facilities should collaborate to create an energy efficiency retrofit guidebook for departments, to be housed on the Sustainable Duke website. This guidebook should provide information about energy efficiency retrofits and how they can benefit a building. It should also detail the process for investigating the potential of and funding options for a retrofit. Part of this will include points of contact within Facilities that departments and building managers can contact about evaluating potential prospects. The guidebook should also have information about case studies for energy efficiency retrofits on campus, such as the lighting retrofit in Hudson Hall (see Appendix I for details). Sustainable Duke should task a staff member or intern to work with Facilities to create this guidebook so that it can be published on its website.

Rationale

By creating this guidebook, departments will increasingly be able to collaborate with Facilities on retrofit projects. Based on interviews at Yale, one of the issues with its carbon pricing program so far has been a lack of collaboration with the Facilities department.[16] Since FMD is the group capable of executing these projects, fostering collaboration between them and departments by establishing points of contacts in the guidebook will help ameliorate this potential issue. Additionally, departments will simplify the retrofit process by knowing where to start in Facilities and how to schedule an evaluation.

[16] Ibid.

Category 3: Pricing Carbon

The first two categories of recommendations are geared towards influence through information. This category and the final one are geared towards influence through financial incentives and resources. In addition to raising awareness and spreading information, the Team's research has concluded that some financial incentives will also be needed to further nudge the University towards carbon neutrality.[17]

The second section of recommendations aims to inform decision-makers about departmental energy consumption and ways to mitigate it. Information ensures they can be as educated as possible to make effective energy-saving changes. At the moment, however, there are informational gaps that prevent departments from facing adequate incentives to reduce their emissions – departments do not see their energy costs (these are aggregated into a "Rent" line item) and may not even know that there are ways to decrease their energy use. Currently, Facilities Maintenance Department (FMD) takes on debt as it purchases all of the energy needed for campus, then recoups the costs through billing individual departments on campus. For buildings that are occupied by multiple departments, each department pays the percentage of the total building energy bill that corresponds to the percentage of square feet occupied by the department in the building. Rates do not vary based on space occupied, so in a lab building, for example, departments with office space will pay the same rate per square foot for energy as departments that occupy energy-intensive lab space. For each department, all of these costs are aggregated, then combined with other fees such as for Police and Fire services into one line on the bill, labeled "Rent."

Policies that tackle billing and financial protocols are important because building the right financial incentives can be very powerful in further making cost-minimizing entities aware of the financial impact of their consumption. Sending a price signal by attaching a fee for carbon emissions

[17] Ibid.

will force high-emitting entities on campus to choose between making decisions and investments to reduce energy consumption or simply paying the fee. The price signal will lead some departments to work harder to reduce consumption, thereby lowering on-campus emissions. The entities that choose to pay the fee will also help the University reach carbon neutrality because the fee, which should be set to the cost of the average carbon offset purchased by the University (say $10), will fund offset projects to negate the emitting entity's emissions.

The long-term goal of these billing and finance tools are to create a billing system that adequately captures the cost of carbon offsets in financial decision-making. This can be achieved either implicitly, under the category of general "cost reductions", or explicitly through the use of a carbon pricing program.

Proposal 3.1: Implement a Shadow Price

When new capital investments are proposed for campus, whether it be new buildings or retrofits, economic models are used to identify the most cost-effective choice available.[18] Duke University should add a shadow price into financial models for new construction. A shadow price is not a fee or an actual charge levied, but rather a hypothetical cost that is included in economic modeling to reflect the cost of carbon offsets. If a shadow price is implemented, as construction and retrofit projects are evaluated for cost-effectiveness, planners would include the cost of the offsets that would need to be purchased to offset the emissions resulting from energy demand for the building or project. In current planning, the energy demand is forecasted for a building or project, so a shadow price would only require adding the cost of the emissions necessary to offset the forecasted energy consumption.

Rationale

Including the cost of carbon offsets in accounting serves to make lower-emitting options more

[18] Interview with Duke University Energy Manager, Casey Collins, interview by author, March 24, 2017.

cost effective.[19] For example, say in planning for a new building, two different heating, ventilation, and air conditioning (HVAC) systems are being evaluated. The first HVAC is less energy-efficient but also cheaper, with an estimated payback period of seven years. The second HVAC is more energy-efficient, but also more expensive, with a payback period of nine years. Under current decision-making processes, the first HVAC is the more likely choice because of its quicker payback period. However, it is cheaper in part because the decision-making process does not account for the offsets that the University will need to buy during the HVAC's lifetime to account for its emissions. By accounting for this in the payback period calculations, it could nudge the decision in favor of the second HVAC, which while more expensive now, is more cost-effective in the long-term because less offsets will need to be purchased on its account in the future. If a shadow price is not implemented, energy costs will increase for departments in the long term; by not accounting for offsets in current decision-making processes, the University will have higher levels of emissions to buy offsets for in the future, increasing the rate base and causing these additions to be spread across the energy bills around campus. For Duke University, a shadow price will save the University and individual departments money in the long term, nudge decision-making processes towards more environmentally-friendly alternatives, while also signalling the University's commitment to its carbon-neutrality goal.

Implementation

To evaluate the potential for a shadow price, the special subcommittee of the CSC should determine the specifics. The subcommittee would need to determine the scope of projects that need to account for the shadow price, such as new construction, building retrofits, employee travel, fuel consumption for on-campus energy production, etc.

[19] Adele Morris, "Why the federal government should shadow price carbon | Brookings Institution," Brookings, July 29, 2016, https://www.brookings.edu/blog/planetpolicy/2015/07/13/why-the-federal-government-should-shadow-price-carbon/.

Creating and deploying a shadow price for campus would be a task with an intermediate level of difficulty. It would not be as easy as adding a budget line item for carbon because it would require further review and would influence decision-making. However, it would not be as challenging as implementing new pricing programs, such as the ones detailed below. A shadow price for carbon will ensure campus decision-making is steered towards lower-emitting sources for years to come, and accordingly should be pursued with vigor by the university.

Proposal 3.2: Charging Departments Based on Consumption and Related Emissions

To achieve emissions reductions beyond those resulting from the educational initiatives in sections 1 and 2, Duke should implement a carbon charge program to further send a price signal to departments about the cost of their emissions and to fund offsets. The design and implementation will be a sizable task for the CSC subcommittee, but one that will play a significant role in helping the University meet its 2024 carbon neutrality commitment.

3.2.1: Consult with Departments and Add a Blank Budget Line Item for a Carbon Charge

Currently, energy costs for units on campus are aggregated with other facility costs into a line item labelled “Rent.” These other costs include costs for police, fire, and building rental space. Through this method of billing, it can be challenging for departments and cost centers to understand how much energy they actually use. One of the first action items in developing a carbon charge program should be informing departments about the idea behind it and the forms it could take. Then, a budget line item in the billing system should be added for a “Carbon Charge,” which will initially be blank, and not an actual charge. The actual charge should then be implemented a year after the budget line is added, after a pilot study is conducted to evaluate the most viable pricing structure.

Rationale

Educating departments about the budget line item before its implementation is a necessary precursor and should be publicized and addressed so that departments are not taken by surprise.

After addressing the information about it, a budget line item should be added for a "Carbon Charge." Immediately following implementation, this line will remain blank. However, it will lay the groundwork for any sort of carbon charge program, detailed below. Implementing this budget line item early on will facilitate a smoother administrative transition to a carbon charge program, leaving only the calculated charge to be added to each unit's bill.

Implementation

Based on interviews with Duke staff members in the finance office, the addition of a budget line item would not be very challenging at all. Someone in the finance department could realistically insert a line in the billing structure. Since there will not yet be an actual charge associated with it, adding this line to the budget will be quite easy, yet very important in laying the groundwork for a carbon charge program and ultimately, incentivizing reduced energy consumption amongst units on campus.

3.2.2:Possible Examples: Peer Institutions with a Carbon Charge Program

Various peer institutions have or are in the process of implementing carbon charge programs.

Yale University

Following the recommendation of Yale Carbon Charge Task Force, Yale piloted its internal carbon charge during 2015-2016 academic year. Based on the social cost of carbon emission ($40/MTCO2e), four schemes (Information, Target, Redistribution, Investment) were tested on campus. The pilot convinced many of the potential of internal carbon pricing on campus and illustrated the importance of clear information and incentives.[20]

Swarthmore College

Three interconnected schemes were proposed to be implemented from fall 2016 with a budget of $300,000. Shadow pricing, a carbon charge fund, and an increase in metering, feedback and

[20] Yale University, "Yale University's Carbon Charge: Preliminary Results from Learning by Doing," October 10, 2016, http://carbon.yale.edu/sites/default/files/files/Carbon_Charge_Pilot_Report_20161010.pdf.

messaging. The carbon charge fund will be used for renewable energy installations, energy efficiency upgrades, improved metering, reductions in energy consumption, and education initiatives.

University of Maryland

The Carbon Offset Program includes two parts: one is optional for parking permit consumers, and another is mandatory for the whole university.[21] This program is still pending for approval. Their scheme is unique because they are trying to implement a voluntary carbon charge scheme on campus. Since the parking charge for commuters would be optional, behavioral changes here would depend on individuals' social responsibility.

3.2.3: Revenue Options for Pricing Programs

There are two primary types of revenue options for pricing programs: revenue collection and revenue neutrality. Revenue collection entails charging emitting entities in one of the methods detailed below, and then using the collected revenue to fund carbon offsets, renewable energy, or energy efficiency projects on campus. The revenue neutrality method is the one employed by Yale's carbon charge program; it amounts to charging departments that do not reduce their emissions compared to the University's average and returning the money to departments that perform better than the University's average reductions.

3.2.4: Criteria for Evaluating Pricing Programs

When evaluating the potential for types of pricing strategies as well as specific policy design, the University should account for five primary factors: implementation and long-term feasibility, emissions reductions, research value, student engagement, and behavioral incentives. Implementation and long-term feasibility needs to account for how onerous execution of the plan would be, the necessary resources to make it happen, and planning to ensure its long-term success.

[21] Angela Jacob, "UMD's Sustainability Council Is Calling for a Mandatory University Carbon Fee," *The Diamondback*, November 2016, http://www.dbknews.com/2016/11/16/university-of-maryland-climate-action-plan/.

Emissions reductions potential can help the University choose between strategies because it will allow decision-makers to see which strategy will have the biggest impact on emissions. Research value ties into the University's mission as well as its image as a climate leader. It also reflects the opportunities for outside attention. For example, Yale's carbon charge program was the first of its kind and is often pointed to as an example of what universities can do to address their carbon footprint; Duke can be another one of these examples. Student engagement reflects the potential for students to be involved in the project, be it through implementation, research, or experiential learning tied to project work. Finally, behavioral incentives reflect how much the proposed design can influence decision-making behavior on campus.

3.2.5: More Concrete Policy Design Options

While there are endless options and variations for the finer details of a carbon pricing program, here is a look at specific options that fit broadly into three common categories for carbon policies: tax, cap-and-trade, and hybrid.

Tax

The most administratively straightforward category of carbon pricing is a tax which sets a price at which carbon emissions will be taxed.

Tax: Flat Tax (Revenue Collection)

After determining the average cost on an offset (likely to be around \$10/ton CO_2), each department will be taxed \$10 for every ton of CO_2 emitted. Funds collected from the tax can go towards a carbon fund which can be used to fund offsets, energy efficiency, or other CO_2 mitigation projects on campus.

Tax: Graduated tax (Revenue Collection)

In this model, there are varying levels of taxation on carbon based on either overall departmental emissions or measured against a baseline. For example, each department could be taxed \$20/ton CO_2 emitted up to 100 tons, then \$40/ton emitted between 100 and 300 tons, then \$60/ton emitted above

300 tons. Alternatively, if measuring against a baseline, it will be a percentage of the department's historical emissions. In this case, once a baseline is set for each department, they can each be taxed $20/ton for all carbon emitted until they reach 80% of their baseline, then $40/ton between 80%-100% of the baseline, then $60/ton for all carbon emitted beyond the baseline.

Tax: Tax Redistribution (Redistribution)

In the redistribution model, at the end of the year, each department is measured against a benchmark, which could be set in a variety of ways. When setting a benchmark in a redistribution program, the key is to set one such that departments who beat it are rewarded, those who miss it have to pay, and that these two categories balance each other out to ensure neutrality. For example, the benchmark could be an annual targets set based on the type of space occupied by a department or the carbon reduction of the university as a whole. The latter is the case with Yale's carbon charge program, with departments taxed if they reduce emissions less than the university average or reimbursed if they reduce emissions beyond the university average.[22] Say, for example, campus reduces its campus-wide carbon emissions by 2% from one year to the next. At the end of the year, departments will be taxed against a 2% baseline. If a department reduces its emissions by 2% over the same year, it will not pay or be reimbursed. If the department reduces its emissions by 10%, it will be compensated for the difference of 8%. If in the same year, another department's emissions increase by 3%, it will have to pay taxes on 5% of its total emissions to match the university average of a 2% reduction.

Cap-and-Trade

A cap is set on overall emissions, after which the cap is divided into emission allowances which are allocated to departments either for free or through an auction. Over time, the cap is reduced. Theoretically, with less emission credits on the market, the price will increase and departments will be incentivized to determine the most cost-effective option: purchase more emission credits at a

[22] Yale, "Yale University's Carbon Charge"

higher price to continue emitting as usual, or invest that money into energy-reduction strategies. Departments that emit beyond their allowances will be subject to a fine.

Cap-and-Trade: Fair Share Cap-and-Trade (Redistribution)

The "free-market" variation of cap-and-trade. Under this option, once emission allowances are auctioned off to departments, they can be freely traded or purchased between departments throughout the year. Emissions credits are usable for one year, after which the cap is reduced and another auction is held to allocate credits for the following year.

Cap-and-Trade: Cap-and-Dividend (Revenue Neutral)

Under this model, emission credits are auctioned off to departments at the beginning of the year. At the end of the year, all the money collected from the emission credit auction is returned to departments on a per-capita basis according to their relative rates of emissions.[23]

Hybrid Cap-and-Trade and Tax

This combined model uses a cap-and-trade program for some emissions on campus and a tax for others.

Hybrid Cap-and-Trade and Tax: Initial Cap with a Backup Tax (Revenue Collection)

This model initially functions like a cap-and-trade where emission allowances are auctioned off to departments and then can be traded and sold between them. In the case that a department's emissions exceed the associated credits it has purchased, it will be taxed for the overage emissions. The backup tax is likely to be assessed at a high rate in an attempt to deter departments from emitting beyond what they have purchased credits for.

3.2.6: Analysis of Revenue Options Based on Outlined Criteria

This section discusses the potential effects of certain ranking criteria on different pricing strategies and how they could influence the decision-making process. For each pricing mechanism

[23] Amy Sniden, "Revenue-Neutral Cap and Trade," 2009, *Environmental Law Reporter 39*, no. 10: 10944-10961, https://elr.info/news-analysis/39/10944/revenue-neutral-cap-and-trade/.

criteria, the Team ranked the two pricing tools (revenue collection and redistribution or revenue neutrality) from most to least likely to satisfy the criteria (1 being the highest and 2 the lowest). The associated rankings in *Table 2* are based on analysis in the context of Duke and are not meant to be perceived as universal truths. They are a ballpark estimate and are subject to change with the way each policy is carried out.

	Revenue Collection	**Redistribution**
Implementation and Long-Term Feasibility	1	2
Emissions Reductions	1	2
Research Value	2	1
Student Engagement	1	2
Behavioral Incentives	2	1
Total	7	8

Table 2: Ranking of Price Mechanisms

Implementation and Long-Term Feasibility

Both pricing options will be politically challenging to implement, as they each require departments to incur new costs. Revenue collection is slightly easier to manage than redistribution though, since a flat tax could be applied to all departments. Redistribution requires more work because it further requires more staffing on the back end to manage the baseline emission comparison and financial redistributions.

Emissions Reductions

Revenue collection has the most potential for reducing emissions because a flat tax can be applied to all departments, ensuring each will be financially incentivized to reduce its consumption. Additionally, the collected revenue can be used to purchase carbon offsets. The redistribution method has a lesser potential to reduce emissions due the fact that departments are only expected to match the university on a business-as-usual scenario per year.

These rankings are not solidified, especially as the actual amount of emissions reductions under each model are highly dependent on the specific details of how the program is implemented. They could be designed in such a way that reverses the order of the rankings, such as if the University invests in large-scale energy and emissions reduction tactics, pushing departments in the redistribution model to shoot for more aggressive targets.

Research Value

Both pricing categories boast significant research value for the University. Redistribution has the highest research value because of the rarity of revenue-neutral carbon pricing schemes. It requires more comparison and integration between departments. Revenue collection provides less for research as it does not have these elements, but rather applies a similar charge to all departments.

Student Engagement

Student engagement has the most potential in a revenue collection model because of the carbon fund. With such a fund, there is financing available for research grants and various energy-related

projects, all of which pose significant potential to engage students each year. Redistribution does not have this potential, but redistribution comes in at second because students could be involved in assessing the program and administering it.

Behavioral Incentives

Redistribution and revenue collection could both alter behavior in the long-term by nudging departments towards lower-emitting alternatives. However, they may be viewed more as just an added cost that departments will have to burden one way or the other, and thus not result in significant behavioral changes. As with some of the other criteria, specific rankings for behavioral incentives depend largely on how programs are implemented.

3.2.7: Implementation

A carbon pricing policy is a long-term objective. The advantage is that it fundamentally embeds the desired financial incentive where it belongs. It may not have the largest impact right away - there are many reasons why choices about energy use are flawed even before considering carbon emissions. As these flaws are corrected, however, a carbon price ensures that the opportunity cost of offset purchases by the University are not ignored.

With this in mind, the proposal for carbon pricing policies is 1) Weighing the pros and cons for the feasible carbon pricing schemes, 2) Implementing a pilot program to test the viability of identified options, and 3) Implementing the most effective policies campus-wide if they are viable. It is important for Duke to solicit support from FMD for ease in implementation.

The timeline for implementation of a pilot program and subsequent expansion should best suit the interests of all stakeholders. The Campus Sustainability Committee should take up the responsibility to foster discussion. However, the implementation of carbon pricing policies need a large amount of resources, including but not restricted to political support and additional personnel. A detailed policy analysis or cost-benefit analysis should be performed before the launch of any policies or programs to ensure the most efficient and impactful policy be in place.

Category 4: Building Improvement

In addition to the carbon pricing programs outlined in section 3, Duke should increase money available for energy efficiency projects and work to ensure compliance with the Sustainable Building Guide to further drive emissions reductions on campus as a means of reducing the number of carbon offsets the University will need to purchase to meet carbon neutrality.

Rationale

Targeting new construction and investments in existing buildings is important because it allows Duke to anticipate future emissions and act now to reduce them, thereby lowering the number of offsets needed to meet carbon neutrality. Creating policies that push for energy-efficient new buildings provides a chance to have long-term impacts on Duke's emissions. Policies that increase efficient construction will require fundamental institutional change to be successful.

Some energy efficiency projects are paid for using debt financing through Facilities, meaning that an increase in the number of projects will increase the cost of energy for all ratepayers at Duke University because it will increase the rate base. The University could sidestep this by creating a fund specifically for energy efficiency projects. If Facilities is able to partly claim some of the savings (versus the department where the savings occur) – the fund can be replenished from such projects. Savings should be returned in part to the department to create incentives to save energy, and in part to Facilities to help fund future projects.

Proposal 4.1: Increase Funding Allocated to Energy Efficiency Projects

Duke should increase the amount of funding allocated to energy efficiency projects on campus to ensure buildings are made as efficient as cost-effectiveness allows for, reducing on-campus consumption to minimize the number of offsets needed. Two options for increasing such funding include more money allocated by the Office of the Executive Vice President (EVP) or creating a revolving fund for energy efficiency projects.

Background: Current State of Funding

Presently, about $300,000 annually is allocated from the Provost's Office to an energy fund under the jurisdiction of FMD. This fund is a collective pool that FMD can use to either subsidize or fully fund energy efficiency projects for departments on campus, depending on factors such as capital investment, expected rate of return, and total carbon savings.[24] The savings of these projects are directly seen by the departments.[25] Presently, FMD uses these funds to upgrade 6-7 buildings per year. Past beneficiaries include French Family Science Center, LSRC, CIEMAS, and Hudson Hall.

In addition to utilizing this energy fund, FMD also recommends improvements to departments, who later pay for the improvements themselves. Lately, the Athletics Department has been a main beneficiary of this model, making changes to their lighting and HVAC systems at the recommendation of FMD. In total, between energy fund disbursements and departmental consulting, FMD is responsible for energy retrofits in about 15-20 buildings per year.

The Office of the Executive Vice President (EVP) also has discretionary funds that in the past have been used to purchase carbon offsets and energy-saving equipment. However, EVP funds must be net-zero revenue, suggesting that any funds allocated to particular departments are essentially loans.[26]

Access to more money would enable larger and more effective energy performance improvement projects, and consequently, larger carbon reductions. Two pathways toward increasing available funds include increasing the annual allocation from the Provost's Office and establishing a green revolving fund.

[24] Email Interview with Duke University Energy Manager, Casey Collins, April 5, 2017.
[25] Interview with Director of Business Services (Facilities & Management Department), Joe Stewart and Associate Vice President of Budgets & Central Business Operations, John Clements, interview by author, March 2, 2017.
[26] Interview with Duke University Executive Vice President, Tallman Trask, interview by author, March 3, 2017.

Proposal 4.1.1 Option 1: Increase Allocation from Provost

Authorities from FMD[27,28] suggested that the $300,000 allocation for energy efficiency projects per year is used relatively quickly and that this sum is insufficient for supporting the University's long-term carbon neutrality goal. Based on their accounts, increasing the Provost's allocation would improve Duke's ability to meet its carbon neutrality goal, likely by allowing them to perform retrofits on more buildings per year and/or increase the impact of each retrofit. To quantify how much more money should be allocated, FMD should quantify the carbon reductions enabled by the present allocation and estimate how much more in carbon emissions would be avoided per incremental investment.

Proposal 4.1.1 Option 2: Establish Revolving Fund

Another way to increase available funds for energy efficiency projects is to establish a green revolving fund separate from the EVP's discretionary funds. An initial pool of money would be set aside for energy efficiency projects, and the fund would be replenished by cost savings from these projects. A proposal and vetting process, as well as a standard for estimating cost savings, would be established to evaluate projects. This revolving fund could be established by either converting the existing FMD energy fund or converting some portion of EVP funds, or by diverting funds from each of these into a separate fund entirely.

Benefits:

- The fund would enable departments to implement more ambitious energy efficiency projects without having to spend their own money, which departments have been hesitant to do.[29]
- This fund is similar to the existing structure of EVP funds. However, instead of being refunded by money allocated to the EVP's office, this fund would be replenished by cost savings associated with each project and not require additional year-to-year funding beyond

[27] Interview with Joe Stewart and John Clements, March 2, 2017.
[28] Interview with Duke University Energy Manager, Casey Collins, interview by author, March 27, 2017.
[29] Interview with Joe Stewart and John Clements, March 2, 2017.

initial seed money.

- The fund would have a likely advocate within the Board of Trustees, which will likely have to approve its creation. Elizabeth Kiss, President of Agnes Scott College, has established a green revolving fund at Agnes Scott and privately advocated the replication of this model at Duke.

Barriers:

- A revolving fund would not be politically palatable because departments will not see savings that are reinvested in new energy projects. If departments must pay the same rates either way, they will only see benefits once energy efficiency projects reach the end of the payback period. This reduces visible benefits to departments and decreases the likelihood of wanting to invest in such projects.
- The existing EVP funds appear able to fund only quick ROI projects. The fund will have to be re-engineered to accommodate longer ROIs, since the payback period for efficiency projects is often at least 3-5 years.
- This fund will also need administrators to oversee and vet proposals. This may require some individuals in FMD or the EVP's office to take on additional responsibilities.

Proposal 4.2: Support Implementation of the Sustainable Building Guideline

The Duke University Construction & Design Guidelines contains a Sustainable Building Guideline, which supports the Sustainable Building Policy adopted by the Board of Trustees in 2015. Presently, this Guideline requires that new construction and major renovation projects should be designed to achieve a 30% energy performance improvement over "baseline design[30]." However, this Guideline has not once been met since its inception.[31]

[30] "Baseline" is an accepted industry standard as defined by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in 2007, referred to as ASHRAE 90.07. Legally, the least efficient building that Duke could build must conform to ASHRAE 90.10, the slightly more progressive standard redefined in 2010.
[31] Interview with Duke University Energy Manager, Casey Collins, March 27, 2017.

- Why: Of the three buildings (Environment Hall, West Union, Wellness Center) that have been constructed since the Guideline was adopted, only the Wellness Center was planned with the Guideline in mind (the other two were already under construction at time of adoption). Perhaps consequently, it has come closest to meeting the Guideline, having achieved a 28% performance improvement over baseline.[32]
- What is being done: Duke University's energy management team is currently working to enforce the Guideline for new construction, but additional support from administration would help enforcement.
- Recommendations: The Sustainable Building Guideline will be up for revision in the near-term (within approximately a year), and it should be edited to include an implementation strategy—perhaps by outlining a review process that ensures construction planners are meeting the standard. Additionally, the fact that the Guideline exists and is not being met should be publicized in order to increase public pressure on construction units.

It should also be noted that the upcoming revisions to the Guideline will likely also reduce the nominal energy performance improvement, since the industry baseline itself has been improving over the past few years, becoming increasingly difficult to exceed.[33] This reduction in standards is because the baseline performance standards for buildings are increasing, so targets for exceeding them need to be reduced to maintain viability.

[32] Ibid.
[33] Ibid.

Conclusion and Next Steps

Duke University has made significant reductions in on-campus emissions since the implementation of the Climate Action Plan in 2007. However, at the current rate, Duke will have to pay for a considerable number of offsets come 2024 to meet its state carbon neutrality goal. By implementing the tools outlined in this report through campus-wide education, targeted education, pricing carbon, and building improvement, Duke can ensure that purchased offsets complement equally cost-effective mitigation on campus. In turn, this ensures that Duke's carbon neutrality is achieved at the lowest possible cost to the community, and positions Duke to be a leader in sustainable action.

Many of the recommendations outlined in this report require high-level political support and institutional change at Duke University. Therefore, Sustainable Duke should work to help implement the first two categories of education recommendations, and the Campus Sustainability Committee should take up the latter two sections and task a subcommittee with further developing and implementing the recommendations outlined beginning in the 2017-2018 academic year.

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Appendix

Appendix I: Hudson Hall Retrofit Example

This retrofit was motivated by students who (aware of a new LED lighting technology and its energy-saving potential) counted all the lights in Hudson Hall, researched the technical specifications of various brands of the LED product, and used this information to calculate the total energy, monetary, and carbon savings for the building if it underwent a full retrofit. Over the lifetime of the LEDs, the building stood conservatively to save $180,000, with a payback period of approximately 1.5 years. The students spent the better part of a semester performing this groundwork, much of which involved establishing the right connections at Duke to supply needed information and approve pilot efforts.