Designing a Proxy Carbon Price Strategy for Smith College

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Abstract

This thesis to *Design a Proxy Carbon Price Strategy for Smith College* was written to internalize the social cost of carbon emissions into financial decision-making. The reason a carbon price is necessary is because the current market price for fossil fuels omits the social cost of carbon emissions, which contribute to climate change (IPCC, 2014; Stern, 2008) A proxy carbon price is a virtual price - meaning it does not apply an actual fee - to acknowledge the social cost of carbon in financial decisions. In general, the proxy carbon price can be used to evaluate investment or purchase decisions. The institutional driver for this thesis derives primarily the Study Group on Climate Change (SGCC) request to "Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision- making processes" (SGCC, 2017). This thesis identified that many business and governments are using carbon price strategies, but only four academic institutions are doing so. As a consequence, there is a lack of peer-reviewed literature, which must be filled through experimentation and publication. In order to understand how a proxy carbon price might be implemented at Smith College this thesis identified and experimented with strategies to incorporate the proxy carbon price into financial decisions, using a mix of background research, stakeholder interviews, and pilot examples. Based on my research into possible carbon prices, the Smith College Committee on Sustainability (COS) recommended a proxy carbon price within the range of \$60-\$75 per $MTCO_2e$ [1](COS, 2018) which was implemented here as a price starting at \$70 per $MTCO_2e$. A pilot project on Renewable Energy Credit procurement demonstrated the general application of the proxy price for placing a value on avoided carbon emissions. For cases that include capital and operating costs, the proxy carbon price should be incorporated into the Lifecycle Cost method for financial decision-making. A Proxy Carbon Lifecycle Cost method can be performed using an Excel tool that was adapted from the Harvard Lifecycle Cost Calculator (Harvard, 2017). Its application was demonstrated with a pilot project on Washburn House, which illustrated the cost- and carbon- saving options of energy retrofit options. This thesis provides 8 recommendations regarding a Proxy Carbon Price Strategy for Smith College.

[1] Metric ton of carbon dioxide equivalent emissions ($MTCO_2e$)

[2] A carbon asset is any infrastructure, vehicle, electricity, or other source that emits carbon emissions and is owned by the institution.

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Chapter I: Introduction: Smith College Proxy Carbon Price Strategy

Climate change is a complex and urgent problem that will require creative, sustainable solutions. The consumption of fossil fuels and changes of land use produce greenhouse gas emissions, especially Carbon Dioxide (CO_2), which results in changes to the Earth's climate (IPCC, 2015). The current market price for fossil fuels does not capture the full cost to society (i.e. a negative externality) (Stern, 2008). In future decades, centuries, and millennia, climate change will act as a driver of geological processes in the new geological epoch called the Anthropocene (Schwägerl, 2011). Furthermore, the consequences of climate change are a social justice issue because climate change will impact economies and societies around the world and particularly impact developing countries and low-income people. (Stern, 2008; UNFCCC, 2016). The science is clear and it is apparent that sustainable actions are needed avoid the worst impacts of global climate change. This thesis investigates one possible strategy to stimulate actions to reduce greenhouse gas emissions (hereafter carbon emissions) at Smith College by internalizing the social cost of carbon into financial decisions through a proxy carbon price.

A proxy carbon price is a way to acknowledge carbon emissions in financial decisions and favor low-carbon options (Gillingham et al., 2017). It is a virtual price that is calculated, though not actually charged, at the point of purchase to evaluate the impact of carbon emissions to society. A proxy carbon price can be used to highlight cost- and carbon- saving opportunities to transition to a low-carbon institution (CDP, 2017; Morris, 2015; Cassidy, 2016). Additionally, a proxy carbon price can be used to illustrate the institutional value of avoided carbon emissions from innovative low-carbon investments. Ultimately, a proxy carbon price is a financial tool to acknowledge carbon emissions in financial decisions and favor low-carbon options to transition to a low-carbon institution and provide net benefits to society through avoided climate damages.

Currently, governments around the world are turning to carbon pricing as a strategy to mitigate carbon emissions and meet National Determined Contributions (NDC) to the Paris Climate Accord (World Bank, Ecofys 2017). Businesses are responding by integrating a carbon price into business strategy. As of 2017, over 1,300 businesses are currently using or have disclosed plans to implement a carbon price in their business strategy to hedge against the financial risk of carbon regulation (CDP, 2017).

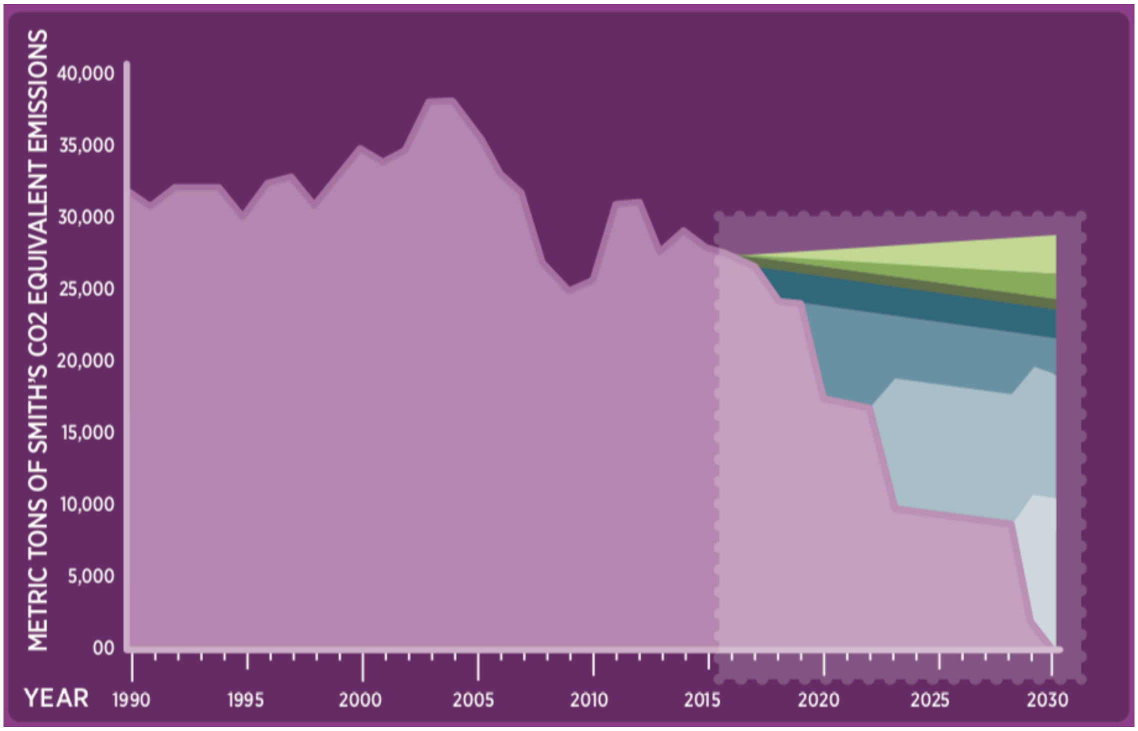
Traditionally, colleges and universities have been centers of education, experimentation, and innovation (Weisbord et al., 2012). Frank Wolak, a Stranford University economist articulated that, "the primary roles of research universities is knowledge creation and dissemination. Universities are especially well placed to address the challenges of pricing greenhouse gas emissions in light of the technical and implementation challenges involved" (Wolak, 2014). There are many academic institutions in the United States that are well suited for experimenting with carbon pricing techniques because they have the knowledge and the capability to conduct research.

A recent paper in *Nature*, "Lessons from first campus carbon-pricing scheme," described Yale Carbon Charge, which is an experiment to model a revenue neutral carbon tax (Gillingham et al., 2017). The report also discussed using proxy carbon pricing as a strategy for institutions and businesses to incentivize low-carbon investments. In response to the Gillingham paper, Dr. Alex Barron and I wrote a Correspondence in *Nature*, "Test proxy carbon prices as decision-making tools," elaborating upon reasons why experimentation is necessary to understand how to maximize the benefits of a proxy carbon price (Barron and Parker, 2018).

Smith College is poised to experiment with a proxy carbon price strategy as a way to address the complex, urgent issue of climate change and expand the literature on this new idea. Futhermore, engaging students in the research of the proxy carbon price can address the Strategic Plan initiative, Campus as Classroom (Strategic Plan, 2016). Therefore, Smith College has an opportunity to become a leader in the emerging field of carbon pricing and increase the institution's social capital.

This thesis to *Design a Proxy Carbon Price Strategy for Smith College* addresses an institutional need for strategies to mitigate carbon emissions. Smith College signed the American College & University Presidents' Climate Commitment (ACUPCC) to become carbon neutral by 2030. Currently, Smith College annually emits approximately 26,000 metric tons of carbon dioxide equivalent (hereafter $MTCO_2e$) (AASHE-Stars, 2017). Therefore, Smith College needs to mitigate carbon emissions or purchase carbon offsets to achieve the ACUPCC commitment (Figure 1).

Figure 1 - Smith's Carbon Emissions through time, including projected emission reductions (SGCC, 2017).



The overarching research question is how can Smith College incorporate a proxy carbon price into the current practices of making financial decisions in capital budget management and sustainability projects? This thesis addresses the request by the Study Group on Climate Change to "Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision- making processes" (SGCC, 2017). Additionally, this thesis explores using proxy carbon price as an environmental economic tool to meet Smith College's carbon neutrality goal of 2030 by incentivizing low-carbon options for capital projects. Specifically, this thesis demonstrates the proof of concept of using a proxy carbon price through two pilot projects: Washburn House Retrofit and the Renewable Energy Credit Procurement Project.

The primary purpose of this thesis was to pursue scholarly research on proxy carbon pricing as a strategy to mitigate carbon emissions and consequential climate change. Ultimately, the goal of the *Design a Proxy Carbon Price Strategy for Smith College* is to align the academic institution's mission of education and sustainability with the operations of the institution, thereby creating positive institutional change.

The research for this thesis to *Design a Proxy Carbon Price Strategy for Smith College* begins with Chapter II: Background, which demonstrates the environmental economic need for a carbon price to internalize the social cost of carbon into financial decisions and describes options for selecting the proxy carbon price. Additionally, it reviews the use of carbon pricing by governments, businesses, and academic institutions around the world. This section answers the research questions, why should an institution incorporate a proxy carbon price?

The next is Chapter III: Methods, which articulates how I designed a Proxy Carbon Price Strategy for Smith College. In this Chapter, I discuss my methods for engaging with internal stakeholders at Smith College and external collaborators at other academic institutions. Additionally, I provide a review of how I adapted the Harvard Lifecycle Cost Calculator to the specifications of Smith College to create the Proxy Carbon Lifecycle Cost Calculator. The final section articulates how I selected and developed the pilot projects to demonstrate the proof of concept.

The following is Chapter IV: Results and Discussion, which describes the key findings of this research. First I describe the key insights from academic institutions, businesses, and governments, as well as share insights from stakeholder interviews. Also, I discuss methods for integrating the proxy carbon price into financial decisions and investigate the sensitivity of the proxy carbon price with respect to other financial costs. Next, I describe the method of using Lifecycle Cost calculations to contextualize the carbon price among other financial metrics. I deploy the proxy carbon price through a pilot project of the Washburn House Retrofit. Additionally, I articulate the method of using the proxy carbon price as a metric for valuing avoided carbon damages. I demonstrate the proof of concept of this method for the possible sale of Renewable Energy Credits (RECs). Additionally, I describe the key insights from the qualitative research of internal stakeholders and articulate the growing support for the Proxy Carbon Price Strategy at Smith College.

Then, in Chapter V: Conclusions and Recommendations section, I tie together the key findings from my background research, external collaboration with other academic institutions, engagement with stakeholders at Smith College, and the results of the pilot projects. I provide 8 recommendations for Smith College regarding a Proxy Carbon Price Strategy for Smith College.

The final Chapter is on Future Work. I outline projects for future student engagement with the proxy carbon price strategy. Additionally, I provide suggestions for future research to improve upon the precision of the Smith College Proxy Carbon Lifecycle Cost Excel tool. This thesis is just the beginning of experimenting with proxy carbon pricing at Smith College.

Chapter II: Background

Section A: Carbon emissions are an Environmental Externality

The climate is changing on Earth at an unprecedented rate, marking a shift in geological epochs to the Anthropocene (Schwägerl, 2011). Consuming fossil fuels to power the modern world produces greenhouse gases (GHGs) such as carbon dioxide, which in high atmospheric concentrations will produce dangerous changes in the Earth's climate system (IPCC, 2014; Stern, 2008; UNFCCC, 2016). Not only will these changes impact ecosystems and biodiversity, but they will also impact society and the economy. For instance, projected sea level rise is likely to result in lost real estate and changes in precipitation are likely to change agriculture yields (IPCC, 2014, Union of Concerned Scientists, 2017). In economic terms, these damages are known as a negative externality because the individual actions of consuming carbon goods imposes direct, unintentional, and uncompensated effects on the well being of society (Nordhaus, 2015; Keohane and Olmstead, 2009).

Typically, free markets are an efficient mechanism to distribute goods throughout an economy and are also a functional tool to determine the price and quantity of a good. Specifically, Pareto efficiency occurs at the point where the marginal cost of production curve (supply) intersects with the marginal benefit of consumption (demand)). However, if there are negative externalities associated with a good, then the market price for the good does not reflect the true cost to society (Nordhaus 2015, Keohane and Olmstead, 2009, Stern, 2008). In the case of a negative externality, markets will produce too much of the good because the marginal cost curve is too low as it only reflects the costs of production and does not include the cost of external damages. For carbon emissions, the negative externality is typically represented by the social cost of carbon emissions (Nordhaus, 2015).

In order to correct the market failure and internalize the negative externality, the marginal cost curve should be raised to the social marginal cost curve to reflect the true cost of production or consumption (Keohane and Olmstea, 2009). In effect, this would result in a new equilibrium at the point of efficiency where the social marginal cost curve (supply) intersects with the marginal benefit of consumption (demand). For carbon emissions, the point of efficiency occurs where the marginal social cost of carbon plus the private marginal cost curve intersects with the marginal benefit of consumption of fossil fuels. Overall, this would reduce the quantity of the harmful carbon emission to the efficient point for society where the marginal costs equal the marginal benefits.

In the case of carbon emissions, determining the social marginal cost of one metric ton of carbon dioxide equivalent is a challenging task because the multitude and magnitude of economic damages of climate change are relatively uncertain. In theory it can be done, however in practice the price is difficult to determine (See Chapter II: Section C). Nevertheless any price greater than zero is better than completely omitting the social cost of carbon emissions. A postive price on carbon emissions will result in a more efficient allocation of capital that better internalizes the negative externality of climate change into financial decisions.

Section B: Strategies to Internalize the Externality

Putting a price on carbon is one strategy to correct the market failure of the negative externality of carbon emissions and account for the climate costs of burning fossil fuels in financial decisions (Nordhaus, 2015; World Bank, 2017; Cassidy, 2016). Increasingly governments are using carbon prices to encourage polluters to find cleaner, lower carbon alternatives (Cassidy, 2016, World Bank, Ecofys, 2017). There two primary methods that governments are: cap and trade policies and carbon taxes (See Chapter: II, Section D).

On a smaller scale, carbon pricing is gaining traction in businesses and institutions as they incorporate a carbon price into their organizations to guide financial decisions and to acknowledge the social cost of carbon. This is known as an internal carbon price. There are two primary models for internal carbon pricing: a revenue neutral carbon fee and a proxy carbon price. Both models have the goal of internalizing the cost of carbon emissions into the finances of the institution, but they differ in the details.

This thesis investigates these carbon price models to provide a recommendation for the internal carbon price model for the institution of Smith College. The Study Group on Climate Change recommended a proxy carbon price strategy for Smith College (SGCC, 2017). Nevertheless, I asked the research question which carbon pricing model is best suited for Smith College? For summary of the comparison between a carbon fee and a proxy carbon price see Figure 2.

A revenue neutral carbon fee applies a financial fee proportional to the carbon content. Then the revenue from the carbon fee is returned equally to balance the budgets. Other times the revenue is used to finance capital projects. This model functions like a regulatory carbon tax and focuses on operational expenditures. The data needs for this method are high because it impacts the budget of every utility user and requires building metering infrastructure to measure the carbon content. Furthermore, this method has a high administrative overhead because staff must measure the change in annual carbon emissions from the baseline of carbon emissions to calculate the carbon fee and then return the dividend (Yale Carbon Charge Task Force, 2017).

A proxy carbon price is a virtual, internal metric to acknowledge carbon emissions in financial decisions. A proxy carbon price creates an assumed cost proportional to the amount of carbon equivalent emissions for an investment or capital project. It is important to note that a proxy carbon price is a virtual price that values carbon emissions but does not impose an actual fee and, consequently, does not generate revenue (Gillingham, 2017). The data needs for this method is selective for projects and does not require metering infrastructure. The proxy carbon price method does require thorough organization and reporting of financial and carbon emission records. The proxy carbon price method is scalable from individual projects to campus-wide evaluations.

A proxy carbon price sends a price signal to decision-makers that reflect the climate cost of carbon emissions on the environment, society, and the institution. The proxy carbon price illustrates the social cost of carbon alongside other traditional financial metrics, making it easier for decision makers to see the full impact of their decisions (Swarthmore, 2017). It is a way to acknowledge carbon emissions in financial decisions and highlight cost and carbon saving projects. Additionally, the proxy price can be used to illustrate the value of avoided climate damages. Furthermore, it can also incentivize more consistent and cost-effective emission abatement than alternative approaches such as renewable energy procurement targets or internal efficiency standards (Morris, 2015). Therefore, the proxy carbon price can be used as a tool to transition to a low-carbon institution.

The proxy carbon price strategy is also a way to identify financial risks associated with future climate regulation. Smith College is located in Northampton, Massachusetts, an area that is already in a carbon pricing cap and trade system known as the Regional Greenhouse Gas Initiative (RGGI, 2018). Additionally, the Commonwealth of Massachusetts is currently proposing three carbon tax bills (MA legislature, 2018). As climate regulation grows in the Commonwealth of Massachusetts, Smith College must consider the financial risk of carbon assets. [2]

Another financial risk of the 2030 carbon neutrality commitment called the American College and University President's Climate Commitment (ACUPCC) (SCAMP, 2010). After this date any carbon asset on campus must be eliminated or offset, through the purchase of carbon offsets. Therefore, any carbon asset on campus after 2030 has an associated financial risk that will impact the Operating Budget and Capital Plan. An internal proxy carbon price is a strategy to manage the financial risks associated with carbon assets currently on campus, such as a building or vehicle. Ultimately a proxy carbon price can be incorporated into financial planning to mitigate the financial risk of carbon from new, long-term capital decisions.

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[2] A carbon asset is any infrastructure, vehicle, electricity, or other source that emits carbon emissions and is owned by the institution.

Ultimately, a proxy carbon price is an environmental economic strategy to better understand the impact of carbon emissions on the environment, society, and the College. This internal carbon pricing strategy also has the benefits of being able to manage the financial risks of carbon assets and highlight opportunities to transition to a low-carbon institution. On the other hand, the carbon fee models a revenue neutral carbon tax, which requires greater overhead and institutional infrastructure.

Figure 2 – A comparison of revenue neutral carbon fee and proxy carbon price models.

	Revenue Neutral Carbon Fee	**Proxy Carbon Price**
Net Charge	Net of carbon fee and rebate	Virtual Price
Function	Carbon Tax	Lifecycle cost criteria, willingness to pay for avoided carbon emissions
Institutional Scale	Institution Wide	Specific Projects
Primary Institutional Focus	Operations	Planning
Institutional Scale	Campus	Capital Project Alternatives
Institutional infrastructure	Building metering	N/A
Impact	Broad (if effective)	Targeted
Timeline Focus	Present Emissions	Future Emissions
Administrative Overhead	High	Scalable

Section C: Government Carbon Price Policies

There are two primary approaches governments around the world use to price carbon: cap and trade policies or carbon tax policies. Cap and trade, also known as an emissions trading system (ETS), is a market approach designed to cap emissions and distribute tradeable permits to private industry. The cap can be set to achieve emission reduction targets or simply to cap emissions to prevent them from rising. Looking to a local example, the Regional Greenhouse Gas Initiative, is a cap and trade system covering New England (RGGI, 2018). Another primary approach for governments to put a price on carbon is to apply a carbon tax. An advantage of this method is that it sends a stable price signal to private industry which can allow businesses and individuals to integrate the price into business models and money management to reduce financial risk.

These carbon price policy options allow private industry to choose to reduce emissions to avoid paying or continue business as usual emissions and pay a fee. There is the risk that the carbon price selected by these government policies significantly undervalue the cost of carbon without proper management. Nonetheless, any price above zero is an improvement from entirely ignoring the social cost of carbon emissions.

However, is is imortant to note that these polices are regressive, which means that the imposed fees have a greater distributional impact on low income groups (Paul, 2015). To mitigate the regressive nature of the carbon tax, governments can recycle the revenue to society through direct rebates, tax reductions, or community investments.

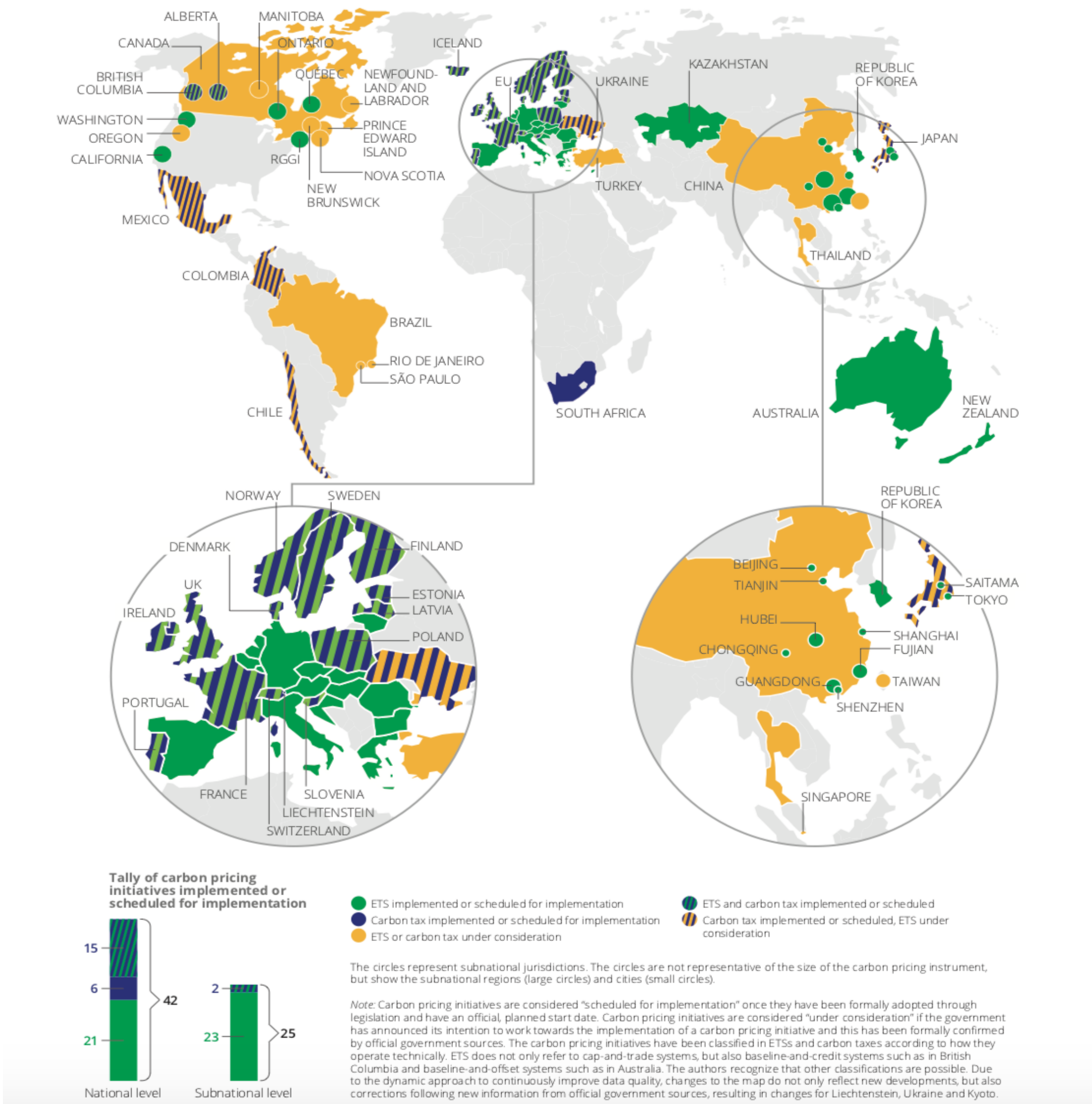
Table 1 Tradeoffs between the government policy options: Carbon Tax and Cap & Trade policy options.

	Carbon Tax	**Cap and Trade**
Price Signal	Stable	Fluctuates
Selecting the Price	Carbon price set by the government	Set at the general equilibrium of the cap and trade market
Emissision Reduction	Based on behavior changed induced by the carbon tax	Reduction set by the cap

Government Carbon Price Policy Around the World

In November of 2016 the United Nations Framework Convention on Climate Change marked the beginning of a new era of global action against climate change with the Paris Agreement (UNFCC, 2016). Countries around the world have committed to the voluntary agreement to cooperate in reducing emissions, through Nationally Determined Contributions (NDCs). Over the next few years governments around the world are likely to implement domestic and regional emissions trading systems (ETSs) as well as carbon taxes to achieve NDCs of the Paris Climate Accord. Since 2016 there have been eight new carbon pricing initiatives around the world that include carbon taxes and cap and trade policies on state, regional, and national levels (World Bank, Ecofys, 2017). For example, China has been experimenting with a cap and trade policy in a sub-regional level and is now preparing to expand the ETS pilot project to cover the entire country, making it the largest carbon pricing initiative in the world (World Bank, 2017). Governments around the world are interested in developing carbon pricing as a strategy to meet global commitments such as the NDCs to the Paris Agreement, and also, to signal private industry to transition to a carbon constrained world.

Figure 3- Carbon price policies around the world. Source: World Bank and Ecofys, 2017



As of 2017, over 40 national and 25 subnational jurisdictions are pricing carbon emissions, covering about 15% of global emissions or 8 gigatons of carbon dioxide equivalent as shown above in Figure 3 (World Bank, EcoFys, 2017). All of the countries within the European Union, plus Norway, Iceland, and Liechtenstein are covered by an emission trading scheme. This totals to about 45% of all European Union emissions. Down in the South Pacific, New Zealand also has an emissions trading scheme, and Australia implemented a safeguard mechanism of the Emissions

Reductions Fund (ERF) to cover about half of the nation's emissions (World Bank, EcoFys, 2017).

Government Carbon Price Policies in the United States

The 2016 United States election of President Donald Trump marked a shift away from progressive environmental policy and climate action. The new administration has decided to rescind the commitment to the Paris Agreement, to dismantle the Clean Power Plan, and weaken the power of the Environmental Protection Agency (EPA) (Executive Order, 13783). Following these sweeping decisions, the opportunity for carbon pricing on a national level in the near term has essentially evaporated.

For these reasons, it has become increasingly important for subnational governments to take climate action and maintain existing environmental policies. Over a decade ago the state of California enacted AB 32, the Global Warming Solutions Act, which includes a cap and trade system for greenhouse gas emissions (California Legislature, 2006). During the summer of 2017, the state reaffirmed its jurisdiction to cap carbon emissions (California Legislature, 2018). On the other side of the country, a collection of New England states came together in 2012 to implement the Regional Greenhouse Gas Initiative (RGGI), which also is a cap and trade system for carbon emissions (RGGI, 2018).

Recently, there has been some interest in the development of state carbon pricing policies. In the state of Massachusetts there are currently three proposed carbon pricing bills, which are gaining traction from local activists and policy makers (Our Climate, 2017; Goldstein-Rose, 2018). The three proposed carbon tax bills are: *An Act relative to creating energy jobs* (HB 3473), *An Act combating climate change* (SB1821) and *An Act to promote green infrastructure, reduce greenhouse gas emissions, and create jobs* (SB1726) (MA Legislature, 2017). The states of Utah, Washington, Maryland, New York, Hawaii, Rhode Island, Vermont, Maine, as well as Washington, D.C. have all proposed carbon tax bills, but none have been implemented to date (Davenport, 2018). Additionally, Oregon is proposing a cap and trade system to mitigate carbon emissions (Resources for the Future, 2017). While a national carbon price policy in the US is unlikely due to political feasibility, there are subnational carbon pricing schemes being proposed or are already implemented.

Section D: Businesses around the World

Businesses are using an internal carbon price for many reasons as the risks of climate change and carbon regulation continue to grow. In 2017, over 1,300 companies around the world disclosed plans or current practices of putting a price on carbon emissions (CDP, 2017). There is a positive trend of more businesses implementing a carbon price into business strategy, including an 11% increase from 2016 (CDP, 2017). Even big oil companies like BP and Shell are using an internal carbon price as the risks of climate change and carbon regulation become apparent.

Incorporating an internal carbon price into business strategy is a way to manage the financial risk of regulation in a carbon constrained world. Recent government action around the world to implement carbon price policies is stimulating businesses to use an carbon price to model regulatory carbon pricing scenarios (CDP, 2017). This is particularly relevant for global companies that must consider multiple governments that are likely to price carbon. Additionally, any business that has a carbon commitment or goal must either reduce emissions to that level or purchase carbon offsets. An internal carbon price can model the financial risk of not meeting a carbon commitment or the financial risk of carbon regulation.

Another reason businesses are using a carbon price in business strategy is to highlight economic opportunities to transition to a low-carbon company (CDP, 2017). The technology revolution presents many opportunities for research and development into energy efficiency, renewable energy, and other sustainable transition tools. The implications of using a carbon price in business strategies are apparent through the examples of Microsoft and Disney. Microsoft invents technology to accelerate the transition to a low-carbon economy and also applies "a financial cost to the carbon impact of our operations, to provide justification to prioritize efficiency...across the organization" (CDP, 2014). Alternatively, Disney does not invent transition technology, but instead uses a carbon price to progress sustainable initiatives while simultaneously having three consecutive years of record-setting financial performance (CDP, 2014).

Business are also using an internal carbon price to increase their social capital. A recent report by the Carbon Disclosure project found that "Companies that use internal carbon prices are signaling to investors that they are aware of the risks posed by climate change to society and their own companies" (CDP, 2017). Investors are looking to companies to refine their operations to be more environmentally sustainable as more people become aware of the dire impacts of climate change.

Integrating a carbon price into business strategy is a way for businesses to illustrate their commitment to combating climate change and gain social capital.

Section E: Academic Institutions

Academic institutions are using an internal carbon price to align campus operations with the mission of education and sustainability. The primary role of universities and colleges is to educate future leaders, entrepreneurs, and inventors with knowledge and critical thinking skills (Winslade, 2017). Traditionally, colleges have been centers of innovation and experimentation before integrating a new idea throughout society (Weisbord et al., 2012). Climate change poses unique challenges because it is a complex problem that interacts with physical systems and socioeconomic systems. Because of the dynamic and interdisciplinary nature of this problem, solving it will require innovative solutions.

Academic institutions can fulfill their role as centers for education by engaging students in experiments on the emerging strategy of internal carbon pricings. Additionally, academic institutions will benefit from aligning campus operations with sustainable financial decisions described by theories taught in environmental economics courses. Furthermore, internal carbon pricing is one strategy to lower carbon emissions and make more informed financial decisions to align with the sustainable initiatives at institutions. Internal carbon pricing is worth testing, especially because there is very little peer-reviewed literature on the topic. (Gillingham et al., 2017, Barron and Parker, 2018).

There are two primary methods to apply a carbon price within institutions, which are a proxy carbon price and/or a revenue neutral carbon fee (Figure 2). By implementing an internal carbon price, academic institutions are fulfilling their role as a thought leader for the complex, urgent problem of climate change. Academic institutions can use their reputation and privilege of being innovative leaders and experiment with carbon pricing and share their cutting edge results with the world.

Section F: Carbon Price Values

A crucial piece of information for the Proxy Carbon Price Strategy for Smith College is a value for the proxy carbon price. Carbon emissions are considered a negative externality because the social cost of carbon emissions are not captured by market prices for fossil fuels (Stern, 2018). In a perfect world, the externality is a knowable and fixed value but the world is complex and constantly changing. Therefore, it can be a challenge to determine the proxy carbon price value. The selected Smith College proxy carbon price signifies the institutional value of the negative externality of carbon emissions in the unit of dollars per one metric ton of carbon equivalent emissions ($/MTCO_2e$).

This background section outlines the various approaches for estimating the price of carbon, which are: Integrated Assessment Models, government policy carbon prices (carbon tax bills as well as cap and trade systems), carbon offset market prices, and academic institution carbon prices. Chapter IV: Section C: Selecting the Smith College Proxy Carbon Price discusses the various approaches to select the proxy carbon price for Smith College.

Integrated Assessment Models

One common strategy to determine the proxy carbon price is to model socioeconomic systems in the context of climate change through Integrated

Assessment Models (IAMs) (Nordhaus, 2015). IAMs model the complex world using climate change predictions and socioeconomic damage modules. The key damage variables within many IAMs are flooding, storm damage, heat-related mortality and increased medical costs, lost agriculture product, increased energy costs, and loss of biodiversity (National Academy of Science, 2017). These damages are quantified in financial terms and then translated into an estimate of the social cost of carbon emissions per one metric ton of carbon equivalent emissions.

Because Integrated Assessment Models provide future projections, they require a discount rate to value the cost of carbon over time in net present values. The discount rate represents the value of future generations as compared to the present generation (Nordhaus, 2015). This is a highly contentious variable and significantly alters the value of a carbon price. A very low discount rate suggests that the future is worth nearly the same as the present, whereas a very high discount rate suggests that the future is worth much less than the present. A justification for a high discount rate it that economic growth and technological advances will prepare the future for climate changes. However, the mounting threats of climate change combined with economic uncertainty in a constantly changing world may suggest a lower discount rate (Weitzman, 2013).

A review of the literature suggests that many IAMs underestimate the true social cost of carbon (World Bank, 2017, Howard, 2014, Stern 2013, Stanford 2015). For example some IAMs altogether neglect some critical variables like widespread biodiversity losses, ocean acidification, large migration movements, as well as vulnerable turning points of irreversible damage (Howard, 2014). With so many variables with uncertainty it can be a bit like looking through "a fuzzy telescope" (Nordhaus, 2015). While there are uncertainties in these estimates of the social cost of carbon, they are better than the alternative, which is zero.

The United States federal government under the Obama administration tasked the Interagency Working Group on the Social Cost of Carbon (IWG-SCC) with determining the uniform federal price of one metric ton of carbon dioxide equivalent emissions (IWG-SCC, 2016). The IWG-SCC reviewed three cutting edge Integrated Assessment Models: DICE, FUND, and PAGE. The IWG-SCC suggested a range of carbon prices roughly between \$10 per $MTCO_2e$ to \$100 per $MTCO_2e$ as shown in Table 2 (IWG-SCC, 2016). The range is a result of calculation of the carbon price with various climate and socioeconomic variables on the global scale (National Academy of Sciences, 2017). The range of prices is a direct result of the different discount rates applied to the calculation.

The Trump U.S. administration has revised the rate of the social cost of carbon to include only domestic variables and has selected a high discount rate of 7%. In effect, this has caused a much lower value of the social cost of carbon that does not capture the full cost. Additionally, the Trump administration also disbanded the Interagency Work Group on the Social Cost of Carbon (Executive Order 13783, 2017).

Table 2- Interagency Working Group on the Social Cost of Carbon 2018 estimates from the 2016 update Technical Support Document Update. The conversion of $2007 to $2017 was completed using the Bureau of Economic Analysis implicit price deflator Gross Domestic Product (GDP) values for 2007 and 2017 (Bureau of Economic Analysis, 2018).

Discount Rate	$2007/MTCO$_2$e (as reported by IWG-SCC)	$2017/MTCO$_2$e
2.5%	$60	$70
3.0%	$40	$46
5.0%	$12	$14

A recent study on an IAM by Stanford suggests a significantly higher carbon price of $220 per MTCO$_2$e (in 2014$) (Moore and Diaz, 2015). This is a particularly interesting case because the researchers used the gro-DICE version of the DICE model, which was also used in the federal study. This IAM estimate is unique because it accounts for increased vulnerability of developing countries in the context of climate change. Additionally, this approach integrates climate damages into economic growth rate estimates, which effectively slows the rate of economic growth. This is an important difference from most models because it does not assume that climate damages can be overcome by economic growth (Moore and Diaz, 2015).

Government Carbon Prices

Another approach for determining the carbon price is to turn to government carbon price policies. Smith College is located in the Commonwealth of Massachusetts, which currently has three proposed carbon tax bills, which are: *An Act relative to creating energy jobs* (HB 3473), *An Act combating climate change* (SB1821) and *An Act to promote green infrastructure, reduce greenhouse gas* *emissions, and create jobs* (SB1726) (MA Legislature, 2017). These bills all propose a carbon tax with a moderate carbon price that escalates over time as shown in Table 3.

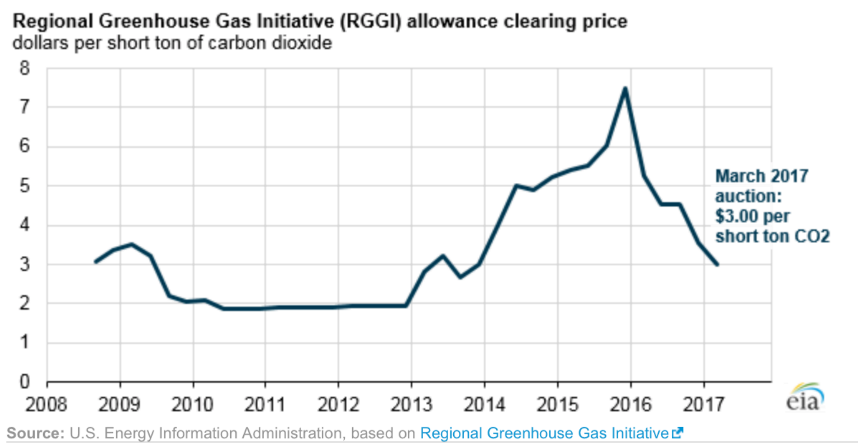
Table 3 Commonwealth of Massachusetts Proposed carbon tax bills in the Commonwealth of Massachusetts. The carbon prices begin with a weak price signal that steadily grows over time to a minimum of $40 per MTCO$_2$e.

Commonwealth of Massachusetts Bill	Initial Price ($/MTCO$_2$e)	Price Trajectory ($/MTCO$_2$e)
SB 1821	$10	Increase $5/year up to $40
HB 1726	$20	Increase $5/year up to $40
HB 3473	$15	Increase $10/year

Additionally, the Commonwealth of Massachusetts participates in a cap and trade system for the electricity sector in the Northeast, which is called the Regional Greenhouse Gas Initiative (RGGI) (RGGI, 2018). The cap and trade system operates by selecting a maximum amount of allowable carbon emissions (cap) and then allocating tradable permits for one metric ton of carbon equivalent emissions. Electricity distributors can only emit carbon emissions for which they have a permit, otherwise they must purchase carbon permits on the RGGI market (RGGI, 2018).

The price signal from this market price is much weaker when compared to other estimates (Figure 4). The weak price signal is a result of a policy choice to cap emissions at 2012 levels, rather than reduce emissions to a greater degree. Recent developments in energy efficiency, clean technology, and renewable energy integration contribute to the steady decline in emissions in the region resulting in a cap that is too high. As a result, the demand for emission allowance permits fell and consequently, the auction price dropped to a low value of about $3.00 per MTCO2e in 2017, as shown in Figure 3 (RGGI, 2017). This price is unlikely to capture the full social cost of carbon. Nor is it likely to influence consumer behavior significantly because it is a weak price signal.

Figure 4- Regional Greenhouse Gas Initiative (RGGI) is a cap and trade system for the electricity sector in the Northeast. Notice that the price signal is low and fluctuates over time due to market mechanisms.



Looking to other countries with a carbon pricing schemes also offers a range options for the price (Table 4). Sweden has the highest carbon tax in the world at $140 per $MTCO_2e$; France is at $36 per $MTCO_2e$ (World Bank and Ecofys, 2017). One of the largest cap and trade systems in the world is the European Union Emissions Trading Scheme to cap carbon emissions, which was auctioning permits at about US$7 during 2017, reaching a peak of US$9.90 $MTCO_2e$ in July (European Union Emission Trading Scheme, 2017). It is likely that countries will need a higher carbon price signal as they seek deeper reductions in accordance to the Paris Climate Accord (World Bank and Ecofys, 2017).

Table 4: Carbon Prices of select carbon taxes and cap and trade schemes of European countries in 2017.

Country	Price per $MTCO_2e$
Sweden, carbon tax	$140
France, carbon tax	$36
European Union Emissions Trading System (EU-ETS)	$7

Carbon Offset Market Price

Another method to determine the price for carbon is to use the market price for carbon offsets. A carbon offset represents the emission reduction of one party that is purchased by another party in order to compensate for an equivalent amount of emissions. To be considered a valid carbon offset the emission reduction must be additional, which means that the reduction would not occur without the investment to reduce carbon emissions. Also the carbon emissions must be permanent (Terrapass, 2018). The price of the carbon offset varies based on the location of the project and the project quality (Conte, 2010). The quality can vary by the type of project (i.e. afforestation or energy efficiency investment) and the significance of the co-benefits resulting from the project to reduce carbon emissions.

Offsets are typically measured per metric ton of carbon dioxide equivalent emissions and can be purchased in international markets. The price of carbon offsets range from as low as $2 per $MTCO_2e$ to over $70 per $MTCO_2e$ as documented in Table 5 (Conte, 2010). Smith College experimented with generating carbon offsets locally through the Community Climate Fund, which had a price of $32.70 per $MtCO_2e$, but the feasibility to generate enough offsets to compensate for emissions is unlikely.

Table 5- Carbon offset market prices

Carbon Offset Market	2018$ per $MTCO_2e$	Source
Local	~$30 to $40	Community Climate Fund
Global	~$2 to $70	Carbon Catalog

Academic Institution Carbon Prices

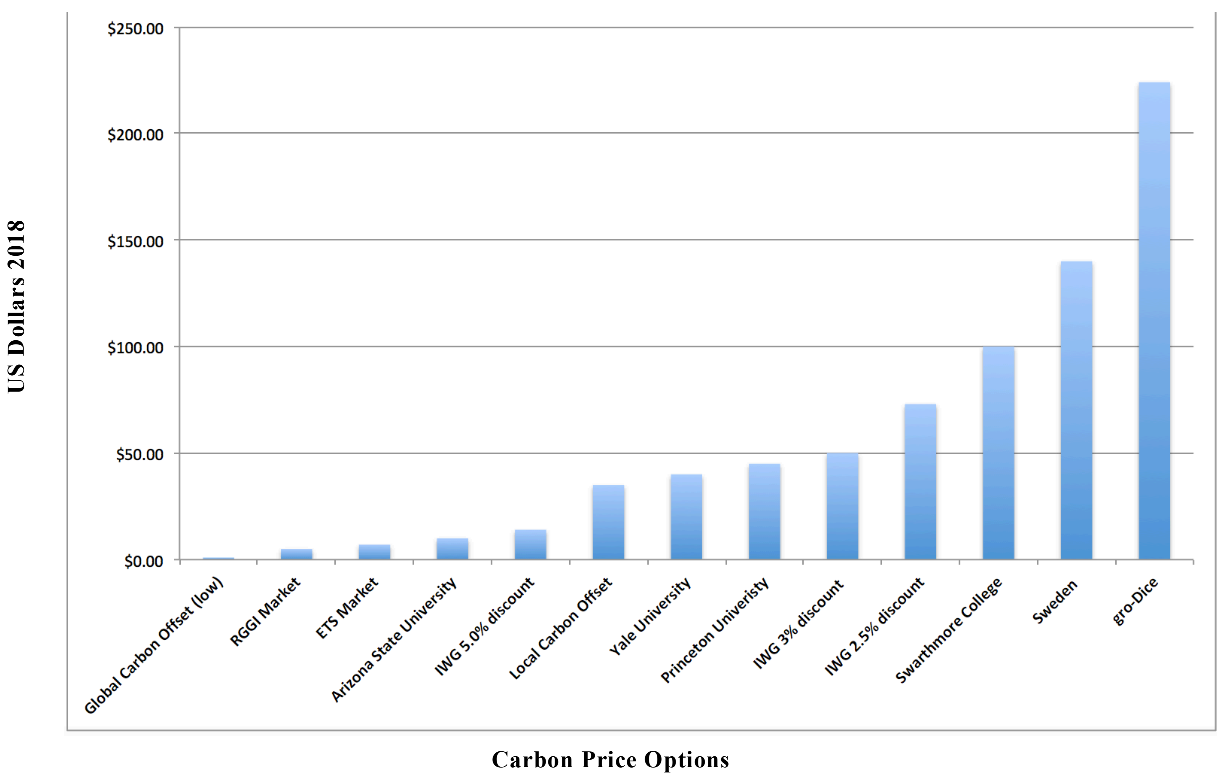
Another approach for selecting the carbon price is to turn to peer academic institutions in the United States that have already established a carbon price (Table 6). Yale University launched the Carbon Charge at $40 per $MTCO_2e$ in July of 2017 (Gillingham, et. al, 2017). This is a fixed carbon price (Picket, 2018). Princeton University began using a proxy carbon price in 2008 with a carbon price at $35 per $MTCO_2e$ value. Then, the price was raised to its current value of $45 per $MTCO_2e$ (Weber, 2017). Arizona State University just began experimenting with proxy carbon pricing at a price of about $10 per $MTCO_2e$ (Dalyrmple, 2018). It is likely that ASU will raise the carbon price, but nothing has been established officially. Swarthmore College has the highest carbon price of known academic institutions with a carbon price at a value of $100 per $MTCO_2e$ (Swarthmore, 2017). The Swarthmore Carbon Charge Committee selected this price in 2016 and has remained the same.

Table 6: United States Academic Institution carbon price values.

Academic Institution	2017$ per $MTCO_2e$
Yale University	$40
Princeton University	$45
Swarthmore College	$100
Arizona State University	$10

To summarize, a carbon price represents the value of the negative externality of climate change known as the social cost of carbon. In theory this value can be determined, however, in practice there is a wide range of estimates for the value of one metric ton of carbon equivalent emissions as shown in Figure 4.

Figure 5- Carbon Price Value: There is a wide range of carbon price estimates which are illustrated in ascending order.



Chapter III: Methods

Section A: Process and Project Development

This Environmental Science & Policy honors thesis pursues scholarship through interdisciplinary student research. The overarching research question of this thesis is how can Smith College acknowledge carbon emissions in capital decisions and other financial decisions? The purpose of the proxy carbon price is to internalize the negative externality of the social cost of carbon emissions into financial decisions. This thesis explores strategies for using the proxy carbon price. Additionally, it demonstrates the proof of concept of two methods for using the proxy carbon price through pilot projects.

These methods integrate the Strategic Plan initiative to use the Campus as Classroom because the thiss involves a distinctive interplay between campus operations and student engagement. Campus as classroom is an approach to teaching that connects students and faculty to real-world challenges through experiential and applied opportunities (Strategic Plan, 2016). Furthermore, this thesis seeks to find solutions to the urgent problem of climate change.

Prior work by the Smith College Study Group on Climate Change (SGCC) enabled me to complete this project. President Kathy McCartney tasked the SGCC with examining how Smith College could most effectively respond to the global challenge of climat change (McCartney, 2015). In response the SGCC published a report in 2017 with a series of recommendations, including, “Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision- making processes” (SGCC, 2017).

Smith College asigned onto the Higher Education Carbon Pricing Endorsement Intiative through Our Climate (Page, 2017). Additionally, the College committed to a carbon neutrality goal of 2030 through the American & University Presidents' Climate Commitment (ACUPCC) (SCAMP, 2010). The SGCC recommendation and these commitments collectively laid the foundation for my thesis *Design a Proxy Carbon Price to Strategy for Smith College.*

To begin this research, I first asked the background research questions: "What is a proxy carbon price and how does it operate? Who in the world is carbon pricing right now? And, what approaches might inform the Proxy Carbon Price Strategy for Smith College?" To answer these questions I completed a thorough literature review of proxy carbon pricing as a strategy to mitigate carbon emissions. Specifically, I investigated how academic institutions, businesses, and governments around the world are using a carbon price.

Next, I narrowed in on academic institutions that are actively carbon pricing. So I asked the research questions: "What carbon pricing strategies are other academic insitutions using and why? What can I learn from the experiences of other academic institutions and apply to the Smith College Proxy Carbon Price Strategy?" To conduct the qualitative research to answer these questions, I attended the 2017 Advancement of Sustainability in Higher Education (AASHE) Conference in San Antonio, Texas, to collaborate with other carbon pricing leaders at Yale University, Princeton University, and Swarthmore College.

Next, I turned inward to investigate the current practices of Smith College in order to determine where and how to incorporate a proxy carbon price into financial decision-making. Therefore, I asked key stakeholders which were decision makers in Facilites Management and Finance & Administration: "What are the current practices for evaluating capital projects and long-term investments at Smith College? Do you have any suggestions or concerns about the plan to design a Proxy Carbon Price Strategy for Smith College?"

My background research and collaboration with Swarthmore College suggested that integrating a proxy carbon price with a Lifecycle Cost (LCC) method was very useful for evaluting capital projects (Swarthmore, 2017). Through interviews with key stakeholders in the insitution I learned that the current practice of capital project evaluation does not include a LCC. Therefore, I had to ask another set of research questions directed at key stakeholders within the institution: "Should Smith College incorporate LCC evaluations into capital projects?" The positive response led me to the research questions, "What tool should Smith College use to calculate the proxy carbon price? What are the parameters for this analysis at Smith College?" These questions required qualitative research through internal and external collaboration as well as detailed quantitative research of Smith College data and Energy Information Agency data.

The final stage of this thesis was to actually apply the proxy carbon price to pilot projects at Smith College. Therefore, I asked the research question: "What type(s) of projects are best suited for experimenting with proxy carbon pricing? What is the sensitivity of energy cost with respect to the proxy carbon price?" To answer these questions, I conducted two pilot projects: Washburn House Retrofit and Renewable Energy Credit Procurement. The Washburn House Retrofit pilot project applies the method of Proxy Carbon Lifecycle Cost calculations, whereas the Renewable Energy Credit Procurment pilot project utilized the method of using the proxy carbon price to demonstrate the value of avoided carbon emissions resulting from an investment.

Section B: Qualitative Research Methods

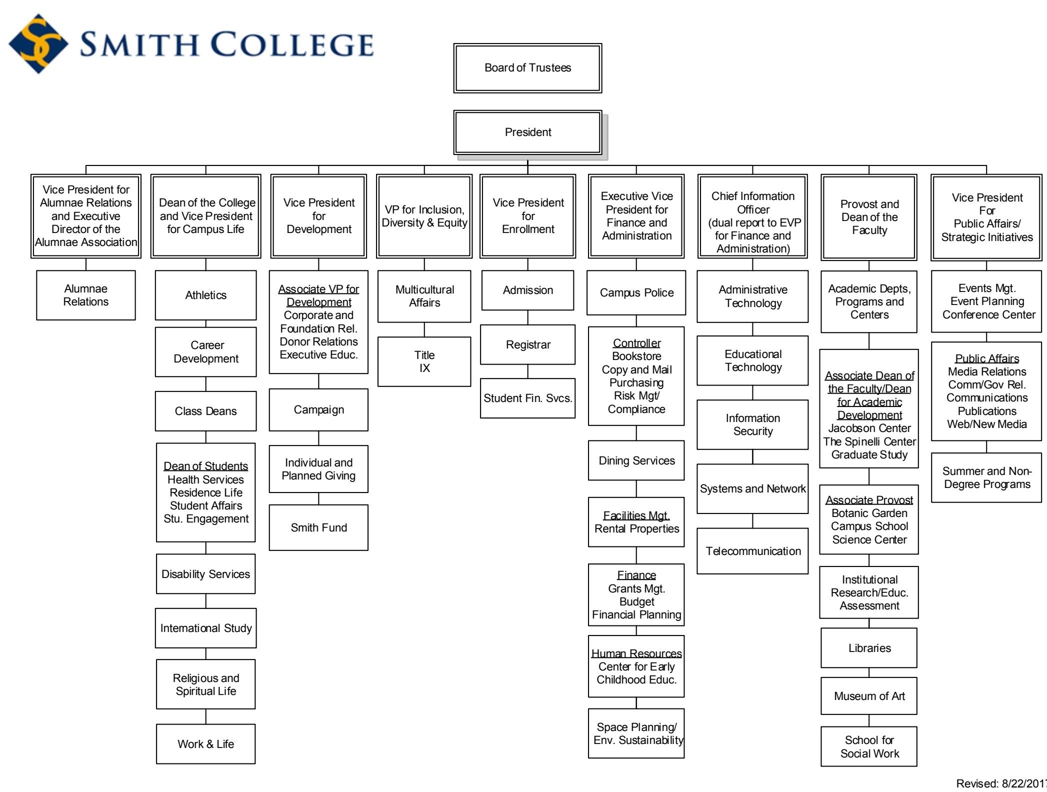
Internal Stakeholders

A primary goal of this thesis was to create a Proxy Carbon Price Strategy specifically for Smith College. To fulfill this goal I needed to tailor the strategy to the needs of the institution and integrate it into the current practices. This thesis represents the co-creation of research through collabortion with faculty and staff because I engaged with stakeholders from the early stages of research to the final days of writing this research.

During the process of engaging stakeholders, I held in person interviews with 16 people on campus. I used the RAPID framework to identify which stakeholders to meet with and to determine their role in the development of the Proxy Carbon Price Strategy for Smith Collge. RAPID was originally developed by Bain & Company to assist in designating roles project management and complex decision making that involves many stakeholders (Bain & Company, 2006). The *Harvard Business Review* gave a positive review of this framework for clarifying decision roles and assigning responsibility in project management (Rogers, 2006). The roles are not mutually exclusive so key stakeholders in the institution play multiple roles in the project framework.

To assign roles to key stakeholders, I used the Smith College Organization Chart, the staff directory, and advice from my advisors (Figure 7). The primary focus within the Organizational Chart was the branch of Executive Vice President of Finance and Administration. Specifically within this branch I engaged with members of Facilities Management, Finance & Administration and Campus Sustainability & Planning.

Figure 6- Smith College Organization Chart. All stakeholders were in the branch of the Executive Vice President of Finance and Administration. Source: Smith College, 2017



In the RAPID framework (Table 7) , the R represents the "recommend" role, which provides the recommendation for the decision at hand. The A represents the "agree" role which is the group of people who must be in agreement about the recommendation for decision. The P represents the "perform" role which is the group of people who will put the recommendation into action. The I represents the “Input” role which supplies the information to develop the recommendation. The D represents the “Decide” role which is the group of people with the most power to decide if the recommendation should be put into action. It is also the responsibility of the Ds to ensure execution of the recommendation to meet the goals of the project or decision at hand.

Table 7- RAPID framework to identify key stakeholders within the administration of Smith College.

Recommend	● Breanna Parker ● Advisors: Alex Barron, Dano Weisbord, Susan Sayre ● Committee on Sustainability (institutional carbon price)
Agree	● **Sustainability Staff** ○ Dano Weisbord ● **Faculty** ○ Susan Sayre (ENV, ECON) ○ Alex Barron (ENV) ● **Facilities Management** ○ Associate Vice President ■ Roger Mosier ○ Energy Manager ■ Matt Pfannstiel ○ Capital Construction Director ■ Peter Gagnon ○ Project Manager ■ Charlie Conant (Senior PM) ○ Facilities Business Director ■ Karl Kowitz ● **Finance and Administration** ○ Executive Vice President Finance & Administration ■ Mike Howard ○ Associate Vice President for Financial Planning ■ David DeSwert
Perform	● **Facilities** ○ Capital Construction Director ■ Peter Gagnon ○ Facilities Business Director ■ Karl Kowitz ○ Facilities Operations Director ■ Karla Youngblood

	○ Energy Manager ■ Matt Pfannstiel ○ Project Managers ■ Charlie Conant (Senior PM) ■ Morgan Wilson ■ Brandy Fagan ○ 3rd party contractors ● **Finance and Administration** ○ Associate Vice President for Financial Planning ■ David DeSwert ● **Sustainability Staff (Management & Update)** ○ Director of Campus Sustainability & Space Planning ■ Dano Weisbord ○ Campus Sustainability Coordinator ■ Emma Kerr
Input	● **Sustainability Staff** ○ Director of Campus Sustainability & Space Planning ■ Dano Weisbord ○ Campus Sustainability Coordinator ■ Emma Kerr ● **Faculty** ○ Assistant Professor of Economics ■ Dr. Susan Stratton Sayre ○ Assistant Professor of Environmental Science & Policy ■ Dr. Alex Barron ○ Associate Professor of Engineering ■ Dr. Denise McKhan ● **Facilities Management** ○ Facilities Business Director ■ Karl Kowitz ○ Facilities Operations Director ■ Karla Youngblood ○ Vice President ■ Roger Mosier ○ Energy Manager ■ Matt Pfannstiel ○ Capital Construction Director ■ Peter Gagnon ● **Finance and Administration** ○ Executive Vice President Finance & Administration ■ Mike Howard ○ Associate Vice President Financial Planning ■ David DeSwert

Decide	● **Facilities** ○ Associate Vice President ■ Roger Mosier ● **Finance and Administration** ○ Executive Vice President Finance & Administration ■ Mike Howard ○ Associate Vice President Financial Planning ■ David DeSwert ● **President** ○ Kathy McCartney ● **Board of Trustees**

All of the internal stakeholder engagement was conducted through in-person semi-structured interviews that lasted approximately one hour each. All stakeholders that were interviewed for this qualitative research gave verbal and/or signed consent to participate in the study [3]. During these meetings I asked questions and fostered a space for ideas to develop into dialogue (Questions can be found in Appendix 1, 2). These meetings were not recorded, but I did take notes on the key points and answers to my questions.

During the Fall Semester of 2017 I primarily met with the stakeholders in the Input role of the RAPID framework. This round of interviews had the primary goal of understanding the current practices of making capital decisions. Additionally, the first round of stakeholder engagement was an opportunity to explain the concept of proxy carbon pricing and to ask stakeholders if they were familiar with the concept of carbon pricing. Furthermore, through individual meetings, I created a space for

[3] The Smith College Institutional Review Board (IRB) concluded that "the IRB does not need to review this project because 'the interview questions are about campus purchasing and capital planning policies and do not ask for the individual's attitudes or beliefs about the policies.'" The IRB did recommend receiving informed consent prior to conducting the interviews, which I did. Additionally I took the CITI ethics training prior to conduction interviews on October 11, 2017.

stakeholders to request features and make suggestions about the design of the proxy carbon price strategy.

During the Spring Semester of 2017 I primarily met with stakeholders in the Agree and Decide category. Most of these were group meetings within departments (i.e. Facilities Management). This round of interviews had the primary purpose of updating stakeholders on the research and development of the proxy carbon price tool and framework. In particular, I worked in close collaboration with the Energy Manager to determine the parameters for the tool. Broadly, the stakeholder interviews during the spring semester was an opportunity for stakeholders to provide feedback and ask questions.

External Stakeholders

I attended the annual Association for the Advancement of Sustainability in Higher Education (AASHE) Conference in San Antonio, Texas during the preliminary stages of my research. This proved to be very useful because I was able to collaborate with other carbon pricing leaders at academic institutions early in the developmental stage of the Proxy Carbon Price Strategy. Additionally I attended the workshop, "Carbon Pricing & Higher Ed: Internal Carbon Fees, Shadow Prices for LCA, Engaging Beyond the Campus."

While at the conference, I interviewed the carbon price policy representatives from Yale University, Princeton University, and Swarthmore College. I met with each of them individually, in person, to ask questions regarding the carbon pricing policy at their respective institution (Pickett, 2017; Winslade, 2017; Weber, 2017; Graf, 2017). The style of the interview was semi-structured to allow ideas to transform into dialogue. These interviews were not recorded, but I took notes on the key points and answers to my questions. Upon return to Smith, I continued collaboration through e-mail with carbon pricing leaders at Yale University, Princeton University, and Swarthmore College for additional information during the design and development phase of the proxy carbon price strategy.

Each interview lasted about 45 minutes to an hour and was composed of about 10 questions; these questions were the same for each interview (Appendix 3). At the beginning of each interview I first explained the goals and objectives of my thesis to *Design a Proxy Carbon Price stategy for Smith College*. Then, I began asking questions regarding the details of their carbon pricing strategy. The key pieces of information that I needed to know what the value of the carbon price, the carbon price model, and the types of decisions that it applies to. Additionally, I asked if there were any examples or key insights they could offer from their experience with carbon pricing. Finally, at the end of each interview I asked for their contact information and for any advice they had to offer.

Also at the AASHE conference I attended the workshop, “Carbon Pricing & Higher Ed: Internal Carbon Fees, Shadow Prices for LCA, Engaging Beyond the Campus” on October 18, 2017 with Dr. Alex Barron. The workshop was led by Aurora Winslade, the Director of Sustainability, and Nathaniel Graaf, the Climate Action Senior Fellow, both from Swarthmore College, and Casey Pickett, Director of the Carbon Charge at Yale University. The workshop began with presentations on the different carbon pricing models that each school was experimenting with. Workshop attendees were encouraged to collaborate and discuss strategies for integrating a carbon price into the financial plans of their respective academic institutions.

Section C: Adapting the Harvard Lifecycle Cost Calculator for Smith College

I adapted the Harvard Lifecycle Cost Calculator (Harvard LCC) to the specifications of Smith College to create the Proxy Carbon Lifecycle Calculator (Proxy Carbon LCC) using Excel. This tool calculates the future and present costs to understand the Lifecycle Costs over a 20 year study period (Harvard, 2018).

It was necessary to adapt the internal variables of the Harvard LCC calculator to the specifications of the institution because utility rates and greenhouse gas content vary by source (EIA, 2018; Verly, 2018). To adapt the Harvard LCC Calculator, I interviewed the Sustainability Coordinator at Harvard University, Caroleen Verly on March 1, 2018 (Verly, 2018). I called the Sustainability Coordinator for a 30 minute interview to discuss the function of the Harvard LCC and the adaptation (Harvard Readahead, 2018). Additionally, I collaborated with the Smith College Energy Manager, Matt Pfannenstiel, to establish institutional variables for the Proxy Carbon LCC.

The adaptation process for the the Proxy Carbon Lifecycle Excel tool involved data content changes to align with institutional and regionally specific data as well as aesthetic changes to promote the institutional brand. The variables of the utility rates, escalation rates, and carbon emissions were modified to the Smith College specifications because they vary according to campus infrastructure, the region, fuel source, and escalation rate. Additionally, I created a new tab called "Charts" to visualize the costs of each option. In this tab I created a stacked bar chart to illustrate the initial net cost, operating & maintenance costs, utility costs, and the proxy carbon costs. The lifecycle costs are displayed in net present value terms over the 20 year study period. Each of these cells are linked to the data within the calculator (as specified in the Excel comments for each cell) so that the charts will be propogated simultaneously.

Marginal Utility Cost by Source

To begin the adaptation process, I first needed to identify the utility rates, escalation rates, and carbon emissions that were specific to Smith College. My primary sources for these data were *Smith College Historical Utility Data speadsheet*, *Smith College Master GHG spreadsheet* ,and the United States Energy Information Agency (EIA) databases (Pfannenstiel, 2017; Kerr, 2017; Energy Information Agency, 2016, 2017). Then, the data was organized into a spreadsheet that can be found in Appendix 4.

Once the rates were established, the data were changed within the respective cells in the tab labeled "Price GHG Detail." Additionally, the labels for the utility columns of "Details_Baseline," "Details_Alt A," and "Details_Alt C" were also changed. The final adaptation was for aesthetics; the Smith College logo was inserted at the top of the calculator to promote the institutional brand.

To determine the marginal cost for heat and electricity I used the institutional rates for Smith College. These rates are unique to Smith because the College has an Combined Heat and Power plant (CHP) on campus. The CHP produces steam for a turbine to produce electricity and then uses the steam to heat the buildings on campus. These marginal costs for heat and electricity were obtained from the records kept by the Energy Manager within Smith College Facilities Management department (Pfannesteil, 2017).

Chilled water for cooling is produced through a dual source of commercial electricity and steam from the CHP. To create chilled water the cogeneration plant produces electricity to power four electric chillers and steam to fuel two absorption chillers on campus. This dual source system does not have metering, which makes it very difficult to determine the marginal prices and greenhouse gas content. For the purpose of this pilot phase this project, the rate was estimated at $1.92/ton-day. To calculate this value I used Smith College data analyzed by GreenerU to find the electricity consumption per ton hour. Then I multiplied that by the cogeneration rate of electricity and by 24 hours to find the rate per ton-day (Adamian, 2018). This number should be revised as outlined in Future Work.

The marginal costs of the remaining variables of commercial electricity price, fuel oil number 2 and 6, as well as transportation diesel and gasoline were derived from the U.S. Energy Information Agency (EIA) databases (Appenix 4). The EIA data varied in availability by geographic precision and most recent update. The fuel oils data were selected at the national scale, the transportation diesel data were selected at the New England scale, and the transportation gasoline data were selected at the Massachusetts scale. Another small gap in data was the fuel oil #6 because the EIA only had data available up to 2016, while the others had more recent updates of 2017. I chose to use the best available data for each source, rather than maintain consistency across the geographic scale and time in the database. Nevertheless, I maintained consistency of the source through the EIA database.

Escalation Rates by Source

Perhaps the most challenging part of adapting the Harvard LCC calculator was estimating the escalation rates. An escalation rate is an estimate of the change in price of a good or service over a given period of time. The escalation of each variable is located in the column denoted "MTCDE" on the "Price GHG Detail" tab of the LCC spreadsheet.The formula for estimating an escalation rate can be derived from the formula to calculate compound interest, where P_2 is the present value, P_1 is the past value, t is the time between P_2 *and* P_1 and e is the escalation rate over the given period of time.

Equation 1- Escalation Rate

$$P_2 = P_1 (1+e)^t$$

$$\frac{P2}{P1} = (1+e)^t$$

$$\left(\frac{P2}{P1}\right)^{1/t} = 1+e$$

$$\textit{Escalation rate} = \left(\frac{P2}{P1}\right)^{1/t} - 1$$

To conduct the analysis, three data sources were used in order to determine the appropriate estimate of the escalation rates for utilities, labor, materials for the life cycle cost calculator. The first method used historical data from Smith College to determine the increase in price of water, electricity and natural gas. The second method used data from the United States Energy Information System (EIA) for commercial electricity, fuel oil #2, fuel oil #6, and transportation gasoline. The third method used the Consumer Price Index for Urban Consumers (CPI-U) from the Bureau of Labor Statistics for the variables of materials and labor (2018).

The reason why this historical analysis is limited to utilities is purely because that was the only available data for analysis. Specifically, the time period 2010-2016 was selected to estimate the escalation because natural gas prices were relatively stable during that time period. Extending the period beyond 2010 could be misleading due to the external influences of the spread of hydraulic fracturing for natural gas in the United States and the 2008 economic recession. The natural gas projection is particularly relevant to Smith because the CHP plant on campus uses natural gas. Consequently, the fluctuations in price of natural gas became embedded into the institutional prices of electricity and steam because of the CHP plant. For consistency, Smith historical data over the same time period was used to estimate the escalation rates for water and electricity.

To be consistent among methods, the federal estimates based data from the United States Energy Information System (EIA) on the of escalation rates for commercial electricity, fuel oil #2 and #6, and transportation gasoline were selected over a seven-year period from 2010-2016. Another reason for choosing a seven-year time period is because the longer the time period for estimating an escalation rate, the greater the uncertainty. Essentially, the farther into the future escalation rates project, there is a greater likelihood for fluctuations in price due to global trade, resource shortages or surpluses, and unexpected events like the 2008 economic recession.

For the purpose of this study the escalation rates of labor and materials was derived from the Consumer Price Index for Urban Consumers (CPI-U) from the Bureau of Labor Statistics to identify the inflation rate for the most present year

(Bureau of Labor Statistics, 2018). The CPI-U is a measure of the average change of prices of goods and services paid by urban consumers (Bureau of Labor Statistics, 2018).

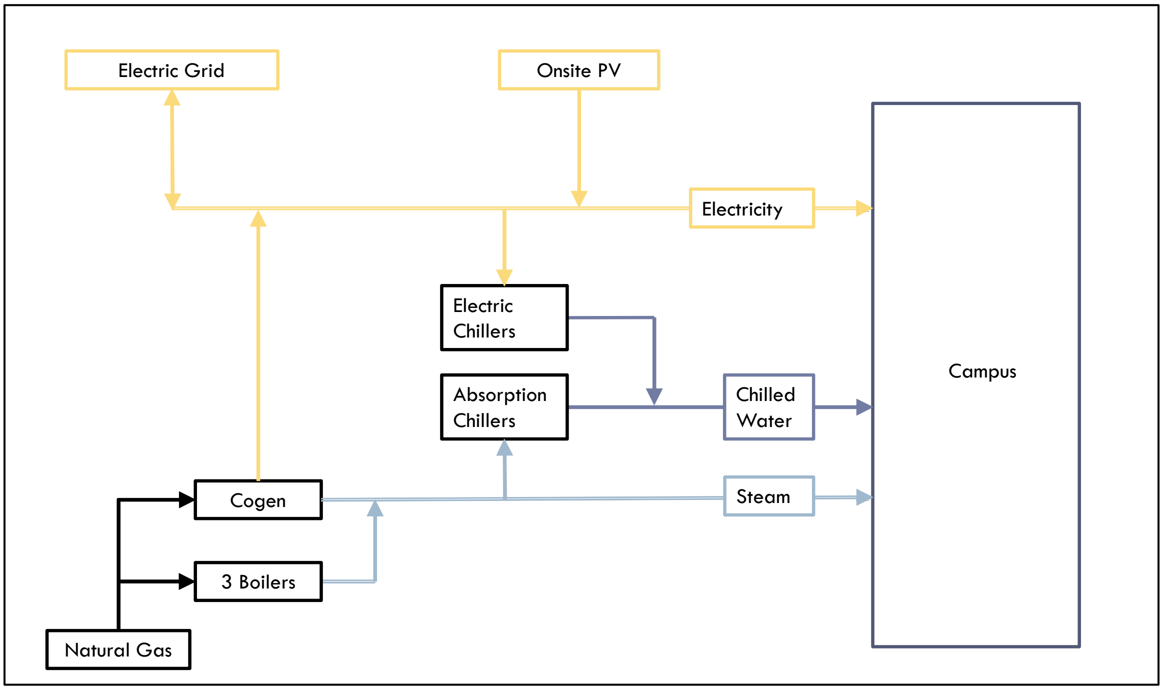
Carbon Emission Rates by Source

The purpose of the proxy carbon price is to place a monetary value on emissions that contribute to climate change in order to value them in project evaluations. To do so, it is essential to know the carbon emission rate of each variable of the Proxy Carbon Lifecycle Cost Excel tool. The marginal of each variable is located in the column denoted "MTCDE" on the "Price GHG Detail" tab of the Proxy Carbon LCC spreadsheet.

A question relevant to identifying the carbon emission rate for utilites at Smith College is: how does the design of the campus's energy infrastructure alter the carbon emissions for electricity and steam? The campus has a combined heat and power plant (CHP) that operates to produce electricity and steam for heat as illustrated by Figure 8. This infrastructure design accentuates the need to use institutional rates for carbon emission rates. However, the precise carbon emission rates for electricity and steam to produce heat had not been determined at the time of this study (Pfannenstiel, 2018).

Figure 7- A schematic of the Smith College Combined Heat and Power (CHP) plant.

Source: Smith College Consulting Engagement for Scamp 2.0 from the Energy Manager, Matt Pfannesteil.



To determine estimates for the carbon emission rate of the CHP, I collaborated with the Energy Manager, Matt Pfannenstiel. We used the Greenhouse Gas protocol tool "Allocation of Emissions from a Combined Heat and Power (CHP) Plant" to identify emissions deriving from the Smith College CHP (Greenhouse Gas Protocol and World Resource Institute, 2006). An assumption we made was to use the total energy of steam and an enthalpy value that aligned with water vapor. Additionally, we made the assumption to only use the primary source of natural gas and omit the contribution of the fuel oil to determine the carbon emission rate of the CHP. Therefore, this is a conservative estimate that should be refined as outline in Chapter V: Future Work.

The first step to determing the carbon emission rate deriving from the CHP was to determine the total carbon emissions of the CHP. To do so, we used the total natural gas in the most recent year in units of cubic feet as criteria for the Greenhouse Gas protocol tool "Allocation of Emissions from a Combined Heat and Power (CHP) Plant". Please note that for the year of 2017, the Power Plant Report estimated the efficiency of the CHP incorrectly because the main meter was off by 8% when compared to the utility meter (Pfannenstiel, 2018). To adjust the value, a factor of 1.08 was used to account for the meter discrepancy.

The next step was to break down the carbon emissions into the outputs of electricity and steam for heat. For the purpose of the pilot phase the chilled water carbon emissions was assumed to be equivalent to the Harvard estimate and was not calculated using Smith data because it is not used very often and the production process is very complicated which makes it very time consuming to determine. This number should be refined by future work. The total annual quantity of steam and of electricity was identified from Spreadsheet data and converted into the common unit of MMbtu.

Once the total quantity of steam and electricity was found, the two primary outputs were added together to determine the total energy output of the CHP. The next step was to find the percent of energy used to produce steam or electricity (Equation 1.2). Finally, Equation 1.3 describes the carbon emission rate for steam as a proportion of the total emissions resutling from energy production (Equation 1.3). The last calculation brought the outputs together again to find the carbon emission rate of the CHP overall in units of $MTCO_2e$ per MMBtu (Equation 1.4).

Equation 2- Percent of Energy to Produce a MMbtu of steam at the Smith College CHP plant

$$Ps = \frac{Ts}{Tchp}$$

Equation 3-Effective Marginal Carbon Emissions of Steam at the Smith College CHP plant

$$Effective\ Marginal\ Carbon\ Emissions\ of\ Steam = \frac{Ps * Gchp}{Ts}$$

Equation 4- Carbon equivalent emissions from the Smith College CHP plant

$$Carbon\ equivalent\ emissions\ of\ CHP = \frac{Gchp}{Tchp}$$

Where,

Ps=Percent of Energy to produce steam

Ts=Annual Total Steam

Tchp=Annual Total Energy CHP

Gchp=Annual Total Greenhouse Gas CHP

The same methods were used to determine the carbon emission rate for electricity.

The carbon emission rates for the remaining variables of commercial electricity, fuel oils, and transportations fuels were obtained from the Office of Campus Sustainability Records (*GHG Master Spreadsheet,* 2017; Emma Kerr, 2018). These institutional values were derived from the University of New Hampshire Campus Carbon Calculator. A key variable that is dependent on the region is the carbon emission rate of commercial electricity because ISO-NE has a lower fossil fuel intensity than the national grid (ISO-NE, 2016). One modification was made to the transportation diesel because the campus fleet uses B20 diesel, which is a biofuel blend that has a smaller carbon emission rate than traditional diesel (*GHG Master Spreadsheet*, 2017).

Section D: Pilot Projects

This section describes the methods for two proxy carbon price pilot projects: Washburn House Retrofit and Renewable Energy Credit Procurement. These pilot projects will respectively demonstrate the proof of concept of using the Proxy Carbon Lifecycle Cost Calculator method and the proxy carbon price to demonstrate the value of avoided carbon emissions resulting from an investment.

Washburn House Retrofit

The Washburn House Retrofit pilot project used the Proxy Carbon Lifecycle Cost Calculator method to analyze three options: 1) Existing Baseline, 2) retrofit to seal the envelope of the building prevent thermal convective loss, and 3) retrofit to seal the envelope and insulate the walls to improve the thermal blanket. The data needed for the calculator is the initial cost, the replacement cost (if it differs from the initial), the operating and maintenance costs, the annual utility demand, and the anticipated lifetime of the project.

For the purpose of this pilot project the escalation rate for steam (the energy source that will be impacted by the retrofit options) was 3.34% and the institutional discount rate was 4.00% (Pfannesteil, 2017; DeSwert, 2017). The current Facilities practice is a payback period for energy efficiency projects is a 5-year payback period (Pfannesteil, 2017). The proxy carbon price for this pilot project was $70 per $MTCO_2e$ (Committee on Sustainability, Parker, 2018).

The cost and energy data for this pilot project was derived from an engineering thesis by Etta Grover Silva which was supervised by the Associate Professor of Engineering, Dr. Denise McKahn (Grover-Silva, 2010). The utility energy data of the Grover-Silva thesis are likely to be reliable because the results were verified using actual metered data on heating energy consumption for a full heating season in 2016-2017 for Lawrence and Morris houses. The post-retrofit consumed within 5% of the predicted amounts using the categorical method (McKahn, 2018).

Specifically, I used the data from the *Graphs* spreadsheet for initial cost and the utility data for thermal energy demand (steam from CHP) (Grover-Silva, 2010). There was not data on the operating and maintenance costs so they were assumed to be zero to avoid fabricating data. Also, the anticipated lifetime was not given by the data so it was assumed to be 21 years to avoid the replacement cost and retaining value over the 20-year Proxy Carbon Lifecycle Cost calculation. Also it is important to note that the initial costs for each retrofit option were in $2010. Therefore, I had to convert the costs into $2017. To do so I used the Bureau of Economic Analysis GDP deflator factor for 2010 and 2017 (Table 8). Furthermore, there is a risk that these data are out of date, but it was the best available data for these specific retrofit options.

Table 8- The conversion of costs from 2010$ to 2017$ of each Washburn Retrofit option.

	2010	**2017**
GDP deflator	100.5	112.8
Initial Cost: Sealing	$1,800	$2,019
Initial Cost: Sealing + Insulating the Walls	$12, 095	$13, 567

Table 9- Annual energy use of each Washburn retrofit option.

Option	Thermal Energy Use (MMBTU/year)
Baseline	645
Sealing the envelope	537
Sealing the envelope and Insulatig the walls	428

Once the data had been collected for Table 8 and 9, I then used the "Input" tab of the Proxy Carbon Lifecycle Cost Calculator. It is important to note that I included the proxy carbon price value of \$70/ $MTCO_2e$. Then, I analyzed the data using the "Results" and "Charts" tab of the Proxy Carbon Lifecycle Cost Calculator.

Renewable Energy Credit Procurement

The Renewable Energy Credit (REC) Procurement evaluation utilized the proxy carbon price to demonstrate Smith College's value of avoided carbon emissions resulting from the RECs. A REC certifies ownership of one Mega-Watt-hour of renewable electricity and has a market value in units of dollars per Mega-Watt-hour (\$/MWh) (EPA, 2017). The standard unit from the proxy carbon price is dollars per metric ton of carbon dioxide equivalent (\$/$MTCO_2e$). Therefore, it is possible to translate the proxy carbon price into the units of \$/MWh to compare the value of the REC to the proxy carbon value of avoided carbon emissions.

Equation 5- This equation translates the proxy carbon price from the unit of $\$/MTCO_2e$ to the unit of $\$/MWh$ for equal comparison to the Renewable Energy Credit (REC) price.

$$Proxy\ Carbon\ Value\ of\ Avoided\ Carbon\ Emissions = Proxy\ Carbon\ Price * Carbon\ Emission\ Rate$$

Where,

$$Proxy\ Carbon\ Price = \frac{\$}{MTCO2e}$$

$$Avoided\ Carbon\ Emission\ Rate = \frac{MTCO2e}{MWh}$$

Because,

$$Proxy\ Carbon\ Value\ of\ Avoided\ Carbon\ Emissions = \frac{\$}{MWH} = \frac{\$}{MTCO2e} * \frac{MTCO2e}{MWh}$$

The data for the greenhouse gas emission rate was derived from the ISO-NE regional grid because the RECs would eliminate the need for commercial electricity and thus avoid the corresponding carbon emissions. The carbon emission rate for ISO-NE was 0.38 $MTCO_2e$ per MWh in 2018 at the time of this study (ISO-NE, 2018). The rate varies according to Locational Marginal Units and time (LMUs). A LMU represents the marginal unit of energy that responds to the constantly changing electrical system demand by providing the next increment of electricity (Lau and Wong, 2015).

Chapter IV: Results and Discussion

Section A: Lessons from governments, businesses, and academic institutions

Carbon pricing is an environmental economic strategy to mitigate carbon emissions. Governments around the world are considering implementing carbon price policies, especially in the wake of the Paris Climate Accord. On a local level, the state of Massachusetts has three proposed carbon tax bills, which are gaining traction.

As carbon regulation continues to grow, businesses are responding by modeling a carbon-constrained world using internal carbon pricing schemes. As of 2017, over 1,300 businesses reported that they plan to, or are already, using an internal carbon price in their business strategy (CDP, 2017). The primary reasons that businesses use an internal carbon price is to manage the financial risk of regulation and carbon commitments and to highlight opportunities to transition a low-carbon company. Furthermore, businesses are using an internal carbon price to gain social capital by indicating to investors that they are a climate conscious company.

Academic institutions are using internal carbon prices as a way to align the missions of education and sustainability to the operations of the institution. Prior to this research there was not documentation on which academic institutions use an internal carbon price. As of 2018, there are over 40 academic institutions out of 5,300 in the United States that have endorsed using an internal carbon price (Our Climate, 2016). According to the research, there are only 4 are actively using an internal carbon price, which is starkly less than the number of businesses around the world. Currently, Princeton University, Yale University, Swarthmore College, and Arizona State University are experimenting with internal carbon pricing (Yale Carbon Charge Task Force, 2016; Princeton University, 2008; Swarthmore College, 2017; Dalrympe, 2018). This results section describes the models of all active internal carbon pricing models at academic institutions in the United States as shown in Table 10. Furthermore, this section describes lessons from other academic institutions that can be applied to the Smith College proxy carbon price strategy.

Princeton University has the oldest carbon pricing policies of the academic institutions. In 2008, the University began using a proxy carbon price in capital decisions within the facilities department (Princeton University, 2008). To incorporate the proxy carbon price into financial decisions the Director of Sustainability created an Excel spread-sheet tool to calculate the lifecycle cost of operating and maintenance costs (Weber, 2017). The Excel tool calculates the present value of lifecycle costs with the proxy price, over a 60-year period. This is the only financial metric it calculates, but it also included a tab specifically for qualitative comparisons among the alternative project options.

While the Princeton carbon pricing policy has been operating for the longest time, there is currently no analysis of outcomes of using the proxy carbon price. The initial institutional carbon price was $35 per metric ton CO2e but it was later raised to $45 per metric ton CO2e. Initially, the proxy carbon price did very little to impact decisions, but later the price was raised to send a stronger price signal (Weber, 2018). However, even after the increase, the proxy price has altered very few decisions, but not zero (Weber, 2017).

It is my hypothesis that the proxy carbon price used by Princeton has only a small impact on total cost of large capital projects and, consequentionally, it has not altered many capital decisions. Furthermore, the Princeton University's calculator does not use the proxy carbon price to evaluate payback periods or other financial criteria that may alter capital decisions, which may be another reason why it has not altered any capital decisions. Without sufficient project data it is not possible to test the hypothesis.

Princeton University provided an important lesson for Smith College: Once the proxy carbon price strategy is in place, it is essential to record project data and to document the reason why particular alternatives were selected. Carbon pricing is a relatively new strategy that is worth testing and refining. In order to effectively experiment with an internal carbon price, it is important to assess the impact of the price signal. This can be done by evaluating proxy carbon priced projects retrospectively and then recording and later applying key findings.

Yale University launched the Yale Carbon Charge Project in July of 2016 to experiment with a revenue neutral carbon fee (Yale Carbon Charge Task Force. 2016; Gillingham, K., et, al., 2017) This internal carbon price model strongly aligns with the regulatory risk approach because it is designed to mimic a revenue neutral carbon tax. Furthermore, the initial price of the carbon charge was selected at $40 per MtCO2e, but is not escalating (Yale Carbon Charge Task Force, 2016).

The Carbon Charge operates by measuring the carbon emissions from each administrative unit (e.g. Chemistry Department, Provost) and levying the carbon fee on their share of emissions (Pickett, 2017).This policy structure is enabled by the use of electricity meters to record the coorresponding carbon emissions of the buildings of each administrative units. To minimize the impact on the administrative unit's budget while maintaining the carbon price signal, the revenue is rebated to be revenue neutral. At the end of each fiscal year the emissions from each administrative unit is compared to the emissions baseline. Based on performance, each administrative unit recieves their proportional rebate to mitigate the impact of the fee. If the administrative unit emissions are less than the baseline, then the rebate will be postive. An administrative unit can maximize its rebate by reducing carbon emissions significantly below the baseline, which provides a clear incentive.

A key finding from the Yale report, Preliminary Results from Learning by Doing that is applicable to Smith is, "*The combination of clear information and a carbon pricing scheme increases understanding, motivation, and action for reducing energy use at Yale"* (Yale Carbon Charge Task Force, 2016). With the right information and price signal a university can utilize the creative minds of many and lower emissions collectively. A clear benefit of a carbon pricing strategy is that it is a way to start communicating and considering carbon emissions on campus. This was also supported by Swarthmore College which emphasizes the importance of engagment and education through their shadow price policy (Winslade, 2017).

The Swarthmore Carbon Charge Program is a dual approach to carbon pricing because it utilizes both a carbon fee to departments and a proxy price to evaluate capital purchases (Swarthmore, 2017). The program began in 2016 with goals to incentivize emission reductions, to provide capital for emission reducing projects, to create a platform to educate and engage the community in carbon pricing.

Swarthmore College is also taking an activist role to build momentum for governmental carbon pricing by collaborating with Our Climate (Swarthmore, 2017; Our Climate, 2017).

Swarthmore implemented an annual charge on each department or office budget to generate capital for emission reducing projects. The Carbon Charge Committee charges a rate of 1.25% on each of office and department for their carbon use, but excludes charging individuals through salaries and benefits (Swarthmore, 2017). In the first year it totaled $340,000, which included an additional $40,000 of voluntary donations to the Carbon Charge to support sustainable projects (Winslade, 2017). The Swarthmore Carbon Charge is also revenue neutral because all of the collected fees are returned to the departments. What makes this policy different from Yale's revenue neutral carbon fee is that all departments receive equal rebates, regardless of performance.

A critique of this particular revenue neutral fee method is that the fee and rebate is not correlated to carbon emissions. Instead, the fee is equal proportion of 1.25% of the budget for each department. Because it is only a financial charge, the carbon fee does not account for emission reductions in the same way as regulatory revenue neutral carbon taxes or the Yale revenue neutral carbon fee model. For instance, if one department lowers emissions and another stays the same, they would both have the same charge. As a consequence of this design there is not a strong incentive for departments to reduce emissions because if a department lowers its emissions from one year to the next, they will be charged the same amount as a department that does not lower its emissions. Nevertheless, incorporating a carbon fee into the budget of each department is beneficial because it awknowledges carbon emissions and may stimulate discussions on carbon emission reduction strategies.

Swarthmore College also uses a proxy carbon price to evaluate capital projects as part of the Carbon Charge (Swarthmore, 2017). The shadow price provides a framework for incorporating the costs of carbon into Capital Planning and Project Management for evaluating alternatives of facilities projects (Winslade, Graf, 2017). In order to contextualize the carbon price Swarthmore conducts a lifecycle cost calculation to determine the initial and future costs over a 20-year period. For implementation, Swarthmore adapted the Harvard Lifecycle Cost analysis calculator to their institutional specifications and also to include the proxy carbon price of $100 per metric ton CO2e (Swarthmore, 2017; Winslade, 2017; Graf, 2017). At the time of this study, Swarthmore has not published any results because the policy was implemented about a year ago.

Nonetheless, Swarthmore College provided Smith College with insights on how to make the proxy carbon price functional for evaluating capital project options by integrating the proxy carbon price into a Lifecycle Cost (Winlade, 2017; Graf, 2017). Swarthmore measures the lifecycle cost over a designated study period and applies a proxy price to carbon emissions for evaulating facilities projects in Capital Planning and Project Management. Swarthmore College adopted a proxy carbon price to establish a metric for informing capital decisions. To conduct the proxy carbon price lifecycle costing evaluations, Swarthmore adapted the Harvard Lifecycle Cost Calculator, which is unique because it includes a carbon price cell.

The calculator is highly accessible because it is an Excel tool that is available online, for free.

This research found another academic instituion that is experimenting with a proxy carbon price, however nothing official has been written to date (Weber, 2018). Arizona State University (ASU) is actively experimenting with a proxy carbon price of about $10 per $MTCO_2e$ in select projects ((ASU) Dalrymple, 2018). Specifically, they are incorportating a proxy price into the financial plan for new carbon neutral buildings and EV charging stations, as well as their template for evaluating projects for the Sustainability Investment Revoling Fund (SIRF). Once the pilot projects have been evaluated, ASU will considering developing an institutional proxy carbon price strategy to help drive achievement towards sustainability goals ((ASU) Dalrymple, 2018).

Another academic that is considering, but not actively, experimenting with carbon pricing is Vassar College. The Vassar Climate Action Plan stated that the College should considering implementing an internal carbon charge (Vassar, 2016). The report suggested adopting a carbon fee or a proxy carbon price to capital project evaluations. Like Swarthmore and Princeton, Vassar would like to design a lifecycle costing tool to contextualize the proxy carbon price with other financial costs. Vassar indicated that they were likely to adopt a social cost of carbon estimate from the U.S. Environmental Protection Agency (EPA). This research could not confirm Vassar College has taken action beyond the white paper “Vassar Climate Action Plan” (Vassar, 2016).

Table 10: Academic Institutions in the United States actively using a carbon price. This table includes the policy type and year of implementation.

Academic Institution	Carbon Price Policy	Year of Implentation
Princeton University	Proxy Carbon Price	2008
Yale University	Revenue Neutral Carbon Fee	2016
Swarthmore College	Proxy Carbon Price & Revenue Neutral Carbon Fee	2016
Arizona State University	Proxy Carbon Price	2018

Section B: Insights from the Institution

Interviews with key stakeholders indicated that the current practices of evaluating capital projects at Smith College does not include a carbon price and rarely includes a lifecycle cost calculation, except for the largest capital projects, such as the Neilson Library renovation (Pfannenstiel, 2017; Gagnon, 2017; Kowitz, 2017). Instead the financial criteria for most projects are the initial price and the payback period (Pfannenstiel, 2017; Kowitz, 2017; Mosier, 2017). Additionally, there are a host of other qualitative decision metrics such as sustainability, reliability, performance, contracts, and business characteristics that are used to inform capital decisions (Kowitz, 2017). These dynamics result in a semi-structured framework for making capital decisions.

The current structure of making capital decisions is very centralized within Facilities management (Mosier, 2018). Additionally, the institutional infrastructure lacks energy metering for buildings and departments (Pfannenstiel, 2018). These factors are reasons why the College does not have individual energy budgets for each department. This differs from Yale and Swarthmore, which have decentralized budgeting and energy metering, which enables the deployment of the revenue neutral carbon fee method. The policy choice to use the proxy carbon price method is best suited for Smith College because the institution has centralized decision-making and lacks energy metering at the granular department level.

The proxy carbon price strategy is an opportunity to provide more structure to capital project evaluations in Facilities Management. In a meeting with the Project Managers, they advised that the proxy carbon price be deployed in the program and conceptual design phases of project development (Facilities Meeting, 2018). The evaluation could be completed internally be project managers or by third party contractors for long-term capital projects (Facilities Meeting, 2018; Pfannesteil, 2017).

Another observation from interviews with Smith stakeholders is that the current practice for record keeping of capital project data is not very well organized. There is a shared drive on the computers of Facilities Management that contains many folders, spreadsheets, and data. However, the data is not organized in an accessible way for everyone to locate the data they need (Pfannenstiel, 2018; Gagnon, 2017). Therefore, the current practices for data storage is not clear where information is stored and results in a lack of transparency about project information. Additionally, I noticed that some spreadsheets were not completed with all of the project information. The lack of transparency and complete record keeping proved to be a significant challenge for acquiring the necessary data for the Proxy Carbon Lifecycle Cost pilot projects.

The interest for internal carbon pricing at Smith College began in 2016 through a memo from Dr. Alex Barron, assistant professor of Environmental Science & Policy (Memo, 5-24-16). This strategy gained the support of the Study Group on

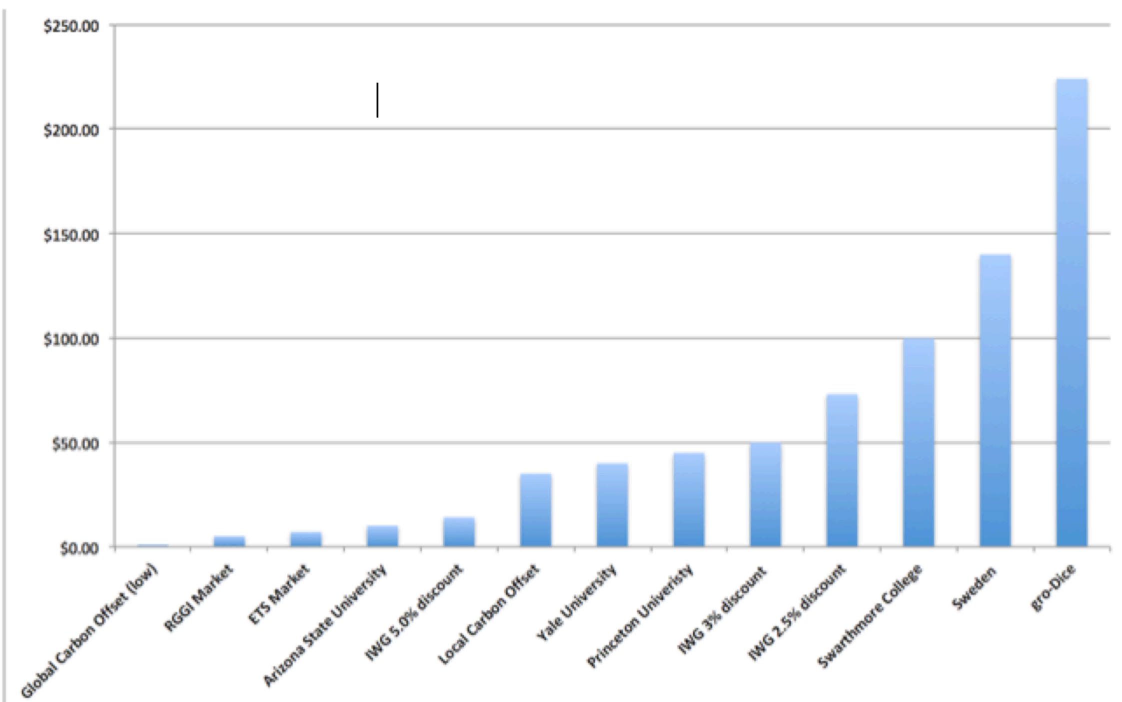
Climate Change, which included a request in the 2017 report to develop an "internalized cost of carbon- such as a proxy carbon price" to create institutional change at Smith College (SGCC, 2017). The results from qualitative interviews with stakeholders in Facilities Management Finance & Administration indicate that the foundational work for proxy carbon price at Smith College was successful because many of the stakeholders were already familiar with the concept of carbon pricing (Pfannenstiel, 2017; Gagnon, 2017; Kowitz, 2017, DeSwert, 2017; Howard, 2017). The institutional support for this thesis enabled fluid conversations that garnered further support for the proxy carbon price strategy at Smith College.

Already, the initial interest is gaining support for tangible action to implement the proxy carbon price strategy and lifecycle cost tool from key stakeholders in the Facilities Management and Finance & Administration departments at Smith College. Mike Howard communicated support of the adoption of Lifecycle Costing integrated with the introduction of proxy carbon pricing at Smith College, "Understanding the full lifecycle costs of our capital projects, including the cost of carbon, will allow the college to understand the full cost of capital projects. With this information at hand, Smith will now be able to better allocate scarce capital to projects that will have the most significant positive impact on the college in the long term" (Howard, 2018).The Capital Construction Director, Peter Gagnon shared, "I am very excited to experiment with Breanna Parker's Proxy Carbon Lifecycle Cost (Proxy Carbon LCC) calculator and will encourage my project managers to do the same. I believe with the use of the Proxy Carbon LCC calculator, Capital Projects will move forward with a more formalized analysis of the true costs of our decision making when related to new and renovation projects."

Section C: Selecting the Smith College Proxy Carbon Price Value

In order to develop the Proxy Carbon Price Strategy, Smith College must select a value for the proxy carbon price. The Smith College Committee on Sustainability met on March 28, 2018 to select the proxy carbon price for Smith College (COS Memo, 3-28-18). There is no single correct way to select the level of a proxy carbon price, but it is clear that any value is an improvement over zero. There are a wide variety of carbon price as illustrated in Figure 9.

Figure 8- Carbon prices from governments, business, markets, and academic institutions.



Carbon Price Options

There are a few strategies for selecting the proxy carbon price from the wide range of price, which include the following approaches: pragmatic, social cost of carbon, regulatory, implicit price, or aligning with peer institutions. The pragmatic approach suggests simply picking a number that works for the institutions and then refining the number as needed. The implicit price approach uses the carbon for the cost to achieve a carbon emission reduction target or goal. The social cost of carbon approach uses Integrated Assessment Models to determine the financial damage of carbon emissions on the economy and society. Aligning with peers is an approach particularly relevant to academic institutions.

The social cost of carbon approach reflects the estimate of socio-economic damages resulting from climate change (Nordhaus, 2015). In theory, this reflects the true negative externality of carbon emissions. However, in practice Integrated Assessment Models (IAMs) are used to estimate the value and include uncertainties. The Interagency Working Group on the Social Cost of Carbon estimate the social cost of carbon using IAMs. At a discount rate of 2.5% the social cost of carbon in 2018 is $70 per $MTCO_2e$ (IWG-SCC, 2016).

The regulatory risk approach to carbon pricing is used extensively by businesses to prepare for future carbon regulation. Currently, the state of Massachusetts participates in the Regional Greenhouse Gas Initiative (RGGI), which is the existing financial risk of carbon emissions (RGGI, 2018). The current market price is very near the price floor, which results in a weak price signal (~$4 per $MTCO_2e$). While a Federal climate policy seems unlikely in the next few years, there are several carbon tax bills are under consideration in the Massachusetts legislature

(MA Legislature, 2017). These proposed carbon tax bills are evidence of future regulatory risk of carbon emissions.

The implicit price approach models the cost of carbon offsets to achieve the 2030 carbon neutrality goal (Smith College, 2010). Carbon offsets are created by reducing emissions (e.g. planting trees, capturing methane) and then sold in voluntary (or regulatory) markets. However, the carbon offset price to reduce a metric ton of carbon is wide-ranging and varies based on quality and type of the offset (Forest Trend Ecosystems Marketplace, 2017). Smith has been collaborating with Hampshire, Williams, and Amherst College on the Community Climate Fund to generate local carbon offsets through investments in emission reduction projects, but the costs are higher than other voluntary offset products (Weisbord, 2017). The wide range of prices makes it difficult to narrow in on an institutional proxy carbon price. This approach results in a range of less than \$2 per $MTCO_2e$ for a low quality carbon offset to over \$70 per $MTCO_2e$ for a high quality and/or local carbon offset.

Another approach for selecting the price is to compare across the carbon prices of our peer institutions. Princeton University began using a proxy carbon price in 2008 with a carbon price at \$35 per $MTCO_2e$ (Princeton University, 2008). The price was later raised to its current value of \$45 per $MTCO_2e$ (Weber, 2017). Yale University launched the Carbon Charge at \$40 per $MTCO_2e$ in July of 2017 (Gillingham et al., 2017). Swarthmore College has the highest carbon price at academic institutions with a value of \$100 per $MTCO_2e$, which was established in 2017 (Swarthmore College, 2017). This approach results in a range of \$35 to \$100 per $MTCO_2e$.

After reviewing these approaches, Dr. Alex Barron and I recommended that Smith College select the price range of \$60 to \$70 per $MTCO_2e$. This price range is consistent with the IWG-SCC social cost of carbon estimate at 2.5% discount rate which place a higher value on the impacts on future generations and may better reflect the true social cost of carbon (IWG-SCC, 2016; Moore & Diaz, 2015). Furthermore, this price is consistent with a trajectory towards 2 degrees Celsius (Barron, 2018). This also aligns with the implicit price approach because there is a greater supply of local offsets with educational and community co-benefits at this price range. Additionally, this price will more than prepare for future climate regulation because it is higher than the carbon prices of the RGGI cap and trade system and the initial price of the proposed Massachusetts carbon tax bills. The final reason for selecting this price is because it is the "goldilocks" price between our peer institutions.

The Smith College Committee on Sustainability selected the recommended range of \$60 to \$75 per $MTCO_2e$ for the proxy carbon price on March 28, 2017. For the purpose of this thesis, I aligned with the Interagency Working Group on the Social Cost of Carbon estimate of the 2018 social cost of carbon at a 2.5% discount rate to select the proxy carbon price of \$70 per $MTCO_2e$ (IWG-SCC, 2016). As stated in the Recommendations section, the proxy carbon price should be reviewed and evaluated to ensure that it is effective.

Section D: Proxy Carbon Price Strategy Integration Methods

The following strategy describes how the proxy carbon price can be used to make informed decisions about reducing carbon emissions through a new investment.

The primary purpose of using a proxy carbon price is to acknowledge the social cost of carbon emissions in financial decisions. In general, the proxy carbon price represents the value of avoided carbon emissions resulting from an investment or purchase. For cases that include capital and operating costs, the proxy carbon price should be incorporated into the Lifecycle Cost method for financial decision-making.

A Lifecycle Cost Calculation is a standardized approach to evaluating the present and future of costs of project alternatives to make more informed decisions (Testa, et.al, 2011). Typically, an LCC includes the costs of initial price, utility, operation, maintenance, and replacement price minus the projected residual value of a project over a study period (Harvard, 2017). Incorporating a proxy carbon price into the lifecycle costing methods illustrates the social cost of the carbon content alongside other operating and maintenance costs in the common metric of money. Hereafter, the method for integrating the proxy carbon price with the Lifecycle Cost method shall be called the Proxy Carbon Lifecycle Cost method (Proxy Carbon LCC).

The Proxy Carbon Lifecycle Cost (Proxy Carbon LCC) method is particularly well suited for informing long-term decisions. The Proxy Carbon Lifecycle Cost method should be used to compare across project options that perform the same function [4](ASTM, 2017). At a minimum, this method illustrates the financial metrics of total cost of ownership and the payback period for each project option. Therefore,

[4] This method is best suited for comparing across options once the capital project has been selected. For example, this method could be used to evaluate a relighting project. The options could be the baseline of halide light bulbs, fluorescent lights, and LED. All options perform the same function of lighting a building, but have different initial costs, expected lifetimes, and energy use.

this method is especially well suited for projects with a substantial percentage of the total costs occur during operation (i.e. energy, maintenance) with respect the initial market price. (Engineering Economy, 2006; Woodard, 1997; ASTM, 2017). This method of using a proxy carbon price illustrates how the carbon price signal can indicate which option is most economically efficient when considering the negative externality of carbon emissions via the proxy price. Incorporating the proxy carbon price alters the total cost of ownership, as well as the payback period of projects, by internalizing the social cost of carbon into financial accounting.

Additionally, this method can be used to highlight opportunities to mitigate carbon emissions. A Proxy Carbon LCC evaluation would inform the decision maker if the new sustainable option has operational cost- and carbon- savings to justify the investment. The baseline “do nothing” option would not have an initial investment, but would result in higher operation costs for utilities and carbon emissions. Whereas a lower carbon investment option would have an initial cost, but would have lower operating costs for utilities and carbon emissions. Therefore, the Proxy Carbon LCC would illustrate if the cost savings from the utilities and proxy carbon price justify the low-carbon investment, with respect to the baseline “do nothing” option.

In order to conduct a Proxy Carbon LCC calculation for a capital project, a decision-maker must have a tool to evaluate the lifetime of costs. The primary reason for this is because the calculation involves escalating commodity prices over the study period and discounts the costs into present values before taking the sum of all costs, which is quite complicated and involves a lot of math. Rather than create a new LCC tool, I used the insight from Swarthmore College to adapt the Harvard

Lifecycle Cost Calculator to the specifications of Smith College (Winslade, 2017; Graf, 2017). The additional criterion that was fulfilled for the selecting a Lifecycle Cost tool was the inclusion of the proxy carbon price. A critique of this tool is that the study period is only 20 years, yet some capital projects (e.g. Buildings) have a longer lifespan (Pfannenstiel, 2017).

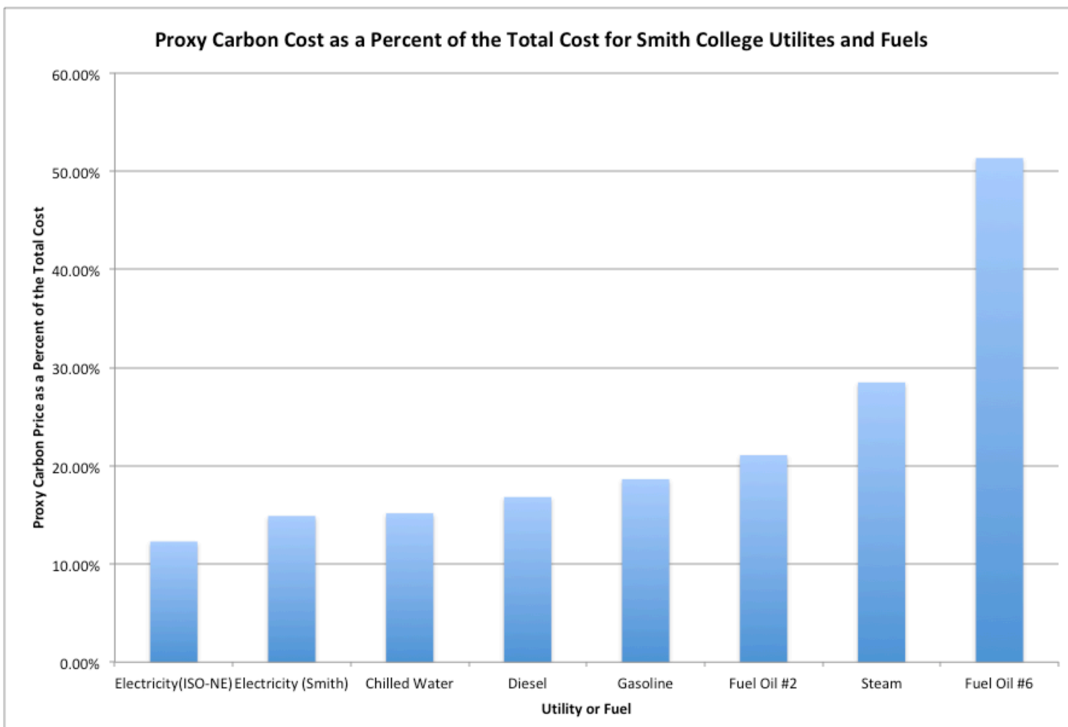
Section E: Sensitivity Analysis

The proxy carbon price can impact decisions by illustrating cost and carbon savings resulting from a low carbon option. Additional, the proxy carbon price adjusts the payback period for low-carbon options by accounting for savings resulting from a reduction in carbon emissions and the corresponding social cost of carbon. For these reasons, the proxy carbon price could tip the scale to alter some capital decisions that are made using the Lifecycle Cost method and/or the payback period. The Smith College proxy carbon price of \$70/MTCO_2e represents the institutional value of the social cost of carbon. At the proxy carbon price of \$70/MTCO_2e, what is the impact of the proxy carbon price with respect to the utility and fuel prices of the Proxy Carbon Lifecycle Cost calculation? And, what is the sensitivity of each of the variables?

The Proxy Carbon Lifecycle Cost calculator calculates financial results of capital projects over 20 year operational cost, as well as initial and replacement cost. The variables for analysis are the utilities and fuels Smith College purchases. Currently, Smith College purchases the utility and fuels of ISO-NE electricity and chilled water as well as the fuels of diesel, gasoline, fuel oil #2 and #6. Additionally the Smith College Combined Heat and Power Plant produces electricity and steam for heat using the primary fuel source of natural gas and an additional fuel source of fuel oil #6. (Pfannesteil, 11-8-17; Master Spreadsheet, 2017).

Of the operational cost variables of the Proxy Carbon LCC the greatest negative externality is fuel oil followed by steam, fuel oil #2, and transportation gasoline (Figure 10). Please note that the carbon emissions resulting from Smith electricity and steam that are produced by the Smith CHP assumes only the natural gas contribution and omits the fuel oil #6 estimate, which results in a low estimate.

Figure 9- The proxy carbon price of utilities and fuels at Smith College as a percent of the total commercial market cost and proxy carbon cost. These results should be interpreted as a per unit basis.



For energy efficiency projects, the utility and fuel savings are likely to indicate the greatest cost- and carbon- savings, using the Lifecycle Cost method. This is because the utility and fuel variables change in parallel for energy efficiency projects because the carbon emissions of the utilities result from the consumption of fossil fuels. Therefore there is benefit from conducting the Lifecycle Cost calculation for fuel efficiency projects. Furthermore, the utility savings illustrate actual cost savings to the institution.

In special cases, the difference in initial and replacement costs plus the operational cost could be very close to equal so the proxy carbon price could potentially tip the scale to incentivize the low-carbon option. Furthermore, the proxy carbon price will alter the payback period of the capital project options and may further incentivize the low-carbon option. Therefore, the proxy carbon price still has value because it acknowledges carbon emissions in financial decisions and supports utility cost-saving projects.

For fuel switching projects, the proxy carbon price is likely to have a greater impact than commercial utility and fuel savings along. This is primarily because the commercial price for utilities and fuels do not change in parallel because there are different market costs for each fuel type and different proxy carbon price for each fuel type because carbon emission rates vary be the source of fuel. Furthermore, the proxy carbon price consistently has a greater weight of the total cost of fuels than utility costs, except for steam (Table 11). Therefore, if projects switch from a fuel source with a high carbon content to a low-carbon fuel or switch to electricity, which has a much lower carbon emissions, then the Proxy Carbon LCC will indicate significant proxy carbon savings.

Table 11- Smith College uses fossil fuels for utilities to run the college. These all have carbon emissions and corresponding proxy carbon prices as well as commercial prices, denoted "energy price" in the table. The units for both the proxy carbon price of $70/MTCO_2e$ and the energy price are in the same units in the final column of this table.

Utility	Carbon Emissions	Unit of Carbon Emission by Source	Proxy Carbon Price ($70/MTCO2e)	Energy Price	Unit for both Proxy Carbon Price and Energy Price
Electricity(ISO-NE)	0.290	MTCO2e/MWh	$20.30	$145.00	$/MWh
Electricity (Smith)	0.250	MTCO2e/MWh	$17.50	$100.00	$/MWh
Chilled Water	0.005	MTCO2e/Ton-Day	$0.34	$1.92	$/Ton-Day
Diesel	0.008	MTCO2e/Gallon	$0.57	$2.84	$/Gallon
Gasoline	0.009	MTCO2e/Gallon	$0.62	$2.69	$/Gallon
Fuel Oil #2	0.010	MTCO2e/Gallon	$0.72	$2.70	$/Gallon
Steam	0.074	MTCO2e/Mmbtu	$5.18	$13.00	$/Mmbtu
Fuel Oil #6	0.011	MTCO2e/Gallon	$0.79	$0.75	$/Gallon

The data from the column labeled Proxy Carbon Price ($\$70/MTCO_2e$) is equivalent to the value of avoided carbon emissions. Therefore, these values can be used to evaluate specific investment options that do not require the use of the Proxy Carbon LCC (i.e. Renewable Energy Credits).

Section F: Pilot Projects

Washburn House Retrofit

The Washburn House Retrofit Pilot Project uses the Proxy Carbon Lifecycle Cost Calculator to evaluate two energy efficiency retrofit options with respect to a baseline "do-nothing" approach. The pilot project investigates the influence of the proxy carbon price with respect to institutional financial criteria over a 20-year study period. Current institutional practices would not calculate the full lifecycle costs and/or the social cost of carbon. This pilot project demonstrates the proof of concept of using the Proxy Carbon Lifecycle Cost Calculator to evaluate retrofit options for a building. This pilot project is scalable to other buildings on campus.

Washburn House was built in 1878 and is in need of upgrades because building is in poor condition relative other residential houses on campus (Weisbord, 2018). The building is situated near the Neilson Library, which is currently under construction for a major renovation. Because of this, there will not be any students living at Washburn House until 2021 when the renovation is complete. These circumstances present an opportunity to improve the building through renovation retrofits to make the building more energy efficient and result in cost- and carbon-savings.

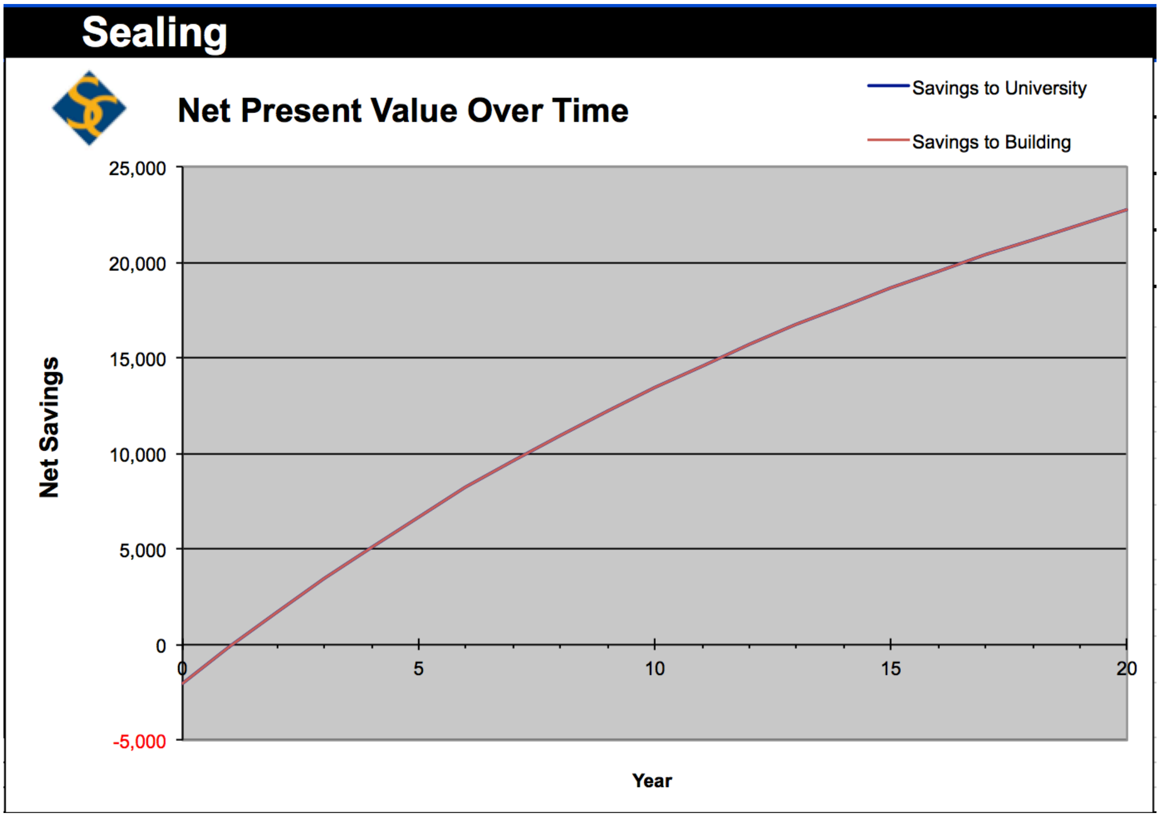
The Washburn Retrofit Pilot Project builds off of previous Smith College student research identified retrofit options for analysis. The Department of Engineering thesis “Cost Effective Efficiency Improvements of Building Thermal Envelopes” assessed opportunities for possible energy efficiency retrofit options in buildings on Smith College campus, including Washburn House (Grover-Silva, 2010). For the purpose of this Pilot Project the retrofit options selected for analysis were: Option 1) sealing the envelope mitigate convective thermal loss and Option 2) seal the envelope and insulate the walls of the building to reduce thermal loss. The retrofit options are sequential, according to standard engineering practices, which is why option 2) includes both retrofit options (McKhan, 2018).

There are three scenarios analyzed by the Proxy Carbon Lifecycle Cost Calculator: The first scenario is the Baseline “do nothing” approach, option 1) and option 2). The total cost of ownership represents the initial, and lifecycle costs, including a proxy carbon price, over a 20-year period escalated and discounted appropriately. The simple payback calculates how long in years it would take to payback the initial cost using only operational energy savings, whereas the discounted payback period calculates how long in years it would take to payback the initial cost using operational energy and carbon savings discounted to the net present value. The proxy carbon price captures the savings from the social cost of carbon, which is reflected by reduction in the discounted payback period proportional to the reduction in carbon emissions.

The baseline consumption of steam for heat is 645 MMbtu annually, which results in about 48 MTCO2e at a proxy carbon cost of $3360 in annual social damages. Over a 20-year period this would result in 960 MTCO_2e equivalent to $67,200 in proxy carbon costs. There was not an initial cost for this option because it assumes the existing conditions. The total cost of ownership for the baseline scenario of Washburn House period is $148,195.

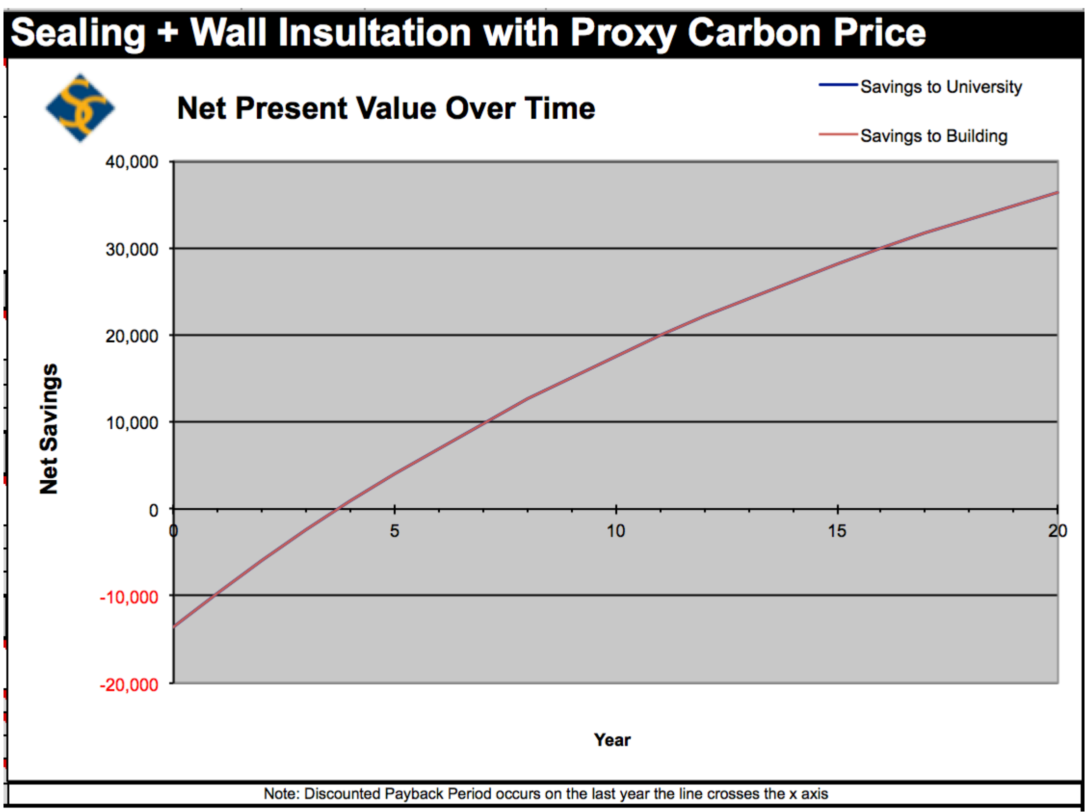
The retrofit option to seal the floors would reduce the annual consumption of steam to 537 MMbtu, and reduce carbon emissions by 17%. Selecting this option would save 160 MTCO2e over a 20-year period, resulting in a $11,130 savings of social damage as indicated by the proxy carbon price. This option has an initial price of $2,020 and a total cost of ownership of $125,440 (2017 real dollars). The discounted payback period without the proxy carbon price is about 1.5 years, well within the existing Facilities practice of a 5-year payback period. The proxy carbon reduces the discounted payback period to about 1 year, as illustrated by Figure 11. The proxy carbon price does not shift the discounted payback period to the institutional practice of a 5-year payback period. Additional data from the results page of the Proxy Carbon LCC for sealing the floors can be found in Appendix 5.

Figure 10- The Net Present Value (NPV) over time for the Washburn House retrofit option of sealing the floors. The discounted payback period occurs when the line intersects with the x-axis. This graph was created using the Proxy Carbon Lifecycle Cost Excel tool.



The second retrofit option is a much deeper retrofit that will result in greater energy savings over time, but also a higher initial cost. To seal the building and to insulate the walls would reduce the annual consumption of steam to 428 MMbtu and would also independently reduce carbon emissions by about 35%. Selecting this option would save 320 MTCO2e over a 20-year period, resulting in a $11,270 savings of social damage as indicated by the proxy carbon price. Sealing the building and insulating the walls of Washburn House has an estimated initial cost of about $13,570 and the total cost of ownership of $111,800 (2017 real dollars). The discounted payback without the proxy carbon price is about 5.5 years, just outside of the existing Facilities practice of a 5-year payback period. Applying the proxy carbon price reduces the discounted payback period to less than 4 years, as illustrated in Figure 12. The proxy carbon price shifts the discounted payback period within the existing Facilities metric of a 5-year payback period. Additional data from the results page of the Proxy Carbon LCC for sealing the envelope plus insulating the walls can be found in Appendix 5.

Figure 11- The Net Present Value (NPV) over time for the Washburn House retrofit option of insulating the walls. The discounted payback period occurs when the line intersects with the x-axis. This graph was created using the Proxy Carbon Lifecycle Cost Excel tool.



Comparing across the options to retrofit Washburn House, the initial cost ascend from Baseline of zero, to the retrofit of sealing the floors, to the retrofit of insulating the walls. The Proxy Carbon Lifecycle Cost Calculation indicates that both retrofit options to seal the floors and insulate the windows have a total cost of ownership over a 20-year period that is less than the Baseline "do-nothing approach." This is because the majority of the costs occur during operation to supply heat via steam to the residential house. Furthermore, the savings to investment ratio (SIR) for the retrofit option of sealing the floors is 12 years and for the retrofit option of insulating the walls is 2 years. The Proxy Carbon Lifecycle Cost Calculation indicate that the retrofit options of sealing the floors insulating the walls of Washburn House would benefit the institution financially in the long-run because total cost of ownership is lower than the Baseline and because the both retrofit options have a positive savings to investment ratio.

The proxy carbon price acknowledges the social cost of carbon in the capital decision and visually illustrates them on the “Charts” table as illustrated in Figure 14. As indicated by Figure 13, the Lifecycle Cost analysis, independent of the proxy carbon price, would illustrate a lower TCO for the two energy-saving retrofit options with respect to the baseline. The proxy carbon price reduces the discounted payback period for both retrofit options. The discounted payback period for the retrofit option to seal Washburn House is within the current Facilities practice of a 5-year payback period, independent of the proxy carbon price. The discounted payback period for the retrofit option to seal and to insulate walls of Washburn was altered by the proxy carbon price to be within the current Facilities practice of a 5-year payback period.

Figure 12- This bar graph compares the 20 year total cost of ownership of the three options for the Washburn House Retrofit analysis using only the initial cost and the utility cost of steam. This bar graph was created using the Proxy Carbon Lifecycle Cost Excel tool.

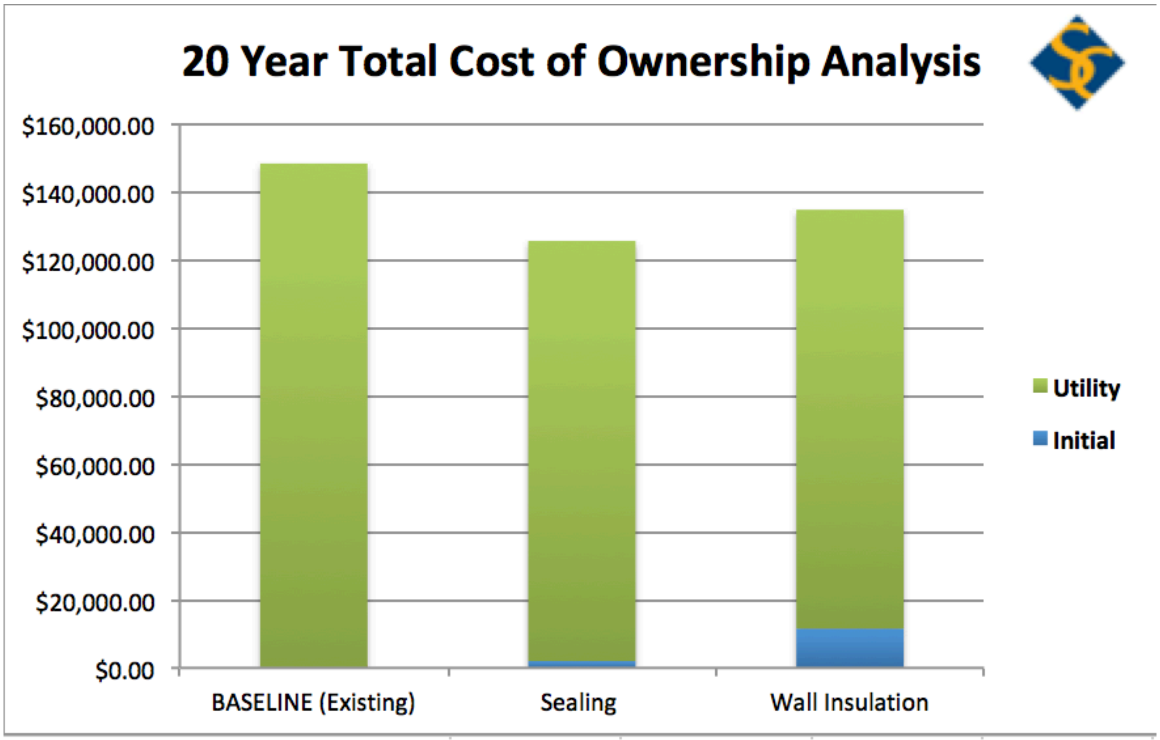
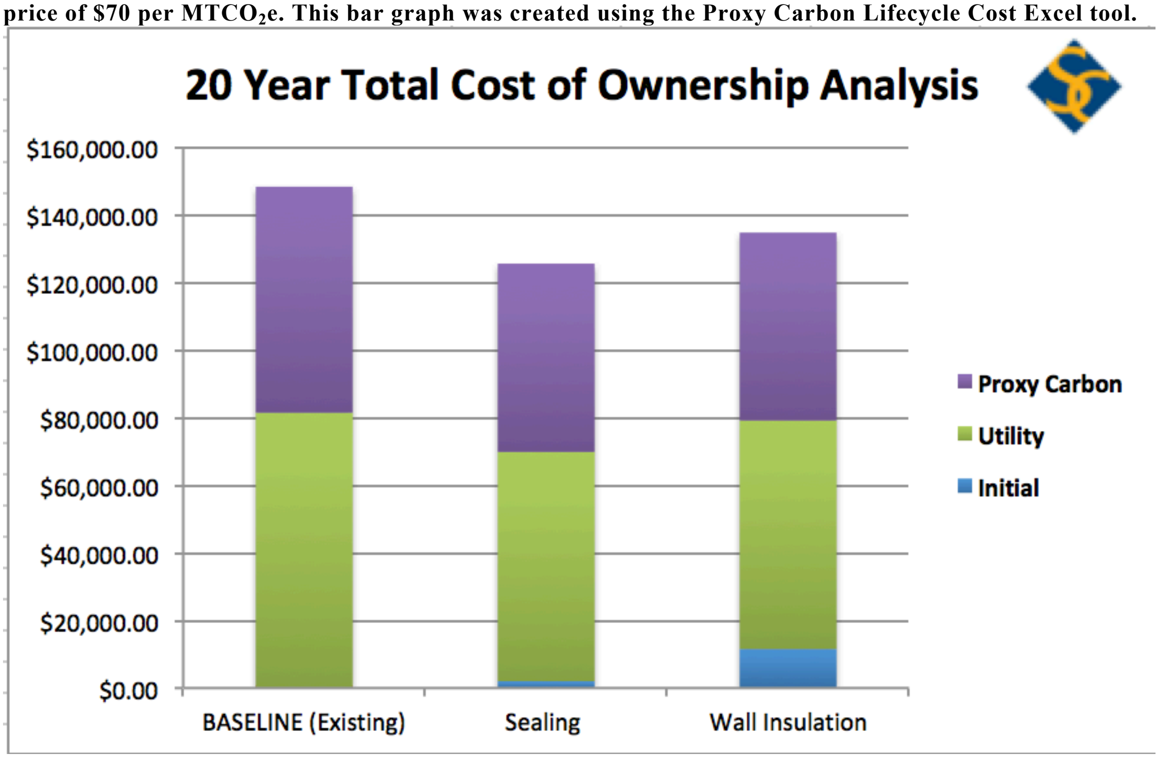


Figure 13- This bar graph compares the 20 year total cost of ownership of the three options for the Washburn House Retrofit analysis using the initial cost, the utility cost of steam, and the proxy carbon price of $70 per $MTCO_2e$. This bar graph was created using the Proxy Carbon Lifecycle Cost Excel tool.



Renewable Energy Credit Procurement

Smith College has decided to invest in a renewable energy project located in Maine because the campus lacks the space to facilitate the construction of renewable energy infrastructure (Weisbord, 2018). Smith College has signed a contract for a renewable energy project that will produce carbon-free electricity for the ISO-NE grid and produce Class I regulatory Renewable Energy Certificates (RECs)[5] (Weisbord, 2018). A Renewable Energy Credit (REC) is a permit that designates ownership of renewable electricity generation that can be used in greenhouse gas accounting (EPA, 2016). The Renewable Energy Credits would allow Smith College to claim carbon emission reductions to progress towards the carbon neutrality goal of 2030.

Should Smith College keep the Class I RECs and retire the equivalent carbon emissions or sell the Class I RECs? The proxy price can be used as a financial metric for determining the procurement of Renewable Energy Credits (RECs). The proxy carbon price represents how much Smith College values the social damage of carbon emissions. Therefore, Smith College should be willing to pay up to the proxy carbon price for avoided carbon emissions resulting from an investment opportunity. This pilot project demonstrates the method of using the proxy carbon price to demonstrate

[5] There are two classes of Renewable Energy Certificates' (RECs) that have the purpose of fulfilling compliance obligations or voluntary commitments. Class I RECs represent any new renewable energy facility that began commercial operation after 1998, whereas Class II RECs represent any renewable source that began prior to 1989. Class I and II RECS can be produced by solar photovoltaic, solar thermal electric, wind energy, small hydropower, landfill methane and anaerobic digester gas, marine or hydrokinetric energy, geothermal energy, or eligible biomass fuel (MA Legislature, 2009).

the value of avoided carbon emissions resulting from an investment. This is scalable to other emission reductions investment decisions.

A Renewable Energy Credit (REC) is a permit that designates ownership of renewable electricity generation that can be used in greenhouse gas accounting. Specifically a REC represents one Mega-Watt-Hour (MWh) of electricity (EPA, 2016). RECs have monetary value because they can be traded on regulatory markets to fulfill state Renewable Portfolio Standards (RPS)[6]. Because RECs are traded on a market, the price varies over time (Spectrometer, 2018). Additionally, due to the policy choice of RPS to fulfill state quotas, the price for a REC also varies by location.

In order to evaluate the decision of keeping or selling RECs, the proxy carbon price can be transformed into equivalent units of the REC. The unit for a REC is $/MWh. The proxy carbon price is $70 per $MTCO_2e$ and the current ISO-NE commercial electricity carbon emissions results 0.38 $MTCO_2e$ per MWh. Therefore, the proxy carbon price, in the equivalent unit of the RECs, is $27/MWh. Table 12 describes the value of avoided carbon emissions at different proxy carbon price values.

Table 12- The value of avoided carbon emissions for different carbon prices. which is represented in the unit of $ per Mega-Watt-Hour. This assumes the ISO-NE has an emission faction of 0.38 $MTCO_2e$ per Mega-Watt-Hour.

Proxy Carbon Price ($/$MTCO_2e$)	**$50**	**$70**	**$100**
Willingness to Pay ($/MWh)	$19	$27	$38

[6] Currently, 29 states throughout the United States have Renewable Portfolio Standards (RPS), including the Commonwealth of Massachusetts (Durkay, 2017). These standards can be meet by producing renewable energy within the state or by purchasing Renewable Energy Credits.

The scale of the renewable energy project would produce approximately the equivalent of Smith College's purchased electricity annually from the ISO-NE grid (Master GHG spreadsheet, 2017). Therefore, the project would produce enough RECs to eliminate Smith's Scope 2 emissions from purchased electricity, which is about 8% (AASHE-Stars, 2017). The value of all carbon emissions from purchased ISO-NE electricity is equivalent to $243,000, according to a proxy carbon price of $70/MTCO2e.

If the College chooses to sell the Class I regulatory RECs, the institution can use the money to purchase cheaper, lower quality Certified RECs from the voluntary Green Power Market[7]. Alternatively, the College could use the money from the sale of the RECs to purchase carbon offsets[8] that could also progress the College towards carbon neutrality. The final option to progress towards carbon neutrality from the sale of the RECs is to invest the money in energy efficiency capital projects on campus.

In order to decide if the College should keep the regulatory Class I RECs or sell the regulatory Class I RECs, consider the following relationships.

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[7] The voluntary markets are driven by commercial electricity consumer demand for carbon neutral energy, not regulation, so they are separate from mandatory markets to ensure that double claims are avoided. As a result, voluntary markets operate on a supply and demand market, unhindered by regulatory distortions. The current voluntary green power market trends indicate a 45% increase in the number of customers and a 19% increase in sales (NREL, 2017).

[8] A carbon offset represents the emission reductions of one party that is purchased by another party to compensate for an equivalent amount of emissions. The emission reduction must be additionally and permanent (Terrapass, 2018).

Relationship 1: If the Proxy Carbon Price per MWh is greater than or equal to the Class I REC price, then the College should keep the Class I REC.

If this relationship is true, then the College values carbon at least as much as the Class I REC is worth. In this case the College should keep the Class I REC and retire that amount of carbon equivalent emissions in greenhouse gas accounting.

Relationship 2: If the Proxy Carbon Price per MWh is less than the Class I REC price, then the College should sell the Class I REC.

If this relationship is true, then the College does not value carbon as much as the Class I REC is worth. In this case the College should sell the Class I REC and, consequently, cannot eliminate that amount of carbon equivalent emissions in greenhouse gas accounting.

To demonstrate the proof of concept of I shall use the data in Table 13 to evaluate the decision using the REC relationships. Renewable Energy Credit prices fluctuate with respect to time, location, and type (Regulatory or Voluntary). Therefore, the decision to keep or sell the RECs should be evaluated during the year that the project is completed.

According to the 2018 data, Smith College should keep the regulatory Class I RECs either from Maine or Massachusetts. This is because Relationship 1 is fulfilled because the proxy carbon price of ISO-NE electricity ($/MWh) is greater than the REC-Massachusetts and REC-Maine ($/MWh). The total value of RECs from Maine is less than RECs from Massachusetts, so the College should keep the Maine RECs.

Table 13- The value of avoided carbon emissions compared to Renewable Energy Credits' cost.

Source	Rate ($/MWh)	Total value to reduce carbon emissions by 8% ($)
Proxy Carbon Price of ISO-NE	27	243,000
-------------------------------------	**------------------------------------**	**-------------------------------------**
REC- Regulatory Massachusetts (2018)	18	162,000
REC- Regulatory Maine (2018)	8	72,000
REC-Certified (2016, best available data)	1	9,000

Chapter V: Conclusions and Recommendations

Conclusions

This thesis to *Design a Proxy Carbon Price Strategy for Smith College* was developed to acknowledge the social cost of carbon emissions in financial decisions within the institution. The proxy carbon price is a virtual price that does not apply an actual fee to impact the capital budget. Implementing a proxy carbon price into the financial framework for evaluating financial decisions may incentivize the purchase of low-carbon options (Gillingham et al., 2017). The reason it is important to purchase low-carbon options for future purchases is because of the complex and urgent problem of climate change and because Smith College signed the American College & University Presidents' Climate Commitment (ACUPCC), which means that Smith College is committed to becoming carbon neutral by 2030 (Smith College, 2010).

This thesis was written in response to the Study Group on Climate Change request to "Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision-making processes" (SGCC, 2017). All of the Smith College stakeholders were familiar with the concept of carbon pricing, which may be attributed to the advancement of formal sustainability goals through the Study Group on Climate Change report. While the stakeholders were familiar with the concept of proxy carbon pricing, the current practices of the institution never used a proxy carbon to evaluate financial decisions, prior to this thesis. Therefore, the overarching research question this the thesis to *Design a Proxy Carbon Price Strategy for Smith College* is how can the institution acknowledge carbon emissions in capital and other financial decisions?

An important part of the research process to develop the Proxy Carbon Price Strategy for Smith College was to conduct a thorough review on carbon price strategies deployed by governments, businesses, and academic institutions. Smith College is located in the Commonwealth of Massachusetts, which currently has three proposed carbon tax bills and already participates in the cap and trade system, the Regional Greenhouse Gas Initiative (RGGI), which puts a price on carbon for electricity sales (MA Legislature, 2017; RGGI, 2018). Governments around the world are turning to carbon pricing as a strategy to meet the Nationally Determined Contributions to mitigate climate change (World Bank and Ecofys, 2017; UNFCCC, 2016).

In response to the growing trend of regulatory carbon pricing, businesses are responding by incorporating a carbon price into business strategy. As of 2017, over 1,300 businesses are currently using or have disclosed plans to implement a carbon price (CDP, 2017). This is in stark contrast to the number of academic institutions that have disclosed using a carbon price. According to this research, there are only four academic institutions in the United States that are actively using a carbon price and one academic institution has plans to use a carbon price (Yale Carbon Charge Task Force, 2016; Swarthmore College, 2017; Princeton University, 2008; (ASU) Dalrymple, 2018; Vassar College, 2015). Because there are so few academic institutions actively using a carbon price, there is a lack of peer-reviewed literature or guidance on developing a proxy carbon price strategy. There is a need to fill this gap through experimentation.

A key milestone for the Proxy Carbon Price Strategy at Smith College was the selection of a proxy carbon price by the Smith College Committee on Sustainability. Selecting the carbon price was a challenge because there is a wide range of values from less than \$5 per $MTCO_2e$ to over \$200 per $MTCO_2e$ (See Chapter II: Section C). There are also a variety of approaches to selecting the proxy carbon price which, include the pragmatic approach, using the social cost of carbon estimates, implicit price, aligning with peer institutions, and the regulatory risk approach. The Committee utilized these approaches to select a price range of \$60 to \$75 per metric ton of carbon dioxide equivalent emissions ($MTCO_2e$). For the purpose of this thesis, Dr. Alex Barron and I selected a proxy carbon price of \$70 per metric ton of carbon dioxide, which is equivalent to the Interagency Working Group on the Social Cost of Carbon (IWG-SCC) estimate in \$2017 at a 2.5% discount rate (IWG-SCC, 2016).

To integrate the proxy carbon price into financial decisions of the institution, I outlined two methods for using the proxy carbon price. One method is to use the proxy carbon price independently as metric for the value of avoided carbon emissions resulting from an investment or purchase. This method was demonstrated using the pilot project of the Renewable Energy Credit Procurement analysis. The key finding from this pilot project was that the proxy carbon price can be transformed from a measurement of the social cost of carbon for one metric ton of carbon equivalent emissions to the social cost of carbon emissions for a unit of energy or fuel. This is scalable to other forms of fossil fuel consumption (Table 11).

Another method to incorporate the proxy carbon price into financial decisions at Smith College is to the Proxy Carbon Lifecycle Cost Calculator (Proxy Carbon LCC). This method integrates the proxy carbon price into a Lifecycle Cost framework. A Lifecycle Cost evaluates the present and future costs over a given study period for a purchase (Harvard, 2017; ASTM, 2017). Carbon emissions occur over the lifetime of a project through fossil fuel consumption during operation. Therefore, the Lifecycle Cost method is ideal for incorporating the proxy carbon price. The current practices for capital project purchase evaluation at Smith College do not typically include a Lifecycle Cost. Therefore, I adapted the Harvard Lifecycle Cost Calculator to the specifications of Smith College so that decision-makers can perform Proxy Carbon Lifecycle Cost evaluations.

The Proxy Carbon Lifecycle Cost method is best suited for evaluating options for a selected capital project. The Washburn House Retrofit pilot project demonstrated the Proxy Carbon Lifecycle Cost method. This pilot project illustrated that the proxy carbon price alters the discounted payback period. For the retrofit option to seal the envelope, the total cost of ownership is lower than the baseline and the discounted payback period is within the current practice metric, independent of the proxy carbon price. For the retrofit option to seal the envelope and insulate the walls, the total cost of ownership is lower than the baseline and the discounted payback period is within the current practice metric, once proxy carbon price applied. A key finding from this pilot project was that the energy savings, independent of the proxy carbon price, demonstrate the cost- and carbon- saving for some options, but not all. Furthermore, this finding illustrates that the proxy carbon price may incentivize the low-carbon option, particularly when financial metrics of the Lifecycle Cost is close to equal. A challenge for this pilot project was the lack of organized and accessible data on the costs of each retrofit option. This challenge may be overcome by more rigorous standards for data collection and storage as outlined by Recommendation 6.

Ultimately, the Proxy Carbon Price Strategy for Smith College is a way to make informed financial decisions that include the social cost of carbon. The proxy carbon price is a virtual price that may incentivize low-carbon options, particularly when using the Proxy Carbon Lifecycle Cost method to evaluate capital project purchasing decisions. The method to use the proxy carbon price to determine the willingness to pay for avoided carbon emissions can highlight opportunities to mitigate Smith College's contribution to climate change and work towards the carbon neutrality goal of 2030 (Smith College, 2010). This thesis to *Design a Proxy Carbon Price Strategy for Smith College* captures the academic institution's mission of education through student research and aligns the operations of Smith College with the sustainability goals outlined by the Study Group on Climate Change. Furthermore, this thesis addresses the need for experimentation with proxy carbon pricing as a strategy to mitigate carbon emissions that contribute to anthropogenic climate change.

Recommendations for Smith College

1. ***Use a proxy carbon price strategy to acknowledge the social cost of carbon emissions in financial decisions.***

This thesis addresses the Institutional Change request by the Study Group on Climate Change (SGCC): "Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision- making processes" (SGCC, 2017). The purpose of the Proxy Carbon Price Strategy is to acknowledge the social cost of carbon into capital decisions and other financial decisions. A proxy carbon price is a virtual cost, meaning it does not charge an actual fee to the institution (Gillingham, 2017; Cassidy, 2016). A key finding from the Renewable Energy Credit pilot project is that the proxy carbon price can demonstrate the institutional willingness to pay for an investment opportunity to reduce carbon emissions. Therefore, the Proxy Carbon Price Strategy may act as a sustainable transition tool to work towards the American College and University Presidents Climate Commitment of carbon neutrality by 2030 (Smith College, 2010).

2. ***Select the proxy carbon price value of $70 per metric ton of carbon dioxide equivalent emission (MTCO$_2$e) and update the value as needed.***

The Committee on Sustainability recommended the proxy carbon price range of $60-75 per one metric ton carbon equivalent emissions (Committee on Sustainability, 2018). Within that range, I recommend the institutional carbon price of $70 per metric ton of carbon dioxide equivalent emissions. This price is equivalent to the findings of the Interagency Work Group on the Social Cost of Carbon in $2017 with a 2.5% discount rate (National Academy of Science, 2017;

Interagency Working Group on the Social Cost of Carbon, 2016; Bureau of Economic Analysis, 2018).

An important lesson from the United States Interagency Working Group on the Social Cost of Carbon (IWG-SCC) is that the carbon price must be reviewed and updated frequently (IWG-SCC, 2016). This is a necessity because climate and socioeconomic factors are constantly changing (National Academy of Science, 2017). Another possible reason to update the price is that the current price signal is untested for actually lowering carbon emissions on campus. Therefor the proxy carbon price must be evaluated and perhaps changed to align with sustainability or financial goals of Smith College.

3. ***Smith College should incorporate the method of Lifecycle Cost (LCC) to the current practices of capital project evaluations within Facilities Management.***

The Lifecycle Cost method should be used for evaluating capital decisions because it demonstrates the present and future costs to estimate the total cost over a study period[9] to make informed decisions. This method is particularly useful for long-term projects that have a high operating cost relative to the initial cost. The Washburn House Retrofit pilot project illustrated that the LCC method can identify cost- and energy-saving options that also result in carbon savings.

The Lifecycle Cost method should be used to evaluate capital projects in the Facilities Management Department (Howard, 2018; Gagnon, 2018; Pfannenstiel, 2018; Weisbord, 2018). To perform the Lifecycle Cost, I recommend that project

[9] The study period that was selected for the purpose of this research was 20 years. This study period should be revised after evaluating the effectiveness of the method.

managers or 3rd party contractors use the Smith College Proxy Carbon Lifecycle Cost calculator. This tool can be used to highlight opportunities to save money and energy while also reducing carbon emissions through capital projects such as, building retrofits, energy efficiency upgrades, and fuel switching, among many other capital project options, with or without the proxy carbon price.

4. ***Smith College should incorporate the proxy carbon price into the Lifecycle Cost method outlined in Recommendation 3.***

Carbon emissions occur during the operating lifetime of capital projects (i.e. electricity, gasoline for vehicles). Therefore, it is essential to apply the proxy carbon price to carbon emissions over the operating lifetime of a capital project. The Lifecycle Cost method is well suited to incorporate the proxy carbon price because it evaluates the initial and operating costs over a long-term study period. Therefore, the Lifecycle Cost method can contextualize the proxy carbon price among other traditional financial costs such as the initial market price, labor, and utility costs, among others. This method is likely to be most useful for capital decision-makers because the primary criteria for making capital decisions are most often financial criteria (Kowitz, 2017; Pfannenstiel, 2018).

5. ***Engage students in proxy carbon price research and development.***

Student engagement with proxy carbon price research and development should be a priority because it is an opportunity to align the mission of education with sustainable operating practices of the institution. Furthermore, the Proxy Carbon Price Strategy addresses the complex and real-world problem of climate change. Therefore, engaging students in the research and development of the

Strategy utilizes the Campus as Classroom technique (Smith College Strategic Plan, 2016). I have outlined a few of the possible opportunities to engage students witht the Proxy Carbon Price Strategy in the Chapter: Future Work.

6. ***Record all data for projects that use the Proxy Carbon Price Strategy in a folder in the Smith College Shared Drive.***

It is imperative that the data from the Proxy Carbon Lifecycle Cost calculations are recorded, organized and stored so that future research can be conducted using the data. Specifically, all data on the present and future costs as well as the utility consumption of each project should be recorded. The data should be stored in a folder that is clearly labeled and accessible to the members of the organizational branch of the Executive Office of Finance and Administration. Another consideration is to make the data accessible to faculty members so they can identify opportunities for student research using the Proxy Carbon Price Strategy to fulfill Recommendation 5.

7. ***Update the utility cost rates and the escalation rates in the Proxy Carbon Lifecycle Cost Calculator as needed.***

The variables within the Proxy Carbon Lifecycle Cost Calculator should be updated with the best available data in order to make accurate decisions using this method. In particular the cost and escalation variables for utilities are likely to change over time. Therefore, it is necessary to update the data to provide accurate results from the Proxy Carbon LCC. The institutional rates should be updated using Smith College data from Facilities Management records and the purchased goods' rates should be updated using data from the Energy Information Agency.

Additionally, the escalation rates of labor and materials should be updated using data from the Consumer Price Index for Urban Consumers (CPI-U).

I also recommend that the Committee on Sustainability should oversee the update process and make the final decision on how frequently to update the data because it is the responsibility of the Committee to implement the recommendations from the 2017 report. I recommend that students conduct the update of the Proxy Carbon Lifecycle Cost Calculator because it is an opportunity to utilize the Campus as Classroom initiative and fulfill Recommendation 5. The Committee on Sustainability should also select the student(s) to complete the update. The utility rates should be recorded in the Master Utility Cost and GHG Rate Spreadsheet to maintain a record of the utility rates used for the tool.

8. ***Pilot Project Recommendations***

a. ***Renewable Energy Credit Procurement***

The Renewable Energy Credit Procurement pilot project demonstrated the method of using the proxy carbon price as the value of avoided emissions to evaluate an investment decision. This is scalable to other carbon emission reductions investment or purchase decisions. A Renewable Energy Credit represents the market value of one Mega-Watt-hour (MWh) of renewable electricity. According to the recommended proxy carbon price of \$70 per $MTCO_2e$ the willingness to pay for RECs to avoid carbon emissions is about \$27 per MWh. I recommend that Smith College use the following relationships to determine if Smith College should sell the RECs or keep the RECs:

- *If the Proxy Carbon Price per MWh is greater than or equal to the Class I REC price, then the College should keep the Class I REC.*
- *If the Proxy Carbon Price per MWh is less than the Class I REC price, then the College should sell the Class I REC.*

b. ***Washburn House Retrofit***

I recommend that Smith College retrofit Washburn House by selecting the retrofit options of sealing between the floors and insulating the walls. The option to seal the envelope would reduce carbon emissions in Washburn House by 17% and the option to seal the envelope and insulating the walls would reduce carbon emissions in Washburn House by 35%.

This recommendation is justified by the Proxy Carbon Lifecycle Cost calculation, which illustrates that both of the retrofit options have a lower total cost of ownership than the baseline "do-nothing" approach. Furthermore, they both have positive savings to investment ratios, which means the retrofit options will save at least as much money as they cost. Additionally, the proxy carbon price alters the discounted payback period such that both retrofit options fall within the current practice of a 5-year payback period.

Chapter VI: Future Work

Academic institutions can act as a living laboratory for experimenting with the sustainable tool of carbon pricing. However, this research indicated that there were only four United States academic institutions that are actively using carbon pricing. Therefore, Smith College has a major opportunity to become a leader in the emerging field of carbon pricing. Researchers at Smith College should share the results of the Proxy Carbon Price Strategy experiments in a peer-reviewed journal. This is a crucial step in the scientific method and should be emphasized because there is a significant need for research on carbon pricing. Furthermore, sharing results of the carbon pricing experiments is especially important right now because there is an urgency to scale the implementation of this carbon mitigation strategy in the context of climate change.

Once the Proxy Carbon Price Strategy has been used in financial decisions at Smith College, there is an incredible opportunity for research through retrospective analysis. I'm most curious about the influence of a proxy carbon price to actually lower carbon emissions. More specifically, are there specific types of decisions that are best suited for using the Proxy Carbon Lifecycle Cost method?

Also, what types of projects can use the proxy carbon price independent of the Lifecycle Cost method (i.e. Renewable Energy Credit Procurement Pilot Project)? The proxy carbon price can demonstrate the value of avoided carbon emissions from a new investment or purchase. I hypothesize that the scale for this method of analysis could be expanded to encompass campus-wide purchases through the Capital Plan.

Another way to engage students is to have them update the internal variables of the Proxy Carbon Lifecycle Cost Excel tool. The more frequently these variables are updated, the more accurate they will be for estimating the costs of projects. To have the best available information the calculator should be updated once a year because the primary databases in the EIA and at Smith College are updated annually (Pfannenstiel, 2018; EIA, 2017). In the future students could gain research experience by seeking out the best available data from the institutional, regional, and national sources. Through this experience, students can build data analysis skills and gain practical experience working with Excel spreadsheets and databases. Furthermore, this is another opportunity to progress the Campus as Classroom initiative through the Proxy Carbon Price Strategy for Smith College.

Another project for future research is to determine the utility rate for chilled water. Chilled water is produced through a dual source of commercial electriciy and steam from the Combined Heat and Power (CHP) plant at Smith College, which makes it difficult to isolate the cost of chilled water. This research assumed the cost determined by GreenerU, but should be revised through further research to achieve more accurate results from the Proxy Carbon Lifecycle Cost Excel tool.

The final suggestion for future research is also in regards to the Proxy Carbon Lifecycle Cost Excel tool and a complication resulting from the Combined Heat and Power (CHP) plant at Smith College. The estimate for the carbon emssions for electricity and steam to produce heat from the CHP assumed only the contribution from natural gas, the primary source of fuel for the CHP. The CHP also uses fuel oil #6 in the boilers to produce extra steam to heat the buildings when necessary.

Therefore, a more detailed analysis of the carbon emissions resulting from the production of electricity and steam from the CHP should be conducted. The updated values for carbon emissions from electricity and steam will improve the accuracy of calculations for the Proxy Carbon Lifecycle Cost Excel tool.

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Internal Stakeholders

Name	Association	Position	E-mail	Meeting Type	Meeting 1	Meeting 2
Internal Stakeholders						
Faculty						
Dr. Alex Barron	Smith College	Assistant Professor of Environmental Science & Policy	abarron@smith.edu	In person	Weekly	
Dr. Susan Stratton Sayre	Smith College	Assistant Professor of Economics	ssayer@smith.edu	In person	Semester Check-In	
Denise McKhan	Smith College	Associate Professor of Engineering		In person	February 27, 2018	March 22, 2018
Staff						
Dano Weisbord	Smith College	Director of Sustainability & Campus Planning	dweisbor@smith.edu	In person	Weekly	
Emma Kerr	Smith College	Campus Sustainability Coordinator		In person	March 6, 2018	
Anne Wibiralske	Smith College	Program Administrator ES&P	awibiralske@smith.edu	In person	February 14, 2018	
Facilites Management						
Karl Kowitz	Smith College	Facilites Business Operations	kkowitz@smith.edu	In person	October 13, 2017	
Peter Gagnon	Smith College	Capital Construction Director	pgagnon@smith.edu	In person	November 17, 2017	March 15, 2017
Karla Youngblood	Smith College	Facilites Operations Director	kyoungblood@smith.edu	In person	December 8, 2017	
Charlie Conant	Smith College	Senior Project Manager	cconant@smith.edu	In person	March 15, 2017	
Morgan Wilson	Smith College	Project Manager	mtwilson@smith.edu	In person	March 15, 2017	
Cheryl Obremski	Smith College	Draftsperson/Engineering Aide	combremsk@smith.edu	In person	March 15, 2017	
Matt Pfannenstiel	Smith College	Energy Manager	mpfannenstiel@smith.edu	In person	Novermber 8, 2017	March 1, 2018
Roger Mosier	Smith College	Assocatiate Vice President for Facilites Management	rmosier@smith.edu	In person	Novermber 27, 2018	
Finance and Administration						
David DeSwert	Smith College	Associate Vice President for Finace & Administration	ddeswert@smith.edu	In person	October 24, 2018	March 21, 2018
Mike Howard	Smith College	Executive Vice President for Finance & Administration	mwhoward@smith.edu	In person	December 2017	March 21, 2018
Committee on Sustainability	Smith College	Faculty, Staff, & Students		In person	March 27, 2017	

External Collaborators

Name	Academic Institution	E-mail	Meeting Type	Meeting 1
External Collaboration				
Shauna Weber	Princeton University	shanaw@princeton.edu	In person, Email	October 15-18, 2017
Trish Devine	Princeton University	pdevine@princeton.edu	In person, Email	October 15-18, 2017
Nathaniel Graf	Swarthmore	ngraf1@swarthmore.edu	In person, Email	October 15-18, 2017
Aurora Windslad	Swarthmore	awinsla1@swarthmore.edu	In person, Email	October 15-18, 2017
Casey Picket	Yale	casey.pickett@yale.edu	In person, Email	October 15-18, 2017
Brian Goldsberg	MIT	bsgold@mit.edu	In person, Email	October 15-18, 2017
Alistair Hall	Vassar	alihall@vassar.edu	Email	
Caroleen Verly	Harvard	caroleen_verly@harvard.edu	Email & Phone Call	March 1, 2018
Michael Dalrymp	Arizona State University	Mick.Dalrymple@asu.edu	Email	

Appendixes

Appendix 1: Internal Stakeholder questions

Karl Kowitz

Facilities Business Operations Director

Friday October 13, 2017

Confidentiality & Consent: yes

1. What is the scope of your decisions?
2. What criteria do you use to make decisions?
3. How far do you plan financially into the future
4. What is your operating budget?
5. What do you report on vehicles?
6. What is the stock of vehicles and how often does it change?
7. Are there electric vehicles?
8. Do you know of any other people in the institution that I should meet with?

David DeSwert

Associate Vice President for Financial Planning

October 24, 2017

Confidentiality & Consent: yes

1. What is your role in the finances of Smith College?
2. Who reports to you? And whom do you report to?
3. Have you heard of carbon pricing as a way to mitigate carbon emissions?

4. Do you know the carbon pricing policy tool proxy carbon pricing?
5. Do capital management projects conduct life cycle cost assessments? Which ones, is there a threshold?
6. What is the process of an idea for a capital project to the creation of an RFP?
7. Who determines the budget for a capital project?
8. Are there a minimum number of options that must be evaluated before making a decision?
9. Who determines those options?

Matt Pfannenstiel

Energy Manager-Facilities Management

November 8, 2017

Confidentiality & Consent: yes

1. Are you familiar with the concept of carbon pricing?
2. What is your role in the institution?
3. Do you conduct energy analysis in the design phase of the project?
4. Do you conduct a carbon analysis in the design phase of the project?
5. How do you think a proxy carbon price could be integrated into Smith College decisions?
6. How do capital management projects progress from idea to completion?
7. What kind of features would be useful in a tool to calculate a proxy carbon price LCC?
8. Do you know of any other people in the institution that I should meet with?

Peter Gagnon

Capital Project Manager-Facilities Management

November 17, 2017

Confidentiality & Consent: yes

1. Are you familiar with the concept of carbon pricing?
2. What is your role in the institution?
3. What is the scope of your decisions?
4. How far do you plan financially into the future?
5. Do you conduct a life cycle cost assessment?
6. Would it be feasible to use a LCC?
7. What features would you want to include in the LCC tool?

Roger Mosier

Also in attendance: Dano Weisbord

Associate Vice President of Facilities Management and Director of Campus Sustainability & Space Planning

November 27, 2017

Confidentiality & Consent: yes

1. Are you familiar with the concept of carbon pricing?
2. What is your role in the institution?
3. Specifically in capital management projects?
4. How far do you plan into the future for the Capital Plan?
5. Who helps develop the Capital Plan?

6. Does Smith currently use Lifecycle Cost Calculation?
7. What criteria do you use to develop the Capital Plan?
8. What reports/data does the college have on past projects?

Peter Gagnon, Matt Pfannenstiel, Charlie Connant, Allison, Cheryl Obremski, Morgan Wilson, Dano Weisbord

Smith College Facilities Management

March 15, 2018

1. Are there any features that should be added or modified in the LCC tool?
2. Where should the proxy carbon price be integrated into current practices of capital project decisions?
3. Who should complete the inputs in the tool for project alternatives?
4. Who should oversee and evaluate the results of the tool to make a decision?
5. Where should the records for project data be kept? How often should that be reviewed in regards to the effectiveness of the proxy carbon price?
6. Who should update the variables within the tool?
7. Do you have any comments, questions, or concerns?

Dr. Denise McKahn

Professor of Engineering

March 22, 2018

Confidentiality & Consent: yes

1. What building would you recommend for a pilot project for the proxy carbon price strategy?
2. What data do you have on that Washburn House?
3. What should the baseline and alternative scenarios be for the Proxy Carbon Lifecycle Cost calculation?
4. How can the carbon equivalent emissions of the Combined Heat and Power Plant be separated into the variables of heat, chilled water, and electricity?
5. What sources do you recommend for data on the labor and material of the retrofit options?

Appendix 2: Readaheads to Key Internal Stakeholder

To: Mike Howard

From: Breanna Parker, Smith 2018

CC: Dr. Alex Barron, Dano Weisbord

Topic: Discussion on Proxy Carbon Pricing at Smith College

Meeting: Campus Center, 9AM 12/14/17

Purpose

To discuss proxy carbon pricing for use at Smith. Your input is very valuable, so I would like to ask you a few questions about an implementation strategy, and in return answer any questions you may have.

Background

My honors thesis addresses the recommendation by the Study Group on Climate Change to explore implementing a proxy carbon price on campus. I am working with Dr. Alex Barron, Dr. Susan Sayre, Dano Weisbord and collaborating with Smith stakeholders.

My research questions are: How can Smith College incorporate the social costs of carbon into decision-making using life cycle proxy carbon pricing as a tool? Who makes key capital decisions and should implement the life cycle proxy carbon price project evaluation tool? What types of projects would work best for life cycle proxy carbon pricing?

This semester I have been conducting background research on proxy prices and studying other schools that have implemented carbon prices and are experimenting with different methods and tools. In addition, I interviewed key stakeholders in Facilities Management and Finance and Administration including, David DeSwert, Thu Quach, Roger Mosier, Peter Gagnon, Karl Kowitz, Karla Youngblood, and Matt Pfannenstiel.

While the research is still developing, preliminary findings include the importance of using a proxy carbon price to acknowledge carbon emissions in long-term projects and as a risk management tool. Including a Life Cycle Cost with the proxy price will allow capital decision-makers to see the full picture of social and economic costs, instead of just the initial price. These strategies will likely work best on capital projects, not only because of the lifespan, but also because of the significant influence they have on the campus operations and mission.

Topics for Discussion

Life Cycle Costing

Have you used Life Cycle Costing at Smith or at other institutions? Do you have suggestions or concerns about applying it here?

How do you determine the discount rate for Smith? How often is this evaluated?

Your perspective on the decision making at Smith

What are the criteria currently used to make decisions for capital plan projects?

From a financial perspective, what types of projects do you think would fit best for applying a proxy carbon price?

From your position do you see benefits of proxy carbon pricing or have concerns?

To: Smith College Committee on Sustainability

From: Alex Barron and Breanna Parker ('18)

cc: Dano Weisbord, Susan Sayre

Topic: Smith College Proxy Carbon Price

*Please note that this Memo includes old monetary values for some of the social cost of carbon values, which were corrected in this thesis to reflect the most up to date values. This is the reason why the range of $60-$75 per MTCO2e was selected, rather than a single value.

Summary: In order to implement a proxy carbon price, Smith College must select an initial price to test. The 4 most common frameworks companies, governments and institutions use to set a proxy price are: 1) the social cost of carbon, 2) regulatory risk, 3) carbon markets, and 4) peer institutions. These are discussed below to inform discussion of a recommendation for a proxy price at Smith.

Background

The Study Group on Climate Change recommended that Smith College "Develop an internalized cost of carbon emissions—such as a carbon-proxy price—to help guide major capital budget management and other decision-making processes."(1) During the 2017-18 academic year we have been working to develop a framework and tool for a proxy carbon price that will allow Smith to account for climate change in key decisions. Selecting the level of the proxy carbon price is an important policy decision so we are seeking guidance from the Committee on Sustainability on establishing the initial level to be used in the piloting of the tool.

There is no single correct way to select the level of a proxy carbon price, but it is clear that any value is an improvement over zero. However, there are multiple approaches to selecting the value, depending upon whether the focus is on accounting for the social cost of carbon, mitigating regulatory risk, accounting for carbon markets, or aligning with peers. These approaches are not exclusive and the range of values suggested by each overlap. Below we briefly describe each approach.

For context, the proxy carbon price will be used to compare costs between options (for example two types of window or fleet vehicles) over their lifetime of use - including operating costs and carbon impact. The proxy price internalizes both the potential costs to Smith associated with future climate regulation and the climate damages associated with the emissions. The price is only used in decision-making, and it does not reflect actual cost to the institution (we can discuss details).

1) The Social Cost of Carbon

Carbon dioxide emissions cause economic damages to current and future generations, but these damages are not reflected in the price of carbon sources e.g. fossil fuel (2). In theory, an optimal carbon tax would be set to reflect the social cost of carbon and result in an efficient market (3, 4). Economists estimate the social cost of carbon using models that integrate climate changes with socioeconomic damage modules (2, 6). Many of these models include consequences such as sea level rise, flooding, storm damage, lost agriculture production, and heat related health issues. However, they omit critical variables like widespread biodiversity losses, ocean acidification and also tend to underestimate the impact of climate change on the economy (5, 7).

Price range: \$10 to \$220 per metric ton of CO_2e (hereafter "ton"), depending upon assumptions

2) Regulatory Risk

Over 1,300 companies are currently using or planning to implement internal carbon prices and a major reason is to manage risk associated with future climate policy (8). The proxy price screens for decisions that would not make sense in light of future climate policy. For example Shell, Exxon Mobil, and Hess all use an internal carbon price in their business strategy to anticipate a carbon-constrained world (8). While a Federal climate policy seems unlikely in the next few years, several carbon tax bills are under consideration in the Massachusetts legislature (9).

Price range businesses: \$5 to \$150 per metric ton (General Motors to Stanley Black & Decker Inc.)

Price Range legislation: MA proposed bills: \$10-\$20 starts prices rising to \$40 per metric ton or higher

3) Current Markets

Some organizations set internal carbon prices based on existing carbon markets. For example, to achieve carbon neutrality any emissions reductions that Smith can't achieve on campus could be offset by reducing emissions elsewhere with offsets. Offsets are created by reducing emissions (e.g. planting trees, capturing methane) and then sold in voluntary (or regulatory) markets (10). The offset price to reduce a metric ton of carbon is wide-ranging and varies based on quality and type of the offset. Smith has been collaborating with Hampshire, Williams, and Amherst College on the Community Climate Fund to generate local carbon offsets through investments in emission reduction projects, but the costs are higher than other voluntary offset products (11).

Price range: less than $1 to more than $50 per metric ton

Another source of market prices are existing trading systems. Currently, the state of Massachusetts participates in the Regional Greenhouse Gas Initiative (RGGI), which is a market designed to cap emissions (12). The current market price is very near the price floor, which results in a weak price signal (~$4). The European Union established the first market system to cap emissions and trade for permits and has fluctuated between about $5 and $35 but is currently at about $7 (13,14).

Price range: $2 to $35 per metric ton

4) Peer institutions

Princeton University began using a proxy carbon price in 2008 with a carbon price at $35. The price was later raised to its current value of $45 per ton (16). Yale University launched the Carbon Charge at $40 per ton in July of 2017 (15). This program models a revenue neutral carbon fee that highlights a regulatory risk approach. Swarthmore College has the highest carbon price at academic institutions with a value of $100 per ton, which was established in 2017 (17).

Price range: $45 to $100 per metric ton

Options

As described above, carbon prices in the business world range from less than $5 to over $100, as do estimates of the damages from carbon emissions. In our research, we have grouped candidate prices into 4 general price ranges, which are described below with a description of how they align with the criteria above.

A- Weak price signal ($5-15/ton) [Not recommended]

- A price in this range is consistent with:
- Estimates of the social cost of carbon that do not take into account impacts of climate change on other countries and/or place a very low value on impacts on future generations
- The low end of carbon prices used by businesses to plan for risk (General Motors $5/ton)(8)
- Prices found in existing carbon markets (RGGI <$5/ton, EU-ETS <$10/ton) that are not stringent enough to achieve decarbonization consistent with the Paris Agreement
- Prices for voluntary offsets that may vary in quality and in the degree to which they actually reduce emissions
- Prices below the carbon taxes being considered in the Massachusetts legislature
- Prices below those used by other academic institutions

B- Common Estimates (~$40/ton)

- A price in this range is consistent with:
- The most frequently cited estimate of the social cost of carbon (which takes into account the global impacts of climate damage but is still missing many critical impacts)
- Carbon prices used by some oil companies to plan for risk (Shell and Hess)
- Carbon prices that are roughly consistent with a trajectory towards 2 degrees C (19)
- Offsets that are locally produced with educational and community co-benefits

- Near-term prices for carbon taxes being considered in the Massachusetts legislature ($40/ton) (9)
- Prices used by Princeton ($45/ton) and Yale ($40/ton) (15,16)

C- Higher Carbon Prices (~$60/ton) [Recommended option]

- A price in this range is consistent with:
- Estimates of the social cost of carbon which place a higher value on the impacts on future generations and may better reflect the true social cost of carbon as estimates are updated to include more missing damages (5)
- Carbon prices used by companies such as TransCanada and Michelin to plan for risk (8)
- Carbon prices that are consistent with a trajectory towards 2 degrees C
- A greater supply of local offsets with educational and community co-benefits
- Higher carbon prices that might be seen in future legislation

D- Highest Carbon Prices (~$100/ton)

- A price in this range is consistent with:
- Some of the most recent literature on the social cost of carbon which places the a high value on future generations (low discount rates) and better accounting for risk aversion (values up to $220/ton) (7)
- Some of the highest carbon prices used by businesses (Stanley Black & Decker, Inc., Novartis) (8)
- The current carbon tax in Sweden is ($126/ton) (18)
- The internal carbon price currently used by Swarthmore College ($100/ton) (17)

Recommendation

In our review, estimates in the A range represent markets that are currently not achieving the needed reductions, a social cost of carbon that significantly discounts future generations, and is less ambitious than many other schools and institutions. The B range is the common value among social cost of carbon estimates, proposed Massachusetts regulation, and on the lower end of our peer institutions. The C range, or the Goldilocks price, is our recommendation because it is a value between our peer institution prices that is safely in line with a 2 degree C target and places a higher value on future generations. The D range is the higher end of the carbon prices, which may be more in line with the true cost of climate damages, but may be significantly higher than is needed, especially to start.

Escalation

One final detail is that we recommend that any price selected rise over time. This the increased damages from any given ton as GHG levels increase in the atmosphere. Escalation rates for the above options can be taken from USG modeling (typically about 2%/year - a $40 price in 2020 become $50 in 2030).

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Appendix 3: External Stakeholder questions

Semi-structured interview questions prepared for the Association of the Advancement of Sustainability in Higher Education (AASHE) conference.

Confidentiality & Consent: yes Casey Picket, Yale University; Shana Weber, Princeton University; Aurora Winslade and Nathaniel Graf, Swarthmore College

1. Does your institution use an internal carbon pricing model? Which one? [if no, skip to No questions]
2. How long has the institution had it for?
3. What is the value for the carbon price?
    a. What is the discount rate?
    b. What sources were used to establish the carbon price?
4. What kind of decisions does carbon price apply too?
    a. What types of capital management decisions is the carbon price applied to?
    b. How does the institution decide which projects to implement the carbon price? What is the criteria?
5. How does the institution apply the carbon price once you have selected the carbon price?
6. Can you explain an example of when a carbon price affected the decision making process of a project?
    a. How many decisions have been altered by a carbon price?
    b. Are these data publically available?

7. What were the greatest institutional barriers to implementing the carbon price?
8. What was one thing that was surprisingly difficult OR successful about implementing the carbon price?
9. Did you monitor the responses of officials and/or students to the implementation of the proxy carbon price?
    a. If yes, how so?

No:

10. Is the institution thinking about implementing a carbon price? Why?
    a. Which type(s)?
    b. What are the motivations for the institution to implement a carbon price?
11. What are the barriers that to implementing a carbon price?
12. Where is the institution at in the development process for a carbon price policy?

Additional Questions:

13. Do you know of any schools, governments, or businesses that are actively using a proxy carbon price?
14. Do you have any advice, questions, or comments for me as I develop a proxy carbon price policy for Smith College?

Caroleen Verly

Harvard University

Phone Call

March 1, 2017

Confidentiality & Consent: Oral

1. Why does Harvard use the lifecycle cost calculator? And not include the carbon price?
2. What are the project criteria to use the lifecycle cost calculator?
3. What types of projects work best with lifecycle cost calculations? Are there any specific variables or criteria to look for?
4. Who performs the lifecycle cost calculation?
5. Is there any retrospective analysis conducted on the LCC usage and decision making at Harvard?
6. How do decisions makers justify their decision if they select a project that is not the best LCC option?
7. How does Harvard determine the greenhouse gas content (MTCDE) for each utility, (e.g. natural gas, electricity)? What is the reference?

Appendix 4: Parameters for adapting the Harvard Lifecycle Cost Calculator to the Proxy Carbon Lifecycle Cost calculator

Utility Rate						
	Smith Produced Electricity	Commercial Electricity	Smith Natural Gas	Water/Sewer	Steam	Chilled Water
Price	$0.1/kWh	$0.165/kWh	$8.75/MMbtu	$13/ccf	$13.15/MMbtu	1.92/ton-day
Year	2016	2017	2016	2017	2017	
Source	Smith Data	EIA: https://www.	Smith Data	Smith Data	Smith Data	GreenerU
Escalation Rate						
Rate	2.08%	0.53%	2.57%	4.98%	3.34%	
Period	2010-2016	2017-2023	2010-2016	2010-2016		
Source	Smith Data	EIA: AEO 2018	Smith Data	City of Noho: http://www.northamptonma.gov/1788/U		
GHG (MMTCDE)	0.000253	0.0002923401	0.05316672207	0	0.074	0.00487
Source	Smith data via NI	Smith data via NI	Smith data via NI	Smith data via NI	Smith data	Harvard

Fuel Oil #2	Fuel Oil # 6	Transportation Gasoline	Transportation Diesel	Labor	Materials
$2.70/gal	$0.75/gal	$2.84/gal (w/tax)	$2.69gal (w/tax)		
2017	2016	2017	2017		
EIA: https://www.	EIA https://www.e	https://www.eia.g	https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r1x_a.htm		
Ask Karl					
4.22%	7.33%	3.82%	-3.63%	2.10%	2.10%
2017-2023	2017-2023	2010-2016	2010-2016	2018	2018
EIA AEO 2018	EIA AEO 2018	EIA-MA https://w	EIA-NE https://www.eia	BLS https://www.	BLS https://www.b
0.01031345245	0.01129610597	0.008823814	0.0082	n/a	n/a
Smith data via NI	Smith data via NI	Smith data via NI	Smith data via NH tool		

Appendix 5- Washburn House Retrofit Pilot Results from the Proxy Carbon Lifecycle Cost calculator

These are the results for the retrofit options to sealing the envelope and insulating the walls.

Sealing

	University Cost/Savings Variable Cost Only
20 Yr Total Cost of Ownership	**$ 125,441**
20 Yr Net Present Value (NPV)	**$ 22,755**
20 Yr GHG Savings (MTCDE)	**159.40**
Simple Payback Analysis	
	University Cost/Savings Variable Cost Only
First Year Utility Savings (FY14 rates)	$1,483
Simple Payback Period (Years)	1.36
First Year Return on Investment	73.5%
Life Cycle Cost Metrics	
	University Cost/Savings Variable Cost Only
20 Year Savings to Investment Ratio	12.39
Discounted Payback Period (Years)	See Graph
Adjusted Internal Rate of Return	106.0%
Greenhouse Gas Metrics	
	University Cost/Savings Variable Cost Only
First Year GHG Savings (MTCDE)	7.97
20 Year GHG Savings (MTCDE)	159.40
20 Year Proxy Cost of Carbon	$55,643.56
20 Year Investment Cost / 20 Year GHG	$12.54
20 Year NPV / 20 Year GHG	$142.75

Sealing + Wall Insulation

	University Cost/Savings Variable Cost Only
20 Yr Total Cost of Ownership	$ 111,796
20 Yr Net Present Value (NPV)	$ 36,399
20 Yr GHG Savings (MTCDE)	320.86
Simple Payback Analysis	
	University Cost/Savings Variable Cost Only
First Year Utility Savings (FY14 rates)	$2,985
Simple Payback Period (Years)	4.54
First Year Return on Investment	22.0%
Life Cycle Cost Metrics	
	University Cost/Savings Variable Cost Only
20 Year Savings to Investment Ratio	3.71
Discounted Payback Period (Years)	See Graph
Adjusted Internal Rate of Return	33.4%
Greenhouse Gas Metrics	
	University Cost/Savings Variable Cost Only
First Year GHG Savings (MTCDE)	16.04
20 Year GHG Savings (MTCDE)	320.86
20 Year Proxy Carbon Cost	44,340.80
20 Year Investment Cost / 20 Year GHG	$41.85
20 Year NPV / 20 Year GHG	$113.44