BUILDING RETROFITS ON CAMPUS:

A CASE STUDY OF THE COMPREHENSIVE COSTS AND BENEFITS OF IMPROVING ENERGY EFFICIENCY AT CARLETON COLLEGE

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ABSTRACT

Buildings represent 40 percent of the total energy consumption and related greenhouse gas emissions in the United States. Much of our building infrastructure is aging and poorly designed, from an energy efficiency standpoint. Thus, buildings present great opportunities to reduce energy use and decrease environmental damage. Various building improvements—known as retrofits—exist, which range from basic techniques for sealing air leaks to comprehensive re-insulation of the structure. Colleges, many of which have stated goals of reducing their carbon footprint, are uniquely positioned to lead the charge in retrofitting buildings because of their resources and ability to educate their communities regarding sustainable initiatives. However, many colleges have structures with historical or social significance that could be impacted by the retrofits. Thus, it is necessary to create a methodology for deciding whether or not a school should invest in structural energy efficiency improvements. Here we present a case study of Carleton College, a small liberal arts school in Northfield, Minnesota. We conduct a cost benefit analysis, contextualized by historical research, expert interviews, and a discussion of the school's ethical duty to promote sustainability, in order to determine the optimal level of investment in energy efficiency. In addition to interdisciplinary contextualization, the cost benefit analysis uses a willingness-to-pay methodology to quantify historic and aesthetic value. Using this approach, we find that basic retrofits pay back within the necessary timeframe specified by the school, while comprehensive deep retrofits and the replacement of current structures with net zero energy use buildings result in a negative net present value over the lifespan of the projects. However, more comprehensive retrofits may prove to be a better value to the school if building elements require replacement, independent of energy efficiency considerations.

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INTRODUCTION: THE NEED FOR COLLEGE RETROFIT MODELS

Buildings represent 40 percent of the total energy consumption and related greenhouse gas emissions in the United States (World Business Council for Sustainable Development 2010). This large percentage of energy consumption is exacerbated by the fact that aging infrastructure, conventional architectural practices that give minimal regard to energy consumption, and the fragmented and disconnected design and construction processes of most buildings create significant inefficiency in many buildings' energy use (Lovins 1992). However, because of the high direct and indirect costs of energy, enhancing energy efficiency in buildings has emerged as an effective strategy for reducing financial and environmental costs. The American Council for an Energy Efficient Economy predicts that, at an average cost of one to four cents per kilowatt-hour, it is cheaper to improve the efficiency of energy usage in buildings than to purchase additional energy using any renewable or non-renewable fuel source (Nadel 2009). This concept of utilizing 'negawatts'—or offset energy—to reduce energy costs has driven the market for upgrading the efficiency of buildings (Clark 2010).

There are two general approaches for improving energy efficiency of buildings: constructing new, high efficiency structures, and upgrading the performance of existing buildings, known as retrofitting. Retrofitting presents various advantages over the construction of new buildings. The substantial cost and effort put into constructing a new structure gives credence to the claim that "the greenest building is one that is already built" (Curtis 2008).

In the United States, we have a "covered wagon" mentality towards innovation; we have become very skilled at forging into new territory and taming unused land, but we are lacking in the skills to renew established sectors (Bonvillian 2012). This applies to our construction strategy—"the default approach […] has been to create new space from the ground up" (Stein 2010). This focus on new construction ignores the embodied energy already invested in a structure, "the total energy resource committed to produce a specific result," including planning, raw materials, transportation, labor, and the management of the structure (Stein 2010). By accounting for the energy costs of new building construction (which makes up for about 5 percent of domestic energy consumption in the U.S.), retrofitting becomes even more cost-effective (Stein 2010).

Retrofits have been successful at many scales in reducing energy consumption while saving costs. In large buildings, retrofits have seen huge successes in recent years, as high-energy costs and creative engineering solutions drive a new retrofit market. Through a deep retrofit, the Empire State building was able to reduce energy costs by 4.4 million dollars per year with a three-year payback, while creating 252 jobs and reducing the building's carbon footprint from electricity by 38 percent (Clinton 2011). While aggressive retrofits in individual residences may be more difficult to achieve in a cost-effective manner due to economies of scale, cost-effective solutions can be found by taking a whole-systems approach and utilizing existing replacement needs (Brew 2011).

The demonstrated success at the Empire State Building is indicative of the broader potential of the market. The World Business Council for Sustainable Development predicts that investment in building energy efficiency measures can reduce carbon footprints in the United States by 40 percent with a 5 year discounted payback (World Business Council for Sustainable Development 2010). Furthermore, some areas of the country—particularly those with cold climates—have higher retrofit potential, which allows even shorter payback times on retrofit projects. In a comparative study of retrofit savings in eight cities, Minneapolis, Minnesota had the second-highest cost savings at 366 dollars—or 32 percent of annual energy costs—compared to a national average of 289 dollars (Polly et al. 2011).

Despite demonstrated savings potential, corporations tend to be slow to adopt cost-effective measures that require payback periods, due to high levels of risk aversion (Hu 1990). This trend persists in educational institutions as well. Fahlquist (2008) claims that because educational institutions have substantial resources and the ability to educate the members of their community about the benefits of sustainable initiatives, colleges have a moral responsibility to move forward with measures addressing pressing environmental issues. Many colleges have taken the initiative by addressing issues like climate change. For example, 661 institutions of higher education have committed to the American College and University Presidents' Climate Commitment (ACUPCC), which demands campus carbon neutrality by 2050 (American College & University Presidents ' Climate Commitment 2012).

But retrofitting becomes more complicated when the form of the building is as important as the function. Aesthetic value (the intangible worth placed on a building's appearance) can play a substantial role in community perception of a building, and community input tends to be highly valued on college campuses (Kenney et al. 2005). Whether people value a building's appearance for its historic significance or its architectural charm, any attachment to a building's form can cause issues when a retrofit model indicates that substantial changes or a tear down is the most efficient solution. Thus, as American architect Winston Elting claimed, campus leaders must be conscious of "physical and aesthetic functions" of architecture when proposing any transformation to campus buildings, including retrofit opportunities (Elting 1951).

Given the demonstrated benefits of retrofitting buildings, and the unique position of educational institutions to promote sustainability, we need a decision-making methodology to determine whether schools should implement such measures. Papers modeling cost effective retrofits (Krarti 2000; Diakaki et al. 2010) examine component parts of a physical building, such as door type, window type, ceiling material, heating and cooling systems, and floor structure. Other models determine whether a particular retrofit scheme should be implemented by performing a cost benefit analysis, which weighs estimated costs versus estimated benefits of a particular policy or action to determine if the net value is positive or negative (Clinch and Healy 2001; Goodacre et al. 2002). Neither approach, however, takes into account aesthetic value of the building.

Our research aims to improve existing cost benefit analysis for small liberal arts colleges using an interdisciplinary approach. Our area of focus, regarding ideal investments of retrofits at small colleges, cannot fully be comprehended using only traditional economics, because such models are not capable of fully explaining peoples' decisions.

Therefore, in order to better model these investment decisions, we make three additions to traditional cost benefit methodologies. First, in addition to considering the role of variables such as energy price and savings, we consider factors such as fuel price projection, impacts of retrofits on occupant behavior, additions of retrofits in conjunction with scheduled replacements, financing, performance degradation, and standards forecasting—which should, ideally, be included in a decision making model (Polly et al. 2011). Second, the cost benefit analysis is expanded with a contingent valuation survey regarding aesthetic value, an inherently interdisciplinary technique (Portney 1994). Finally, we use ethical and historic analysis, expert interviews, and non-monetary survey responses to add to further inform our cost benefit analysis.

In understanding what role these factors play at colleges, our case study will examine three houses at Carleton College in Northfield, MN. Using an interdisciplinary approach that focuses on a cost benefit methodology, contextualized by expert interviews, non-monetary survey responses, and historic analysis, *we aim to model the decision-making scenario faced by administrators and decision makers at small liberal arts colleges when determining the ideal investment level for retrofit projects. Through our modeling process, we will determine both payback times and net present values over the lifetimes of the retrofit projects.*

RELEVANT LITERATURE: FRAMING THE APPROACH

The literature related to this study necessarily draws on multiple disciplines because the decision making process to determine whether a college should retrofit buildings is highly complex. First, we present the literature related to a college's ethical duty to pursue environmental initiatives. We then discuss the existing models for determining whether or not a retrofit should be implemented. In order to enhance existing models, we review the literature related to historic and aesthetic value of buildings. Lastly, we discuss the literature related to willingness to pay surveys, the methodology we employ in order to quantify the costs and benefits of retrofits considered in this study.

Ethical Dilemmas of a Small Liberal Arts College

Colleges face an interesting dilemma when it comes to ethical decisions that may or may not be within the direct economic interests of the organization; for-profit corporations face the same dilemma. In his seminal piece, "The Social Responsibility of Business is to Increase its Profits," Milton Friedman (1970) argues that for-profit corporations are only responsible for fulfilling their mission statement and creating shareholder value. He claims that while environmentally friendly objectives may initially help the institution by providing benefits or attracting employees, these objectives are only beneficial if they help the business profit. Thus, Friedman would argue that retrofitting does not directly benefit employees or investors unless the money is going towards the institution's intended goals of making a profit.

If we extend Friedman's argument to include educational institutions, money spent on retrofitting a campus building does not benefit the campus community unless it is going towards the institution's intended goal of providing students with an education. Pursuing sustainability initiatives can help a college's bottom line, since adopting pro-environmental behaviors can help institutions mitigate future financial risk, reduce their carbon footprint, and stand out as environmentally friendly to potential customers (Komarek et al. 2010). Given this framework, it may be beneficial for both colleges and for-profit corporations to engage in retrofits, even if they have no moral obligation to do so.

Defining a college's community is important in understanding to whom they have obligations since duties arise out of recognized relationships. Groups that have legal rights to property at colleges include their board of trustees, students, and people who rent from the college, such as tenants in faculty housing. According to Aldo Leopold, the ethical duty of stewardship is tied up in property rights (Leopold 1949). The Board of Trustees are the property owners that make decisions on college campuses, and are thus responsible for stewardship initiatives like retrofits. According to Edward Freeman, the Boards of Trustees have a binding fiduciary duty to put the needs of the college's stakeholders first by creating as much value as possible for them (Freeman 1984). Stakeholders for small colleges include students, faculty, staff, alumni, parents of students, donors, and future generations of students. All of these stakeholders are affected by decisions about how buildings on the college campus look or how sustainable they are.

It is difficult to gauge the moral responsibilities we have to the non-legal stakeholders of future generations of the college. There is a disagreement among scholars about what our duties to future generations are. Martin Golding argues that we have limited obligations to future generations, since we cannot know to which future people we have obligations, what future people oblige to us, or what kind of responsibilities are obligations to future people. He questions how we can have obligations if nothing is claimed by people from the future (Golding 2009). According to Golding, in order to form a community with future generations there needs to be a sense of a shared life. The more distant future people are, the less likely we are to form a community, and the less obligations we will have (Golding 2009). Also, the further away future people are, the less likely we are to know what these people will want. Without this knowledge, we may be better off doing nothing (Golding 2009). However, Derek Parfit (2010) claims that we have responsibilities to prevent future harms and that our current actions can either have good or bad consequences for future generations. He claims that our choices that affect future generations matter morally, even though nobody in the future is made worse off by our decisions, since they do not exist yet (Parfit 2010). Therefore, current acts that cause environmental damage are wrong, because they bring about less well-being for those in the future (Parfit 2010). Even if decisions are made before future people exist, they are considered to be objectionable if they cause harm to future generations.

However, we argue that it is in the college's self-interest to take a long-term perspective on ethical issues, regardless of the amount of weight they put on future generations. Because the college is a single entity that will persist for a long time, planning for the future is in its own long-term self-interest. Investing in sustainable buildings is one example of how a college can plan for its future by mitigating future costs and projecting a long standing image of environmental friendliness.

Non-profit institutions such as colleges may face a different ethical standard than corporations since they are in a position to transform our energy system (Fahlquist 2008). Fahlquist claims that institutions are primarily responsible for the implementation of policies that ultimately shape and define the relevant contexts in which individual members of a given society operate. Colleges, to a greater extent than individuals within their communities, have a responsibility to pursue environmental ends because institutions have the resources to do so (Fahlquist 2008). Institutions normally have more resources than individuals, and Fahlquist (2008) claims that those who have "reasonable alternatives, capacity, and resources to do something about the environment should be seen as responsible". Because colleges have the resources, they have an ethical responsibility to be sustainable.

This ethical responsibility is further emphasized by the claim that colleges can have a multiplicative impact: "institutional agents have the power and resources to affect the number of individuals who possess such capacity and resources" (Fahlquist 2008). Colleges can provide leadership in addressing environmental issues specifically through campus design and planning

(Kenney et al. 2005). Issues relating to attentiveness and awareness to our surroundings can result in more informed decisions about how to treat the land. As a college community moves about the campus buildings and grounds every day, they receive important messages about human interactions with their environment (Reynolds et al. 2010). These messages can either reinforce or undermine an individual's connection to the environment. Therefore, colleges have obligations to its community to provide positive human-environment images using their campuses as tools.

Sustainability is important to many colleges and is demonstrated by the fact that 661 institutions of higher education have committed to carbon neutrality by 2050 when they signed the ACUPCC (2012). This ethical responsibility is particularly relevant for small liberal arts colleges because their small size allows them to make decisions about retrofits easier and their liberal arts approach allows the ethical implications of retrofits to extend beyond the classroom (Reynolds et al. 2010). Small liberal arts colleges are institutions that are ethically and logistically capable of completing retrofits and their justification for completing retrofits falls both inside and outside of a classic cost benefit analysis. Because of these reasons our interdisciplinary framework applies particularly well for creating a system for evaluating retrofit opportunities for small liberal arts colleges.

Carleton College as Case Study

Carleton College is a small, private school in Northfield, MN whose mission statement is to provide an exceptional liberal arts undergraduate education (Carleton College 2007). Carleton also has buildings with social, historical, and aesthetic importance on its campus. Since most small colleges have buildings with social, historical, and aesthetic importance (Bowdoin College Office of the President 2012; Colorado College 2012; Macalester College 2012) and every small liberal arts college's goal is to provide an outstanding education (Grinnell College 2002; Williams College 2007; Whitman College 2012), Carleton College serves as an excellent case study for this research.

Furthermore, Carleton is a signatory of the American College and University Presidents' Climate Commitment (2012). As part of this commitment, Carleton completed a greenhouse gas emissions inventory and developed a Climate Action Plan that outlines actions to attain carbon neutrality by a future date. Carleton College's Climate Action Plan (CAP) aims to promote a "focused awareness of campus-wide sustainability initiatives, inspire educational opportunities, and instill a widespread network of environmental best practices into our standard operating procedures," (Carleton Climate Action Plan Steering Committee 2011). By incorporating retrofits and other environmentally friendly actions into the CAP, Carleton encourages its students to be environmentally aware, and make environmentally friendly decisions.

Because Carleton College is a small, private educational institution dedicated to sustainability initiatives aimed at addressing climate change, it is an ideal case study in which to explore the viability of early-stage retrofit potential. Savings from retrofits have been demonstrated at Carleton College before, and even simple retrofits have shown significant impacts. At Carleton's Gould Library, a lighting-only retrofit reduced energy consumption of the building by 35 percent, representing an energy savings of 1,363 dollars per month (Noe 2010). Additionally, as previously mentioned, Minnesota has strong returns on investments in retrofits relative to the rest of the United States. Thus, Carleton may be an ideal location to implement these upgrades. Furthermore, Carleton has already conducted pilot energy retrofits, and was willing to produce additional audit data and provide us with data and resources.

Existing Cost Benefit Models

Various cost benefit models concerning building retrofits to enhance energy efficiency exist (Clinch and Healy 2001; Goodacre et al. 2002; Diakaki et al. 2008; Diakaki et al. 2010; Polly et al. 2011; Asadi et al. 2012). Generally, these models fit into two broad categories. The first category consists of models used to determine the most cost effective retrofits for a given type of building in a given climatic zone, by determining the most appropriate technologies to achieve the greatest energy savings per unit cost (Diakaki et al. 2008; Diakaki et al. 2010; Asadi et al. 2012). However, these models are based mainly on technical efficiency, and fail to address a variety of societal factors such as the social cost of carbon and health benefits. Furthermore, they often fail to provide broader institutional guidance for determining whether proposed retrofits should be implemented.

The second category of model determines whether implementing the upgrades of a given retrofit program will result in a net societal benefit or cost, and thus whether or not they should be implemented. These models incorporate variables such as energy savings, environmental benefits, and health gains to determine net cost and benefits, as well as a payback timeframe, to aid in the decision making process (Clinch and Healy 2001; Goodacre et al. 2002). According to Clinch and Healy (2001), studies that consider variables beyond economic and energy savings often attempt to quantify environmental benefits by using CO_2 reductions as a proxy variable. They note, however, that most do not incorporate social and health benefits. For their case study of an Irish residential retrofit program, Clinch and Healy incorporate increases in comfort acquired by retrofits and reductions in morbidity and mortality associated with improvements of cold, moist conditions, in addition to environmental and energy savings benefits. They found that with the inclusion of these societal factors, the retrofits resulted in a net social benefit and a payback time of about seven years. Similarly, Goodacre et al. (2002) examine fuel savings, comfort increases, CO_2 damages avoided, health benefits, and potential employment gains. However, these models fail to incorporate historic and aesthetic values that might be relevant to buildings such as those on a college campus.

Authors in the literature certainly recognize the complexity of decision-making with respect to building retrofits. Asadi et al. (2012) notes that "economic, technical, technological, ecological, social, comfort and esthetical" factors must be considered when making these decisions. However, none of the studies we have found are ultimately this comprehensive. Furthermore, none of the studies we have encountered have conducted a cost benefit analysis on deep energy retrofits, a type of retrofitting that is relatively new to the United States. All have been on lower cost, basic retrofit programs. Additionally, none incorporate historic and aesthetic factors relevant to a small liberal arts educational institution.

Historical and Aesthetic Value

As retrofits are typically done on older houses, it's a possibility that these houses could have a valuable history, or an aesthetic character that is valued within the community. Accounting for this historic and aesthetic value creates a more comprehensive model; however, the significance of these factors depends on building being examined. For example, the community may oppose a retrofit on the grounds of historic integrity, or support it due to the poor aesthetic character of a building. Because "there is no way to directly evaluate contribution to sense of place against gallons of oil required for preservation" (Stein 2010), we understand that these factors are rough estimates in our study, but it is still important to include them to the best of our abilities.

Historic structures are important artifacts of culture and design; their importance is demonstrated by the fact that the United States has an entire branch of the National Park Service, the National Register of Historic Places, dedicated to preserving historic structures that fit under at least one of four main criteria related to historic events, persons, and types of architecture (Quaide 2001). Retrofits can have significant consequences for the history of a site, considering that "authentic historic value cannot be recreated in new construction, regardless of economic or environmental expenditure" (Stein 2010). Well-established college campuses are likely to own older structures with possible historic value; for example, the Historic Campus Architecture Project has collected data on historic places for over 400 private college and university campuses with less than 5,000 students, and Carleton College has five buildings on the National Register of Historic Places (Council of Independent Colleges 2006).

Architecture also serves an aesthetic interest in the community. Winston Elting (1951), an American architect, laid the claim that educational institutions in particular have a responsibility not only to produce physically functional buildings, but also structures with a certain degree of integration and ingenuity. Some architects have addressed issues of "lovability" – if a building is an eyesore, it will likely fall out of community favor and be demolished sooner than later, despite energy savings, high embodied energy, or other redeeming qualities (Curtis 2008). "Economic considerations and technological efficiencies dictate that such [utilitarian] buildings be constructed with a view to inward functions, accompanied by a corresponding neglect of the external appearance;" if form is ignored, it could have economic repercussions in the future (Carter 1976).

Beauty can essentially be considered subjective. Though the field of computational aesthetics has been developing methodology for objectively valuing aesthetics since George Birkhoff's groundbreaking work *Aesthetic Measure* was published in 1933, it has not yet reached a point of maturity regarding the evaluation of existing architectural structures that would render it appropriate to utilize in retrofit evaluations as a part of this study (Birkhoff 1933).

Currently, examining the historic and aesthetic significance of structures requires research and investigation, and discussion with the relevant communities. This can be a time consuming and contested process. There are worksheets and briefs available on how to evaluate the history and appearance of a structure (Nelson 1988), but in the end, opinions can vary concerning the actual importance of preserving or changing these factors. A potential method to simplify this process for college administrations and quantify the monetary value of the historic and aesthetic value of a structure is to conduct a willingness to pay survey of the community involved.

Willingness to Pay as a Method of Determining Historical and Aesthetic Value

Multiple techniques exist for quantifying the value of public goods—such as the historic value of a building—that are not traded in a market, and thus have no explicit price. Methods such as revealed preference theory can be used to quantify non-market goods; the prices of related goods can reveal the market values of goods without an explicit price. For instance, the value an individual places on the presence of a park in a city might be correlated with their travel costs to go to the park (Tietenberg and Lewis 2010), or with the costs of homes near parks, when controlled for other structural characteristics (Geoghegan et al. 1997). Because there are no related goods with market prices to use to quantify the value of the intangibles in our model, we cannot use these methods.

Another method focuses on stated preference, or contingent valuation, which utilizes surveys in order to measure personal preference of a particular population, and the value that the population places on a non-traded good (Mitchell and Carson 1989). These surveys offer hypothetical situations and ask respondents to provide their "willingness to pay" (WTP) for the good represented in the survey. For example, WTP surveys might ask if a resident of a particular city would be willing to pay a certain percentage increase in taxes for the implementation of stricter environmental policies (Guber 2003; Tietenberg and Lewis 2010).

Contingent valuation has been utilized in cost benefit analyses of home retrofits before, as demonstrated in a review article by Amann (2006). The intangibles discussed in the review paper include, but are not limited to, aesthetic improvements, health and comfort enhancements, and noise reduction (Amann 2006). The aesthetic value we analyze falls into the same category of intangible costs and benefits discussed in the Amann paper.

There are various types of contingent valuation survey methodologies. Direct elicitation—including open-ended, close-ended iterative, and contingent ranking methods—is commonly used in willingness to pay surveys, but has been demonstrated to have significant problems with survey bias, word choice affects, and anchoring (Boardman et al. 2010). These issues can partially be addressed using the dichotomous choice method. In a dichotomous choice survey, each respondent is presented with a single price for the good and then asked if they are willing to pay that price. Based on the responses, the probability of the general population's willingness to pay for each dichotomous choice is determined, and from these probabilities, the population's willingness to pay is determined (Boardman et al. 2010).

WTP surveys have been heavily scrutinized. Guber (2003) points out that various studies have polled the same population with similar questions and received conflicting results, due to alterations in the wording of a question. For example, respondents might find a survey asking if they are willing to pay a certain percentage increase in taxes more ambiguous than one asking them to pay a dollar amount equivalent to the percentage tax increase. If the survey subjects are uncertain about the costs, the survey results are likely to be conflicting. Additionally, Guber criticizes the fundamental notion of responding to hypothetical situations, claiming that it is difficult for a respondent to provide an accurate WTP to a non-existent scenario. Despite the criticisms of willingness to pay, it is the best option for the purpose of our study. The survey methodology allows us to collect community specific data on the value of buildings on campus, and the community's willingness to allow these buildings to change.

METHODOLOGY: BUILDING THE INTERDISCIPLINARY MODEL

In order to determine whether or not Carleton should retrofit campus buildings or construct net zero energy buildings in their place, we conducted a cost benefit analysis contextualized by interviews with architects, historians, college administrators, and a deep retrofit homeowner. The following sections extensively detail the cost benefit analysis approach. First, we frame the equation of the general model. Then, we discuss the 3 houses, 3 types of retrofits, and 4 scenarios we explored, for a total of 36 versions of the model. Next, we explain the selection of variables to be included and omitted in the model. Within the variable selection section, we discuss the willingness to pay methodology utilized to quantify aesthetic value of the buildings. Finally, we discuss the contextualizing interview methodology.

Cost Benefit Methodology

In order to determine payback times and net present values for the retrofits, we conducted a cost benefit analysis. Cost benefit analysis weighs quantified values of demonstrated costs versus quantified values of demonstrated benefits to determine if a policy or action results in negative or positive net present value over the lifetime of the project. At the most basic level, our model calculates the net value of the retrofit in a given year using the equation:

$$net\ value = b - c$$

in which b are positive benefits, such as energy savings, and c are negative costs, such as the cost of retrofits. Because retrofits involve large upfront costs of construction, and benefits exist as one time rebates and annual savings, we summed annual costs and benefits to determine at what time, if ever, the benefits outweigh the costs, thus signifying that the retrofits have been paid back. The sum of the annual costs and benefits up to any given year represents the net present value of the project at that time. We calculate net present value at the lifespan of the retrofit project. The equation for our model is as follows ($ denotes real 2012 U.S. dollars as the unit):

$$net\ present\ value = \sum_{i=0}^{y} \frac{(epf)_i + t_i + w_{si} + (kej)_i + h_i - c_i - w_{ai} - b_i}{(1+r)^i}$$

y = year
c = cost of retrofits ($)
t = rebates ($)
e = energy saved per year (therms and kWh)
p = price of energy ($)
f = projected energy price multiplier
j = units of carbon per unit of energy (metric tons)
k = social cost of carbon ($)
r = discount rate
b = rebound effect
h = health and safety benefits ($)
w_s = willingness to pay for sustainability ($)
w_a = willingness to pay for aesthetic value ($)

To implement the above equation, we built a model using Microsoft Excel software. The model sums annual costs and benefits, applies an annual discount rate, and then keeps a running sum of each year's net present value. The point at which the net present value becomes positive signifies that the project has paid back. The model allowed us to apply the equation to each house using various values for each variable, and also allowed us to run analyses for three different levels of retrofit, each of which incorporate slightly different combinations of variables.

House Selection

For our analysis, we chose three houses on Carleton's campus that have varying levels of energy saving potential, based off of initial audits. The houses also each highlight varying levels of aesthetic and historic significance. The following houses were analyzed in this study:

Geffert House

Home to eight students, Geffert is the most nondescript house of the three in the study. It has an unclear history; though the property at 112 Division Street has four documented sales in the past (in 1916, 1920, 1990, and finally to Carleton in 1999), there is no documentation of when the current structure was actually built (Nelson 2003). A renovation was performed by Carleton to prepare it to begin housing students in 2002. Geffert has a commonplace appearance, non-central campus location, and relatively small number of residents (compared to other student housing options). As a house with seemingly little historical value and presence in the campus community, we predicted Geffert would hold little aesthetic significance to the community. Because of this, we expected that Geffert might be emblematic of a structure for which payback times would be significantly reduced as the historical and aesthetic value would not exist as a barrier to retrofitting.

Dacie Moses House

The cottage at 110 Union Street was constructed in 1870 and was formerly known to the community as the Ira Sumner house. Though it holds clear elements of the Gothic Revival style, an important era of construction in Northfield, it doesn’t have many important exterior architectural details left after many renovations (Clark and Zellie 1999). However, the house holds significance to the student body and greater Carleton community as the legacy of former Carleton employee Candace Moses. During Moses’ time in Northfield, she opened her house to students for brunch, conversation, and to enjoy a home-like atmosphere. The house was left to Carleton upon Moses’ death in 1981, and has since been open for the same hospitable purposes, 24 hours a day, 365 days a year. It is maintained by two student residents and one house manager. Dacie Moses is home not only to Moses’ legacy, but is the rehearsal space for campus music groups and a site for brunches, activities attended by the wider Northfield community, and an alumni guest room (Carleton College 2005). Because of this, we determined that the significance it holds would likely affect payback time, as people might value preserving the appearance of the house, both internal and external, as it lends itself to the homey atmosphere that Moses provided. Though a student in 1960’s articulated that the house would be nothing without Dacie, the community has become more attached to the structure she left behind since her passing (Northfield News 1969). Deep retrofits or constructing a new net zero energy use building in the place of Dacie Moses House would have significant effects on the aesthetic character of the house.

Nutting House

Constructed in 1887, and given to Carleton in 1970, Nutting House is currently home to the President of Carleton College and his family, used for living purposes and also extensive entertaining. It was placed on the National Register of Historic Places in 1970 as the last remaining example of a large brick Queen Anne-style home of this period left in Northfield (Clark and Zellie 1999; Carleton College 2012). Though many of the original features in the house have been maintained since its construction, a gift by Ruth Nutting, granddaughter of the original owner John C. Nutting, funded a restoration in 2000 to return modified portions of the house as closely as possible back to its original plans (Carleton College 2012). The Nutting Family was held in high regard in Northfield, so in addition to being architecturally important, the house also represents and honors the extensive contribution of the Nutting family to the College and Northfield communities. Thus, we predicted that Nutting would be on the opposite end of the spectrum from Geffert House, and hold aesthetic and historic importance to the community.

It is possible to retrofit and upgrade buildings placed on the National Register of Historic Places—technically, the property owner can make any modifications as long as the structure is not partially owned by the government (National Register of Historic Places 2011). However, renovations are often dictated by local preservation laws, or the intervention of local historic preservation societies. If Nutting were to be retrofitted, we assume the Northfield Heritage Preservation Commission would investigate the process, especially after the extensive restoration work undergone in 2000. If Carleton were to retrofit Nutting House, the school would likely incur significant costs to maintain the aesthetics of the building, due to the necessity for custom-made building elements, such as stained glass windows. Thus, we felt that Nutting would be representative of buildings for which payback time might be extended due to the value placed on its current appearance. However, this public concern for Nutting House could also lend itself to produce benefits from a retrofit—sustainable improvements to such an important structure might also present positive public relations opportunities, effectively reducing payback time.

Types of Retrofits

In our cost benefit analysis, we analyzed three levels of retrofitting. Each level provides more comprehensive energy efficiency gains than the previous one. The three retrofit levels are as follows:

Basic Retrofit

A basic retrofit involves making minor changes to improve the energy efficiency of the building. Improvements are generally not comprehensive, and focus on isolated problem areas such as leaky doors and windows, poorly insulated sections of walls, or high-energy appliances. Retrofits can include very minor changes such as caulking and sealing windows and the addition of weather stripping to door frames. They may also include slightly more intensive insulation improvements, such as the addition of blown cellulose around rim joists, or into wall cavities through small holes. Occasionally, basic retrofits include upgrading inefficient heating and cooling systems. Changes categorized as basic retrofits are generally fast and relatively easy, requiring little to no intense construction. These retrofits also do not change the aesthetics of a building in any appreciable manner. Thus, for the purpose of our study, our basic retrofit model will not include aesthetic changes in determining net present value and payback time. We built the model to include the cost of basic retrofits specified in the Xcel Energy audit (Cobbs 2012b; a; Sparks 2012; Gransee-Bowman 2013).

Deep Retrofit

A deep retrofit involves a comprehensive re-insulation, re-skinning, and sealing of the entire structure in order to drastically reduce air leakage and improve indoor air quality and comfort. Though it is difficult to define a typical deep retrofit, as it can vary substantially by the age and material of the structure, this may involve removing the outer layer of a house, adding insulation, and putting on new siding. This will usually result in much thicker exterior walls, and thicker window boxes and door frames. For brick structures, the walls must be expanded inward, resulting in a loss of interior space. Other changes often include triple paned windows, heavier doors, a new roof, and removal of windows on the north side of the building. Because these efforts are a large investment, there is also usually a conscious effort to choose extremely durable building materials in order to extend the life of the retrofits and the structure itself (Gransee-Bowman 2013). The *EnerPHit* standard is a section of the *Passive House* energy conservation building standard that includes energy use goals more easily attained by a retrofitted structure rather than brand new construction (BRE Group 2011). Though we do not include analysis of these specific standards in this study, they are helpful to conceptualize the energy saving potential of these types of retrofits. We built our model using cost estimates of retrofits that would meet the EnerPHit standard.

Net Zero Construction

Net zero construction involves building a structure that utilizes no energy from the grid. Combining a highly insulated envelope to insure efficient use of heating and cooling with energy producing technology such as solar arrays, a net zero building is a self-contained entity that may in fact be able to produce more energy than it consumes (Gransee-Bowman 2013). We built our model using cost estimates for a building of this standard as the most extreme level of energy efficiency improvements.

Four Scenarios

Our model consists of four different scenarios for each house at each retrofit level: the Worst Case, Projected, Best Case, and Environmentalist scenarios. Each scenario utilizes different combinations of variable values. The Best Case scenario utilizes values for each variable that would create a short payback time and result in the highest net present value. Conversely, the Worst Case scenario utilizes the values for variables from the literature that would create the longest payback time and result in the lowest net present value. The Projected scenario draws upon the recommended values in the literature for each variable. The Environmentalist scenario utilizes values from the literature that reflect an ethical duty to future generations to prevent environmental damage. Ethical duty is indicated in this scenario through the use of an extremely high cost of carbon.

Table 1 shows the combinations of discount rates and costs of carbon used in the four scenarios for all retrofit levels, as well as the combinations of cost estimates and return rates used in the basic retrofit model.

Table 1. Variable combinations for four scenarios.

Variable	Worst Case	Projected	Best Case	Environmentalist
Discount rate	high	middle	low	middle
Cost of carbon	low	middle	high	extremely high
Basic costs	high	average	low	low
Basic Return on investment	low	average	high	high

Selection of Variable Values

The following section details how values for each variable were determined for use in the model. Values that are consistent across houses, scenarios, and retrofit levels, such as cost of carbon and discount rate will be specified in the following descriptions. Values for variables that are house, scenario, and retrofit level specific can be found in Table 2.

In order to accurately measure the cost of retrofits, units of energy saved per year, and rebate opportunities, we hired Xcel Energy to produce Home Energy Audit Reports for Nutting House and Dacie Moses House during November of 2012 and Geffert House in February of 2012. The audits include blower door tests, infrared imaging, and analysis of building materials, use, and age. The full audit reports as presented by Xcel are attached in Appendix 3. Use of the audits in determining variable values will be noted within specific variable descriptions.

Table 2. Values used in the cost benefit analysis that are scenario, house, or retrofit type specific.

		Rebates ($)	Cost of Retrofits ($)	Annual Energy Savings ($)	Therms Reduced	kwh Reduced
Basic Retrofit Specific Values						
Geffert	**Worst Case**	350	2,189	153	187	-
	Projected	350	2,007	181	221	-
	Best Case	350	1,824	201	245	-
	Environmentalist	350	1,824	201	245	-
Dacie Moses	**Worst Case**	410	1,342	81	107	-
	Projected	410	1,230	125	166	-
	Best Case	410	1,118	160	212	-
	Environmentalist	410	1,118	160	212	-
Nutting	**Worst Case**	410	2,288	92	125	-
	Projected	410	2,098	104	142	-
	Best Case	410	1,907	112	153	-
	Environmentalist	410	1,907	112	153	-
Deep Retrofit Specific Values						
Geffert		350	234,769	1,129	1,380	-
Dacie Moses		410	206,164	963	1,275	-
Nutting		410	1,128,360	2,332	1,594	9,821
Net Zero Home Construction Specific Values						
Geffert		350	1,431,000	2,205	1,725	7,004
Dacie Moses		410	1,128,360	2,332	1,594	9,821
Nutting		410	2,689,917	7,478	2,580	51,543

Note: dashes indicate houses that do not have reduced electricity usage due to lack of air conditioning, or audit estimates that do not specify electricity reduction. Values for deep retrofits and net zero home construction are consistent across scenarios since they are based on square footage models, not audit estimates.

Cost of Retrofits

The costs of the recommended retrofits are estimated for each individual house in our case study as a one-time expenditure. Xcel Energy provides cost estimates for basic retrofits recommended in the final energy audit report. Deep energy retrofit cost estimates were made using a model, developed with architect Joe Gransee-Bowman, that predicts costs based on a building's above and below grade wall surface area, roof size, slab size, and total window area. Using industry standard costs for these variables, the model predicted deep retrofit costs that ranged from approximately 50-100 dollars per square foot for Carleton-owned houses. Similarly, the estimated cost of construction of an equivalent net zero energy building was based on a model developed with Gransee-Bowman. Using industry standards for net zero construction, new buildings of equivalent function were estimated to cost 250 dollars per square foot, at 8 percent of the square footage of the existing building, in order to account for more efficient usage of space in a net zero building (Gransee-Bowman 2013).

Rebates

Rebates are the monetary returns given by Xcel Energy for the implementation of certain retrofits recommended in the audit process or in the purchase of low energy use or efficient appliances. Rebates are specified by Xcel energy in the individual house audit reports. The audit reports specify the required retrofits to qualify for rebates, as well as optional retrofits. We include rebates for all required retrofits not already implemented by Carleton (Cobbs 2012a; b; Sparks 2012). Given the methodological and ethical framework of the model, only the institution (Carleton) and the societal impacts associated with the cost of carbon are given standing. Because Xcel Energy is not given explicit standing in the model, these rebates are included as benefits.

Energy Saved Per Year

Energy saved per year is the reduction in annual energy use for each retrofit option. For basic retrofits, energy saved per year is based on estimated return on investments from the audit reports produced by Xcel Energy (Cobbs 2012a; b; Sparks 2012). Because Xcel provides expected ranges of energy savings, the high estimate for each house is used in the Best Case and Environmentalist scenarios, the low estimate is used in the Worst Case scenario, and the average of the two is used in the Projected scenario.

Deep retrofits are estimated to reduce energy usage associated with heating and cooling costs by 80 percent (Gransee-Bowman 2013). Thus, annual energy reductions for the deep retrofits are equivalent to 80 percent of the natural gas consumed by heating and the electricity associated with air conditioning. The amount of energy each house consumes in heating and air conditioning was calculated by subtracting the average gas and electricity of the three lowest months in 2012 (base load) from the average of the three highest months in 2012 (peak load). In our study, Nutting is the only house that has an installed air conditioning system, so it is the only house with electricity savings associated with retrofits.

For net zero buildings, our model assumes that energy savings come from a 100 percent reduction in energy usage, both for heating and electricity, as net zero construction utilizes insulating techniques and electricity producing technology to achieve net zero energy use (Gransee-Bowman 2013). Because the model is house and retrofit level specific, energy reductions range from 107 therms per year (Dacie Moses House, basic retrofit, worst case) to 2,580 therms and 51,543 kWh per year (Nutting House, net zero). The full range of values is included in Table 2.

Price of Energy

The price of energy is the dollar amount paid by Carleton for a unit of heating or cooling energy. These costs are based off of the average rates paid for each house over the course of 2012. Heating costs range from $0.73 (Nutting) to $0.81 (Geffert) per therm, and electricity costs are $0.11 per kilowatt-hour for each house (Xcel Energy 2012).

Projected Energy Price Multiplier

We use multipliers to account for projected growth in price of energy in the future. Because Carleton College buys energy at commercial sector rates through Xcel Energy, we use commercial sector price increases found in the U.S. Energy Information Administration's (EIA) 2012 Annual Energy Outlook, which projects energy prices through 2035 (U.S. Energy Information Administration 2012). Because energy price projections beyond the EIA timespan are not available, we continue using the EIA projections beyond 2035, acknowledging that predictions beyond this time scale are likely unreliable. The EIA predicts commercial natural gas prices to increase by 1 percent annually and electricity prices to remain stagnant. Thus we use fuel price multipliers of 1.01 and 1.00 for natural gas and electricity, respectively.

However, Xcel Energy price increases over the past ten years have averaged 5.52 percent per year for electricity. Because this data is not projected into the future by Xcel, and because we do not have comparable data for heat price increases, we do not use these data in our model. However, Appendix 2 details the results of a sensitivity analysis run using this ten year average as a future projection.

Units of Carbon per Unit Energy

CO_2 per unit energy is used to calculate the carbon emissions reductions associated with the energy savings from a particular retrofit. Values for units of carbon per therm of natural gas and kwh are taken from the EPA website. We use values of 0.005 metric tons of carbon per therm of natural gas and 7.055×10^{-4} metric tons of carbon per kWh (U.S. Environmental Protection Agency 2012).

Social Cost of Carbon

The social cost of carbon (SCC) is "a monetized value of the marginal benefit of reducing 1 ton of CO_2" due to potential climate change damages (Johnson and Hope 2012). Because there are a wide range of SCC values across the economics literature reflecting different methodologies, we deemed it inappropriate to utilize just one value in our model. In 2012, authors Johnson and Hope took a critical approach to reviewing the SCC values recommended by a U.S. government working group in 2007. Though the working group's values for SCC include $5, $21, $35, and $65, these values have been criticized heavily for underestimating future climate damages. Therefore, we chose four of the revised SCC values determined by Johnson and Hope: $5, $21, $62, and $266, to correspond to each level of our model. Because these values were calculated in 2007 US dollars, we converted them to 2012 US dollars using the Bureau of Labor Statistics annual inflation rates from 2007 to 2012, resulting in SCCs of $5.53, $23.23, $68.58, and $294.25 for the Worst Case, Projected, Best Case, and Environmentalist models, respectively (Johnson and Hope 2012).

Discount Rate

We discount yearly benefits in our model, in order to find the net present value of retrofit projects. Following Boardman et al. (2010), we use the optimal growth rate approach to discounting, because our focus is on intergenerational projects in a developed country, and takes into account climate change, rendering market rates of return "entirely inappropriate." Our optimal growth discount rate uses Boardman's assumptions for the long-run rate of growth in per capita consumption, the optimal growth constant, and the pure time preference rate. Using per-capita quarterly data on real consumption expenditures in the United States between 1947 and 2002, Boardman et al. (2010) estimates an average growth rate in consumption per person at 2.3 percent. Using a survey of the literature, he places the optimal growth constant, based on income tax progressivity, at 1.3 percent, and the pure time preference rate at 1 percent. Acknowledging that future predictions are difficult because of a high variation in historical growth rates, this leads him to a discount rate of 3.5 percent, with a sensitivity range from 2 to 6 percent (Boardman et al. 2010). We use 3.5 percent for the Projected and Environmentalist scenarios, and 2 and 6 percent for the Best Case and Worst Case scenarios respectively.

Rebound Effect

The rebound effect is a consequence of an increase in efficiency. As defined by Greening et al. (2000), this effect exists because "gains in the efficiency of energy consumption will result in an effective reduction in the per unit price of energy services. As a result, consumption of energy services should increase." This increased consumption improves customer welfare, but partially negates the gains in efficiency—this is referred to as the rebound. In the context of a retrofit, it is best explained in terms of heating costs. If a house is retrofitted, this should reduce heating fuel use and costs—the same temperature can be maintained with less fuel and less money. However, unless the quantity of heat purchased is completely independent of the price (perfectly inelastic demand), a reduction in heating costs will result in a demand for more heat, partially offsetting the initial efficiency gain. If a family is keeping heating costs low by maintaining their house at a low temperature, an increase in efficiency is a chance for them to live at a slightly higher temperature without incurring more costs. Thus, the rebound effect absorbs some of the expected energy savings. Studies and simulations place the behavioral responses encapsulated in the rebound effect at 3 to 30 percent of total energy savings (Dubin et al. 1986; Hsueh and Gerner 1993; Schwarz and Taylor 1995) for single family homes. In contrast, a comprehensive review focusing on rebound effects across energy saving experiments by Gillingham et al. (2013) demonstrates that "rebound effects are small, and therefore no excuse for inaction."

However, regardless of the size of rebound effects, a person living in college-owned housing has different incentives regarding fuel use and cost savings that negate the impact of rebound effects in our study. For example, at many colleges (including Carleton), students pay utilities in the form of a fixed rooming charge, which is less direct than a monthly utility bill. The bill is paid as the term begins, and subsequently the student can use as much heat as they like without any additional direct cost per unit of energy used. This essentially creates a situation in which the student will set the heat to their ideal temperature no matter how efficient the building is, and *ceteris paribus*, will maintain that preferred temperature after the retrofit, eliminating the post-retrofit increase in consumption, or rebound. Thus, as all houses in our study have utility costs paid indirectly by the residents, the rebound effect will not appear in our model.

Health and Safety Benefits

If a retrofit creates a living environment with better lighting or improved indoor air quality, these improvements could result in a number of both physical and mental health benefits to the residents, including fewer instances of sickness and a more productive environment. One potential variable for our model was a monetary value encompassing potential health benefits that would come from a retrofit. The current methodology on evaluating health and comfort benefits lies mainly in the area of fuel poverty, and the health benefits associated with a warmer home (Boardman 1991; 1994). Because students are likely to maintain the temperature at their ideal comfort level before and after the retrofit due to indirect utility payments, these benefits do not apply to our model. Furthermore, a case study of energy efficiency in Irish homes provides evidence that the majority (up to 87 percent) of people suffering from reduced comfort and health due to cold homes are elderly, which is inapplicable to the population of our study (Clinch and Healy 2001). Robust methodologies for quantifying other types of health benefits have not been developed, and thus were excluded from the model.

Willingness to Pay for Sustainability

Gratification (in this study, feeling good about doing something beneficial for the environment) can have varying effects on whether someone is willing to pay for an energy saving retrofit. Furthermore, our survey demonstrates that there may be institutional benefits associated with being perceived as a green institution. However, because this variable is extremely intangible, creating a quantifiable good proved impossible, limiting our ability to conduct a standard contingent valuation of the variable. So, in our survey, we examine the relative value that the Carleton community places on college's image as a green institution in relation to deep retrofits using a less rigorous analysis than a full willingness to pay methodology. We asked to what extent the deep retrofit in question improves or detracts from Carleton's image as a green institution along a seven-point Likert scale, ranging from "significantly detracts" (value = -3) to "significantly improves" (value = 3). We then calculated the median ratings for each house and checked for anchoring bias based on survey order. While these results are not intended to be used in the model, they help inform the model and future research by demonstrating the extent to which this variable is an important part of the calculus of retrofits. Analysis of all the Likert scales in our survey was informed by Jamieson (2004).

Willingness to Pay for Aesthetic Value

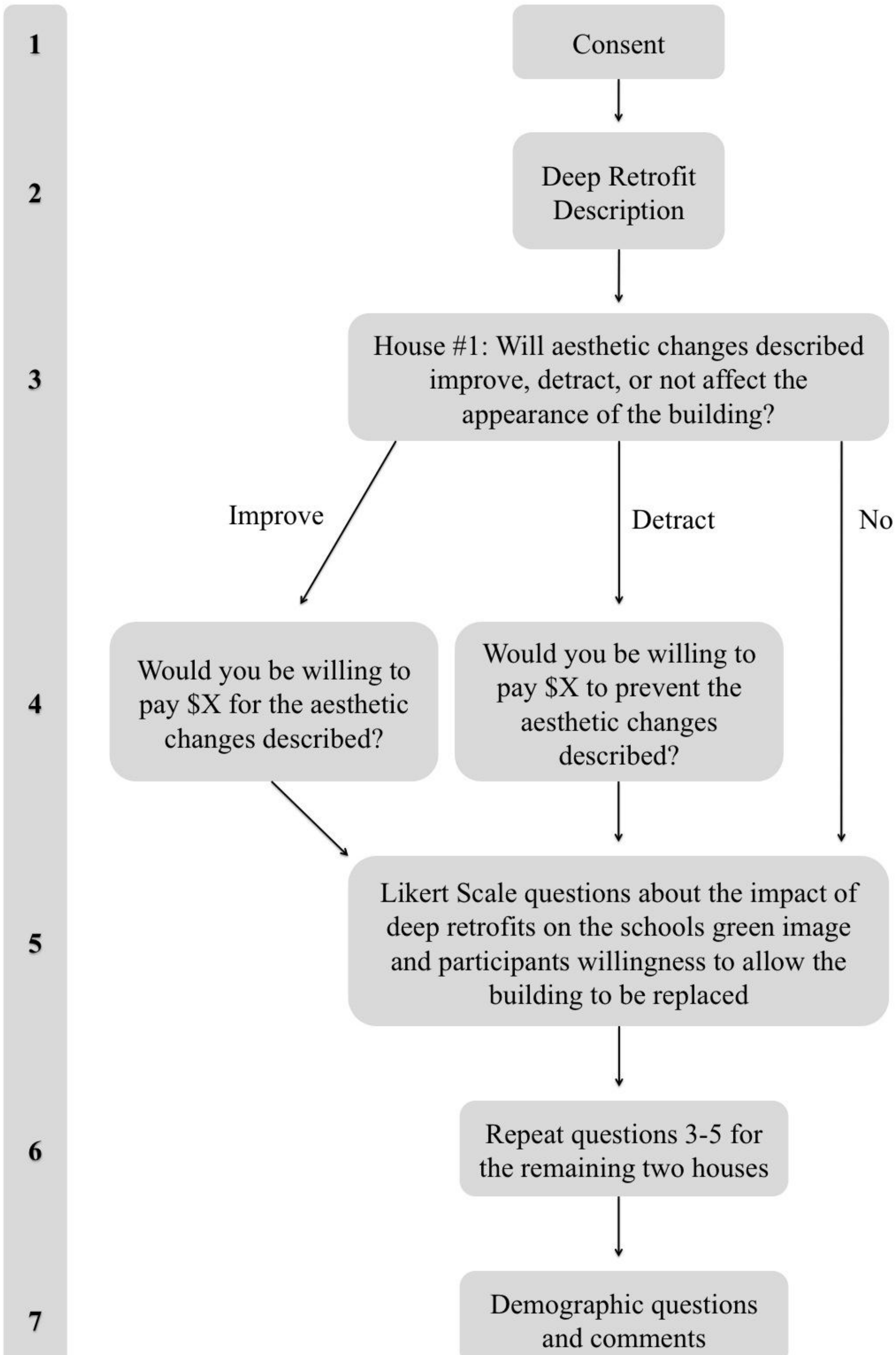
Using the online survey software SurveyMonkey (2012), we conducted a dichotomous choice method survey. Ten different versions of the survey were constructed and each sent to a random distribution of one tenth of our survey sample. To test for anchoring bias, five of the surveys posed questions about the houses in the order Geffert, Dacie, Nutting, while the other five posed the questions in the order Nutting, Dacie, Geffert. Within each order, the five surveys had dichotomous choice values of 30, 60, 90, 120, and 150 dollars, representing an even distribution of the range of values that could potentially pay for the cost of the deep retrofits.

Figure 1 is a flowchart detailing the logic of the survey administered, and the full survey can be found in Appendix 1. The same process occurred for all three houses, and willingness to pay values were calculated by multiplying the number of affirmative respondents in each dichotomous choice value by their given value, dividing by the total number of survey respondents to obtain a value per person, and then multiplying that value by the population of the Carleton community included in the study (students, faculty, and staff).

These values were inserted as costs and benefits for each house in the deep retrofit and net zero models—the two models that require significant aesthetic changes. To verify our use of the willingness to pay results for both the deep retrofit and net zero house models, we explicitly examine the relative willingness of the Carleton community to tear down each of our three houses and replace them with a net zero house. Because this good was too difficult to quantify for a classic willingness to pay methodology, we used a seven-point Likert scale, ranging from "very willing" (value = 3) to "very unwilling" (value = -3), to ask our survey respondents how willing they were to allow these tear-down replacements to occur. We then calculated the median ratings for each house, and checked for anchoring bias based on survey order using a Mann-Whitney test.

We sent the survey to a stratified random sample of 600 people within the Carleton community: 450 students, 50 faculty, and 100 staff, which is approximately 25 percent of the on-campus population of each group. We stratified by community role to capture potential differences between the opinions of these groups, but assumed insignificant differences in opinions between other demographic differentiations, such as gender, class year, and tenure status. A full version of our survey is included in Appendix 1.

Figure 1. Flowchart of willingness to pay survey logic.



Interviews

In order to cover the variables missed by the model and survey analysis, we conducted qualitative open-ended interviews with experts in areas related to some of the intangible variables in our analysis. We also collaborated more heavily with a few individuals who offered insights and expertise along the way. The individuals we spoke to and their qualifications are as follows:

Martha Larson - Larson is the Manager of Campus Energy and Sustainability at Carleton College, with a background in mechanical engineering (B.S. from Northwestern University) and project management. As the chair of the Environmental Advisory Committee, guide to the campus student sustainability assistants, and key player in the campus Climate Action Plan, Larson is an integral part of campus sustainability initiatives. She provided information and perspective regarding the campus energy audits, the scope of our project, and the realities and current state of college residence maintenance, construction, and sustainability projects.

Joe Gransee-Bowman - Gransee-Bowman is an architect (M.S. in Architecture, Sustainable Design Track) and a certified Passive House consultant based in Northfield, MN. Gransee-Bowman helped us delve much farther into the technical aspects of retrofits, especially while we were constructing our willingness to pay survey and defining which specific types of changes would occur during retrofits on our three study houses. We also collaborated with Gransee-Bowman in order to analyze the audit information from Xcel Energy, network with homeowners, and to give realistic context to some of the more theoretical methods and technologies we encountered in our research.

Rick Cobbs - Cobbs is a Senior Crew Leader at the Neighborhood Energy Connection, a St. Paul non-profit organization that "provides energy conservation information, services and programs to residents and communities across Minnesota" (Neighborhood Energy Connection 2011). The NEC partners with Xcel Energy to perform home energy audits for Xcel customers, and Cobbs was our auditor for Dacie Moses and Nutting. While performing the standard audits, he also talked us through the process of evaluating a home's energy efficiency and assisted us in documenting and understanding the process.

Fred Rogers - Rogers is the Vice President and Treasurer of Carleton College. As a 1972 alumnus of Carleton, a member of the Board of Trustees, and contributor to the recent Carleton College Strategic Plan, Rogers offers a unique insight into the financial operations and spending habits of the College, the decision making process surrounding major projects, and conversations within the community about future facilities and college housing initiatives.

Paul Brazelton - Brazelton is the owner of the MinnePHit house, the first EnerPHit certified house in the United States, located in Minneapolis, Minnesota (Brazelton 2012). The rigid standards required by EnerPHit and by the sources of funding made the Brazelton family's retrofit unique. As the first EnerPHit house in the U.S., the project attracted a large number of sponsors. Talking with Brazelton and touring his home, we were able to see first-hand many of the retrofit processes and technologies we have researched, gain a better understanding of the surprises to expect when remodeling an older home, and learn what it is like to live in a structure that has undergone these changes.

Baird Jarman - Jarman has been at Carleton College in the Art History Department since 2002, where he teaches courses on, among other things, American and European art of the nineteenth and twentieth centuries. Jarman's background also includes architecture and historic preservation –he is a member of the committee that screens properties within Minnesota that will potentially be placed on the National Register of Historic Places. Through our interview, we spoke about things such as the importance of aesthetics and historic architecture to a community (both a campus community and a town), Carleton's use of space in regards to the many buildings it owns, and the debate about what a campus' literal appearance should project.

RESULTS: SURVEY, MODEL, AND QUALITATIVE RESULTS

Survey Results

We received 305 survey responses from our random sample of 600 Carleton students, faculty, and staff, of which 279 responses were complete and usable. The distribution of responses across the five dichotomous choice values ranged from n=57 (value=90) to n=63 (value=120, 30), with an average response rate of 61 responses per value. We found no correlation between survey order (anchoring) and response values (Mann-Whitney two-tailed test, all p-values < .01), though our sample size may not have been big enough to significantly test for anchoring. Table 3 shows the number of respondents for each survey.

Table 3. Number of complete responses to each survey.

Survey order	$30	$60	$90	$120	$150
Nutting, Dacie, Geffert	33	28	31	26	29
Geffert, Dacie, Nutting	25	29	24	29	25

Willingness to pay

The dichotomous choice willing to pay survey resulted in the expected order of valuation for aesthetic changes associated with deep retrofits. As predicted, the survey results show that the aesthetic changes associated with a deep retrofit of Geffert House have a positive value to the Carleton community, independent of energy savings and other environmental benefits ($16,215). To a lesser extent, the Carleton community also gave a positive valuation to the aesthetic changes associated with a deep retrofit of Dacie Moses House ($2,516). However, the aesthetic changes associated with Nutting House were deemed to be a net cost of $4,193. Table 4 shows the individual and community willingness to pay values as well as the standard errors for individual willingness to pay.

Table 4. Per person and aggregated willingness to pay values. Negative values indicate willingness to prevent retrofits due to aesthetic changes, while positive values indicate willingness to pay for aesthetic changes. Community WTP was determined by multiplying WTP per person by the number of people included in the Carleton community (n=2600).

	Geffert	Dacie	Nutting
WTP per person ($)	6.24 (SE = 1.52)	0.97 (SE = 1.68)	-1.61 (SE = 1.46)
Community WTP ($)	16,215.05	2,516.13	-4,193.55

Carleton's Green Image

On a seven point Likert scale, the Carleton community deemed that deep retrofits would moderately improve Carleton's image as a green institution for all three houses in the study (see Figure 2). Geffert and Dacie Moses had a Likert median rating of 1, while Nutting had a Likert median rating of 2, which was moderately higher than the other two houses (Mann-Whitney two-tailed test, p-value < .05). Thus, deep retrofit modifications to Nutting House were viewed as providing the highest improvement to Carleton's green image of the three houses. According to the Mann-Whitney test, there was no significant difference between the responses on the two differently ordered surveys (tested difference between GDN and NDG for each house, all two-tailed p-values < .01).

Figure 2. Distribution of responses to the Likert rating of the effect of retrofitting on Carleton's green image.

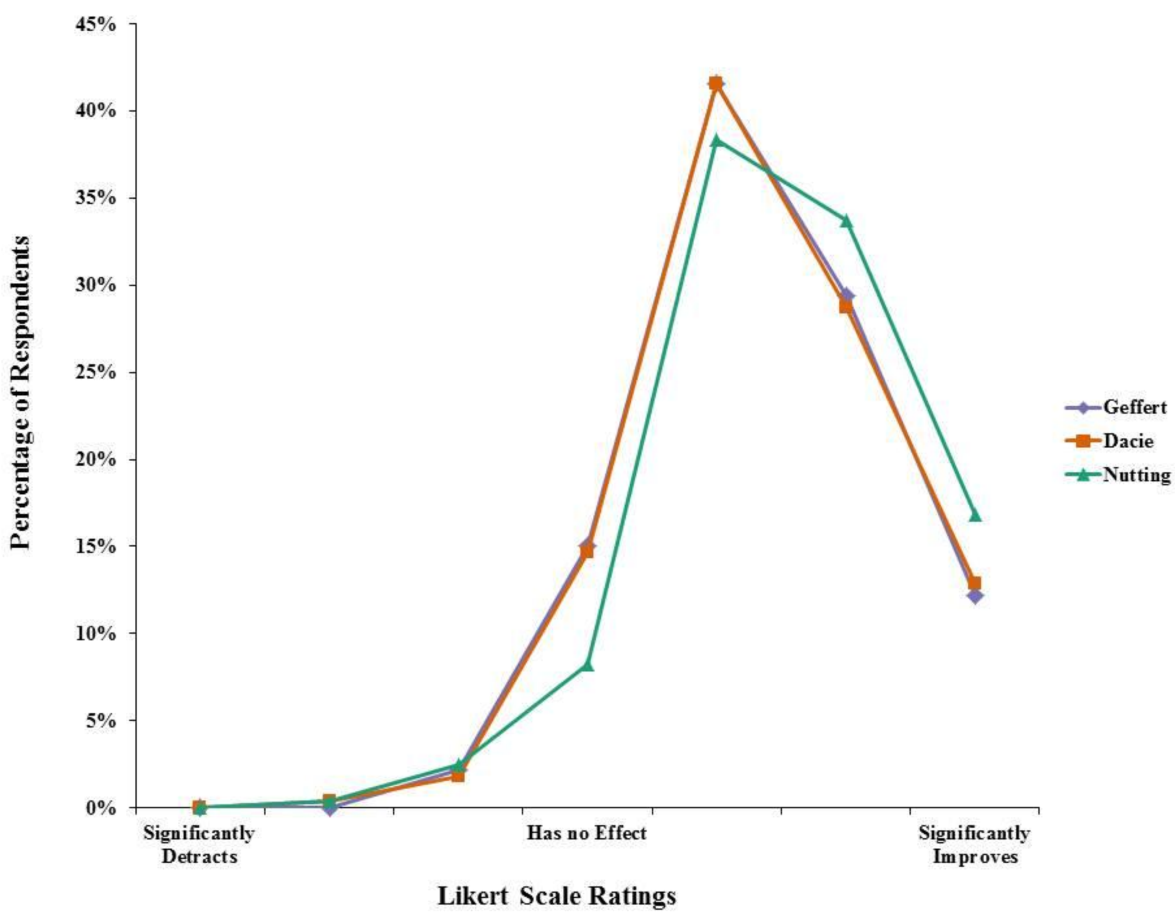


Figure 2 shows that the overwhelming majority of the Carleton community believes that improving the energy efficiency of buildings through deep retrofits would increase the institution's green image. The data indicates that the community believes Nutting house would have a slightly greater effect as more people chose higher ratings for Nutting compared to the other two. Dacie Moses and Geffert house have almost identical perceived effects on the school's green image.

Net Zero Buildings

On a seven point Likert scale, the Carleton community was moderately willing to tear down Geffert House and replace it with a net zero building (median Likert value = 1), but moderately unwilling to tear down Dacie Moses House or Nutting House (median Likert value = -1, see Figure 3). Using a Mann-Whitney two tailed test, there was a very significant difference between Geffert and the other two houses (p-value < .0001). For Dacie Moses House and Nutting House, there was no significant difference between the responses on the two differently ordered surveys (all two-tailed p-values < .01). However, survey respondents were significantly more likely to support tearing down Geffert House when it came last in the survey (two-tailed p-value < .0001).

Figure 3. Distribution of response to the Likert rating of willingness to tear down houses.

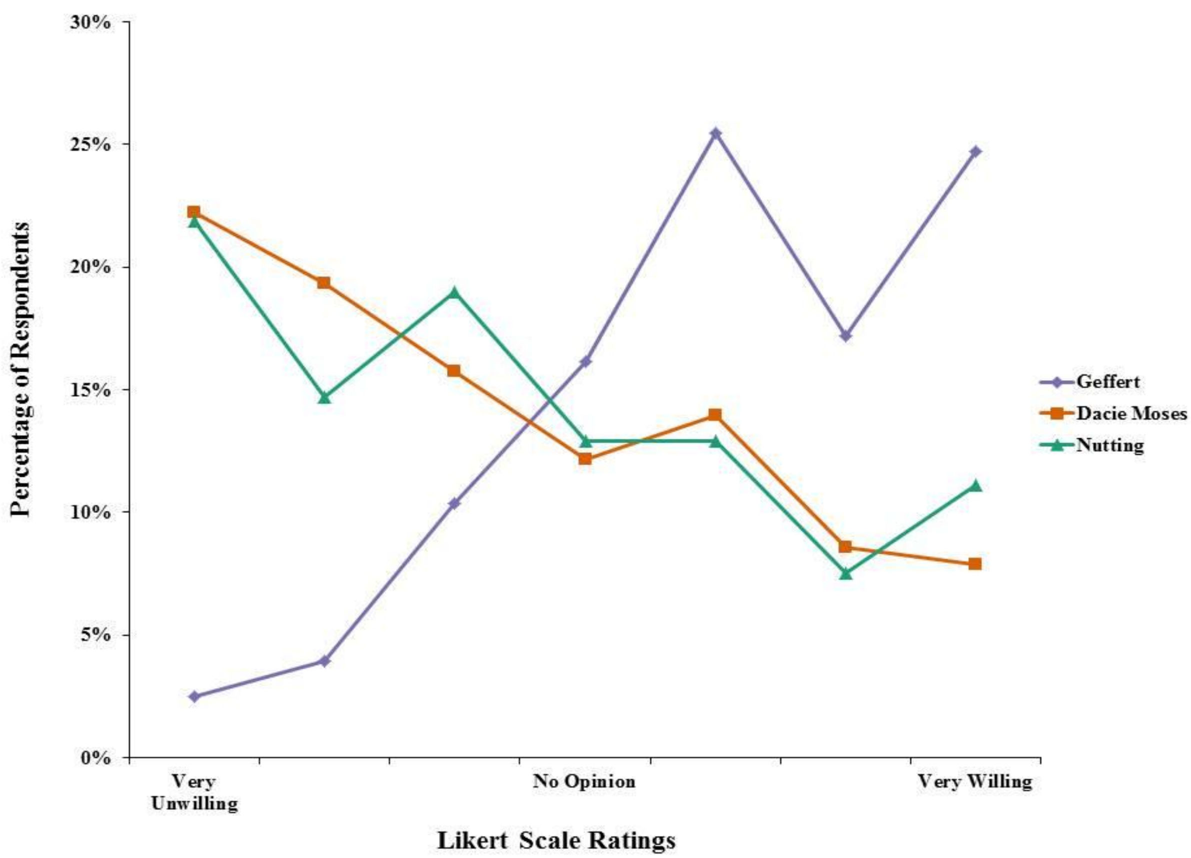


Figure 3 shows the trends in willingness to allow a house to be torn down and replaced with a net zero energy use house. The data shows that the community was significantly more willing to allow the school to tear down Geffert House, a building with little historic and aesthetic significance on campus as compared to Nutting and Dacie Moses Houses. While less than 5% of the community were unwilling to tear down Geffert, around 22% were completely unwilling to tear down Nutting and Dacie Moses. As expected, about 25% of the community was willing to tear down Geffert, while approximately 10% of the community was very willing to tear down either Nutting or Dacie Moses.

Cost Benefit Results

Payback Times

The cost benefit analysis resulted in consistent trends in payback times across houses, scenarios and types of retrofits. For all three houses and all scenarios (with the exception of Worst Case Nutting), basic retrofits paid back within Carleton's specified timeframes for either immediate implementation or consideration. As expected, the Environmentalist scenario presented the quickest payback times. In the case of Dacie Moses House, retrofits paid back within the first year, providing positive net benefits the year after construction. Table 5 displays payback times for basic retrofits for each of the scenarios.

Table 5. Payback times for basic retrofits (years).

	House	Worst Case	Projected	Best Case	Environmentalist
Basic	Geffert	16	8	5	2
	Dacie Moses	15	6	3	1
	Nutting	54	17	9	4

Note: When discounting, deep retrofits and net zero construction both failed to pay back for any of the houses. Only when the discount rate approached 0% did either of these pay back. For all three houses, in the absence of discounting, deep retrofits took greater than 50 years to pay back while net zero construction pay back times approached 200 years.

Deep retrofit return rates also displayed consistent trends across houses and scenarios. For all three houses, given the high cost of construction and the presence of a discount rate, all four scenarios failed to pay back. The discount rate caused the value of a dollar to decrease such that annual benefits approached zero, causing a negative net present value associated with the retrofits.

Net zero construction projects returned similar trends in results to the deep retrofits. All four scenarios failed to pay back due to the presence of discounting, even in the environmentalist despite the high cost of carbon. Figure 4 displays payback time trends for all houses, retrofits and scenarios.

Figure 4. Net present value over time. Lines represent the four scenarios for the three houses and three retrofit levels. When the line crosses zero, the retrofit has paid back.

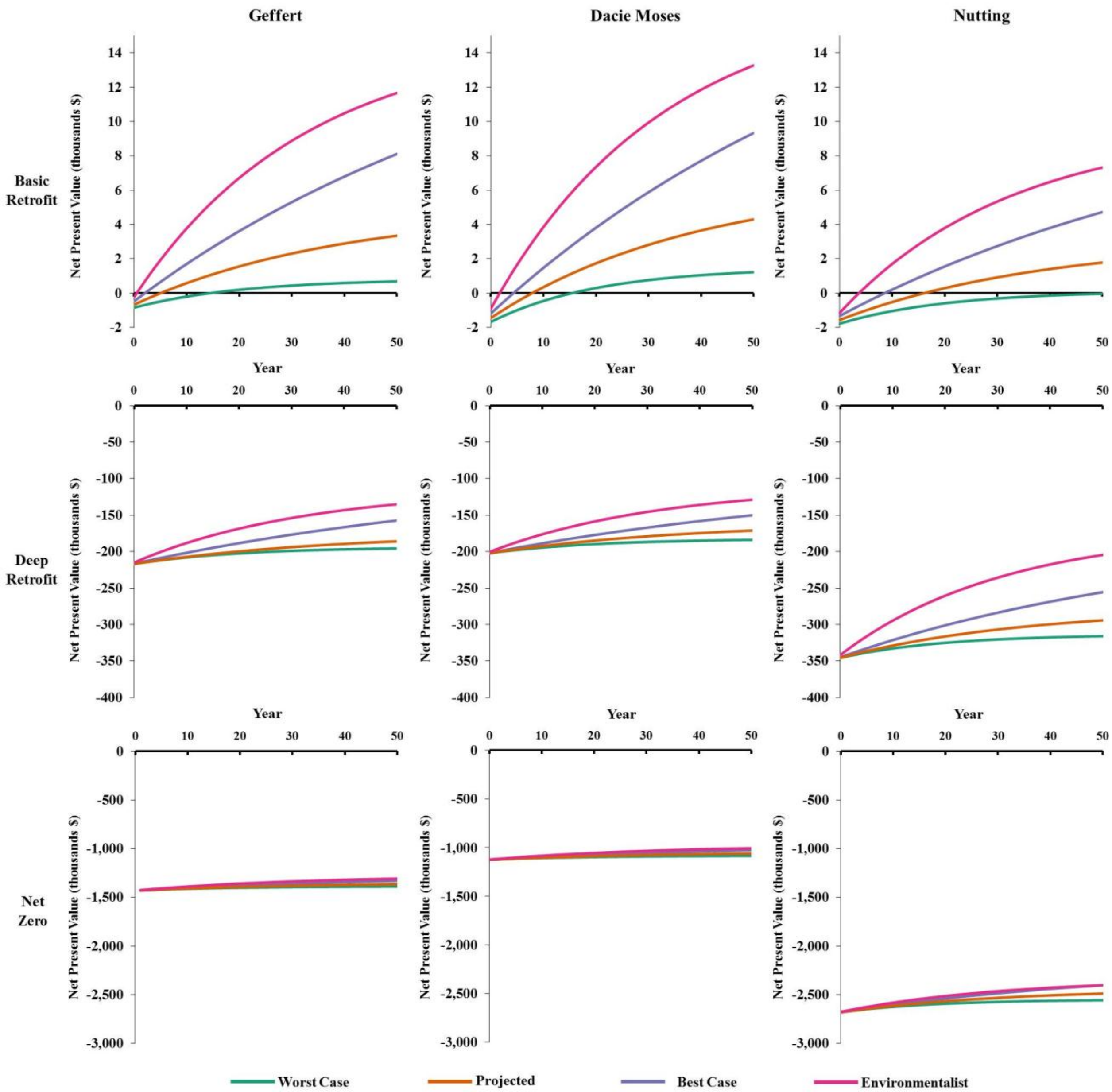


Figure 4 shows that deep retrofits and net zero construction fail to pay back in all scenarios, while the basic retrofit schemes pay back for all houses in all scenarios. Over time, the annual benefits associated with deep retrofits and net zero construction approach zero as the value of a dollar decreases due to the discount rate.

Net present value

Table 6 and Figure 5 shows the net present value over an estimated 50 year lifetime of retrofit projects. Consistent trends are evident across retrofit types. In all scenarios and for all houses, basic retrofits result in positive net present values. Deep retrofits and net zero construction both result in negative net present values over the lifetime of the projects.

Table 6. Net present value of retrofits after 50 year estimated lifetime ($). Positive net present values are blue while negative net present values are red.

	House	Worst Case	Projected	Best Case	Environmentalist
Basic	Geffert	1,200	4,300	9,300	13,300
	Dacie Moses	700	3,300	8,100	11,700
	Nutting	0	1,800	4,700	7,300
Deep	Geffert	-195,700	-186,000	-157,400	-135,300
	Dacie Moses	-184,000	-171,200	-150,300	-128,900
	Nutting	-316,000	-294,300	-255,800	-204,600
Net Zero	Geffert	-1,389,200	-1,365,100	-1,328,900	-1,307,500
	Dacie Moses	-1,084,900	-1,060,300	-1,025,100	-1,007,500
	Nutting	-2,557,900	-2,490,100	-2,403,400	-2,404,200

Figure 5. Net present value of retrofits after 50 year estimated lifetime.

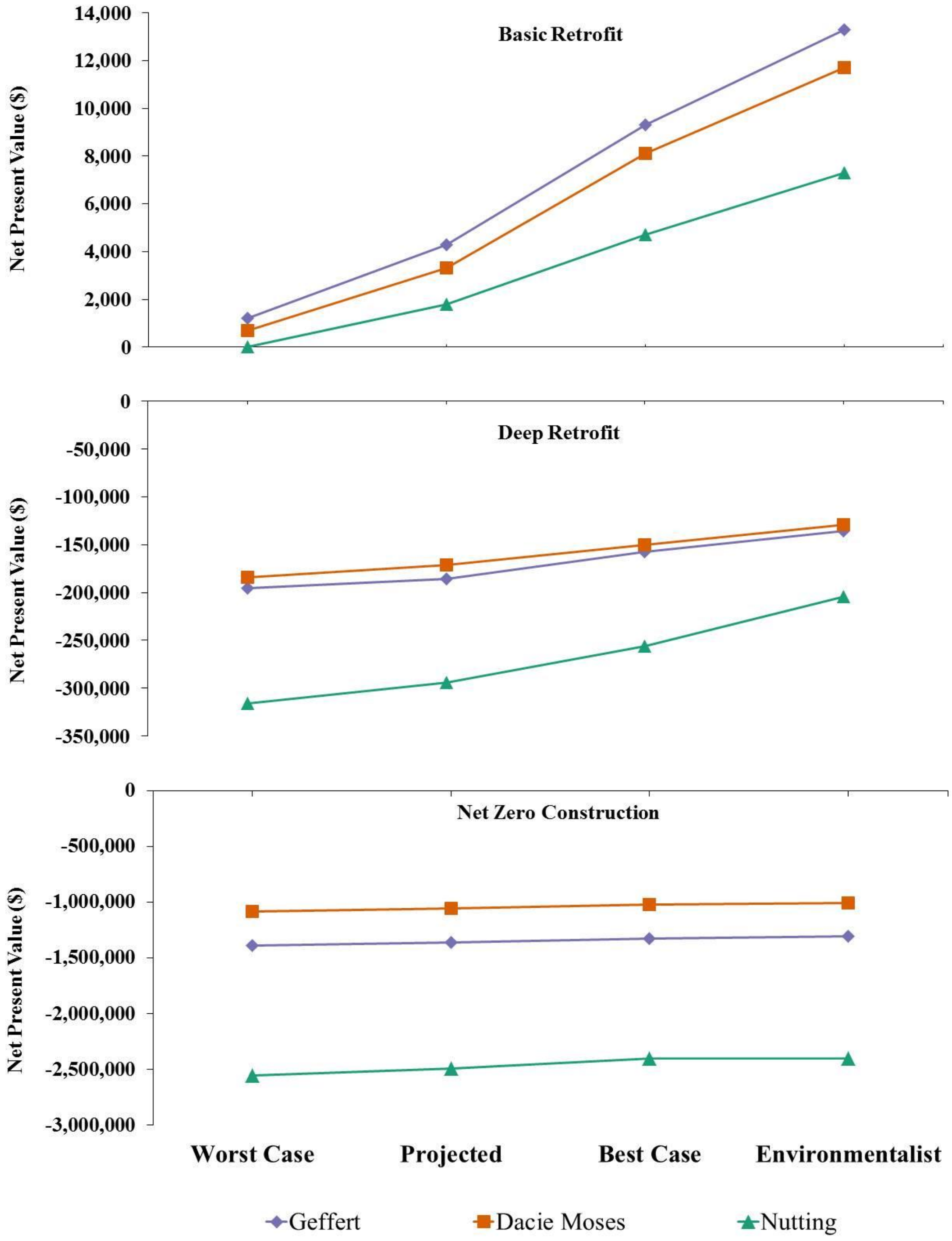


Figure 5 shows the net present value after a 50 year estimated lifetime of the retrofit. Basic retrofits are the only measures that result in positive net present values at the end of their lifetime. The four scenarios have a wider range of values at the smaller scale of basic retrofits.

DISCUSSION: IMPLICATIONS, RECOMMENDATIONS, SHORTCOMINGS, AND FUTURE RESEARCH

The following sections discuss the results of our cost benefit analysis model in terms of payback time—the criteria specified by the Carleton Climate Action Plan—and in terms of net present value. Additionally, we discuss the shortcomings of relying solely on an economic model and the justification for our interdisciplinary contextualization including interviews and historical analysis.

Payback Time

With the exception of the Worst Case scenario for Nutting House, all basic retrofits paid back within the timeframes specified by the Carleton Climate Action Plan either for immediate implementation or consideration. Payback times reflected the discount rate and cost of carbon used in each scenario with the high discount rate and low cost of carbon scenarios taking longer to pay back. Despite utilizing the Projected discount rate in the Environmentalist scenario which would extend payback time in comparison to the Best Case discount rate, the Environmentalist scenario paid back the quickest. This is due to the high cost of carbon used in the scenario. In projects with shorter payback timeframes such as basic retrofits, cost of carbon has a greater affect than it does in a long term project in which the discount rate has a greater effect over time.

In contrast to the short payback times for basic retrofits, deep retrofits failed to pay back for any of the houses in any of the scenarios. Only when discounting was omitted from the model—an unrealistic scenario to consider—did these retrofits pay back. This demonstrates the impact of discounting on deep projects. Cost of carbon did not affect payback times for the projects in the same way that it did for basic retrofits because the discount rate reduced the value of future benefits to such a large extent.

Payback time results for the construction of a net zero energy use building were the same as those for deep retrofits. New buildings failed to pay back at all due to discounting. Even the much larger energy savings and environmental benefits due to the complete elimination of all heating costs and grid electricity usage had little impact on payback time unless Carleton uses a 0 percent discount rate, an unrealistic scenario to consider.

We found that the aesthetic value of the building did not have major implications for payback of retrofits that would alter the appearance of the structure, as none of the willingness to pay values were of a magnitude large enough to have any significant impact on payback time. However, our results indicate a slight willingness for the Carleton community to pay for changes to the wood sided buildings included in this study (Geffert and Dacie Moses). The community was only willing to pay to prevent changes to Nutting House, which is on the National Register of Historic Places. This, along with the fact that people were more willing to pay to change Geffert than Dacie Moses indicates that historic value is likely important to the Carleton community, but not to a great enough extent to prevent aesthetic changes to the buildings on campus, nor to affect the payback times of the projects.

Net present value over the project lifetime

While Carleton's Climate Action Plan calls for the exploration and execution of projects with a payback time of six years or less, more typical economic accounting examines the net present value of projects over their lifespan. In order to appeal to both the Climate Action Plan and more widely utilized economic measurements, we calculated the values of retrofit opportunities in terms of both payback time and net present value.

By limiting analysis to the estimated 50 year lifespan of retrofit projects (Gransee-Bowman 2013), we determined the expected net present value of each retrofit type across each house for each of the four scenarios. Across all scenarios for all houses, basic retrofits had positive net present values over their lifespan, while all deep and net zero retrofits had negative net present values. Net present values for the lifespan of a basic retrofit range from zero dollars (Nutting, Worst Case) to $13,300 (Geffert, Environmentalist). Projected net present savings per house range from $1,800 to $4,300 over the lifespan of a basic retrofit. Therefore, these opportunities seem like clear choices for reducing Carleton's carbon footprint (albeit marginally) while saving money for the college.

Perhaps more importantly, the net present values over the lifetime of a deep retrofit provide comparative guidance for considering the marginal cost of performing the retrofit at the point in time when house renovations become independently necessary. While it is beyond the scope of this project to quantify the costs of necessary renovations to the houses in our study, by obtaining the net present cost of these renovations, decision makers could gain a better understanding of the true cost of deep retrofitting, given that deep retrofits would serve the same purpose as a renovation, and may have a longer lifespan, in addition to providing enhanced energy savings. These marginal costs would likely be substantially lower than the $171,200 to $294,300 projected costs of deep retrofitting the houses in our models.

Shortcomings of economic model

The cost benefit analysis conducted in this study demonstrates the shortcomings of the economic model, and the necessity for an interdisciplinary approach in deciding whether or not to implement comprehensive retrofits. First, as indicated by the payback times and net present values (Tables 5 and 6) the economic model adequately determines that the college should implement basic retrofits and should be more hesitant to implement deep retrofits and net zero construction. However, the model does not distinguish well between houses with differing levels of social, aesthetic, and historic significance. While we attempted to conduct a willingness to pay survey to quantify some of these values, the results indicate that the Carleton community's willingness to pay values would have little impact on the viability of such projects. However, based on comments from our survey and Carleton's use of Dacie Moses in various publications (Scalzo 2009), we can assume that drastically altering its appearance would not be readily accepted by the Carleton community. This, in combination with the widespread criticism of willingness to pay, was our reason for contextualizing our economic approach with qualitative interviews and historical analysis.

In addition to not distinguishing between which houses are more viable for retrofitting, our cost benefit model did not consider Carleton's image as a green institution, and the benefits the school might accrue from the construction of highly energy efficient buildings. If we had been able to fully quantify the values from our Likert scale surveys, these benefits may have drastically shifted the equation in favor of retrofitting depending on how strongly the school values its green image and the ability to use it for public relations and applicant recruiting. As Fred Rogers indicated, the school already considers institutional benefits of being green, and we can assume that when considering retrofits of this nature, the school would weigh these benefits as well. These shortcomings of the economic approach demonstrate the need for our contextualizing interviews, non-willingness to pay survey questions, and our historical analysis.

Contextualized CBA: Interviews and History

Our initial goal was to produce a model capable of encompassing all facets relevant to retrofit decisions faced by small liberal arts colleges. However, throughout the course of our research, we realized the shortcomings of attempting to value intangible variables, and that even with a fairly complete numeric model, any college decision regarding retrofits requires extensive discussion of other factors. Any recommendations based solely on our model would be misleading due to the exclusion of variables that, through our interviews, have been shown to have clear effects, even though they may not be as easily valued.

The monetary cost of a deep retrofit is steep and, in the experience of Paul Brazelton, will not ever pay back. The only way he was able to afford costs of meeting the EnerPHit rating was through the help of sponsorship (Brazelton 2013). Our model takes into account theorized prices of retrofits, but construction, as Brazelton and many other homeowners have experienced, often times can exceed expected budgets and timeframes, especially in older buildings. However, Brazelton made it clear that there are other benefits, such as the environmentally friendly feeling of living in an energy efficient building, exceptional air quality, and thick walls with noise cancelling effects; these factors can make living in an extremely energy efficient house worthwhile (Brazelton 2013).

In our interview, Fred Rogers explained that renovations to campus buildings, first and foremost, must make economic sense. Though the College does have commitments to the principles of sustainability, any energy efficiency improvements in construction are primarily instituted for the economic benefits; if a project doesn't pay back in 20-30 years, these pure financial factors and the fiduciary responsibilities of the College to operate efficiently will make it an extremely tough proposal to pass by the College administration. However, he also acknowledged that it's not as "black and white" as an absolute bottom line—there are sustainable and aesthetic aspects to building design and renovation that the College is willing to spend money on when making construction decisions. For example, when making recent construction decisions for buildings like the Weitz Center, James Hall, Cassat Hall, and Evans Hall, Carleton spent a fair amount of time matching the designs to the rest of the campus (Rogers 2013). According to Rogers, “when you experience new buildings on the campus, they ought to feel like they’re a part of the campus you already know” (Rogers 2013). In other words, the college may benefit from maintaining a uniquely Carleton feel.

However, this is exactly where the ambiguity surrounding aesthetic value and a comprehensive campus aesthetic comes into play. Though at this point in time, parts of the Carleton community look back wholesomely on the facade of buildings like Burton Hall, Davis Hall, the Old Music Hall and Nourse Hall, there was a period in Carleton’s history during which Modernism was heavily embraced, leading to structures such as Boliou Hall, Olin Hall, and the addition onto the Gould Library (Jarman 2013). Even during the planning phase of Cassat Hall and James Hall, there was no consensus over whether the dorms should perpetuate Carleton’s traditional facade. Editorials bounced back and forth in the Carletonian a campus newspaper. One student declared that the act of “not copy[ing] the old but preserv[ing] that feel” would make “students, the administration, and anyone with decent vision [...] delight in how little these new dorms [would] resemble the austere designs of Musser and Myers” (Gibson 2008). Another decried the fact that “each building, through its punctilious repetition of facade elements from Nourse, present[ed] an oppressive image of homogeneity better suited to a campus whose architecture is cohesive” and was ashamed of Carleton’s “dishearteningly conservative” decision to shy away from contemporary design (Duda 2008).

As Jarman contextualized, and as cliché as it may be, “beauty is in the eye of the beholder”—any major aesthetic decision regarding a campus structure will likely attract both positive and negative reactions from the community. As much as scholar Winston Elting wished for it to be true that “perpetuation of a tradition in architecture of any period only because it exists on the campus is indefensible,” in the name of institutions of higher education acting as role models for advancement and creative expression, there is just as much merit to the sentiment, as Fred Rogers expressed, that campuses have a responsibility to preserve a certain “feel,” for the cohesiveness of the community (Elting 1951; Rogers 2013). A comprehensive community WTP survey, as we attempted, can strive to find compromise on aesthetic opinion, but the uncertain reliability of WTP and the struggle to define who to include in the campus community can render this method of no use.

These aesthetic choices can be guided by historic significance. As demonstrated by our survey results, participants in our sample were less likely to want to alter a building with such clear historic significance as Nutting House. If Nutting House was a privately owned property with one family making independent decisions about the values placed on facets of the retrofit process, then a deep retrofit, even with the extensive costs and historical preservation challenges it presents, might still be an option. However, there is a sentiment that Carleton, as the owner of many houses of varying significance and age within the community, would be better off choosing a much less notable house on which to perform something as ambitious as a deep retrofit. As Jarman, a committee member for the National Register for Historic Places, noted, attempting to pursue such a project on a building with such demonstrated significance to the campus, Northfield and the architectural and historic preservation communities would simply show a disrespect for the value these groups associate with the structure as it is, especially because Carleton owns so many other workhorse houses that could prove much more logical canvases for such an undertaking (Jarman 2013). This logic can be applied to Dacie Moses, as well. Even if Dacie Moses isn't necessarily renowned for its architecture or style, it occupies a social niche in the community that could be lost in translation were the cookie program and other elements of Dacie's legacy simply transferred to another structure, or if the house were significantly modified. With other options available, the time and ambiguity spent analyzing aesthetic, historic, and social significance can be saved by simply forgoing these special cases—they should perhaps be left to the drawing board in favor of other less significant structures with similar energy-saving potential.

Ethical considerations

Small colleges must first and foremost take their own missions into account when considering the possibility of retrofitting buildings. After analyzing economic considerations, ethical considerations, and the rights of their respective college communities, they need to find reasonable solutions for funding sustainable changes to buildings on their campus.

We argue that colleges are obligated to invest in environmental initiatives like retrofitting buildings because they have large amounts of resources and are more able to invest than individuals. We argue that their investments in retrofits are especially important if in concurrence with their mission statements and providing education. Using an environmentally friendly campus design, colleges can educate their communities by increasing attentiveness to environmental issues, and thus cultivate more informed decisions about how to treat the land. They must be careful, however, to not overvalue the present since it is in their self-interest to care about long-term projects. By accounting for sustainability, aesthetics, and historical value when renovating houses they are investing in their own future. By adopting pro-environmental behaviors, small liberal arts college can avoid future financial risk, reduce their carbon footprint, and project an environmentally friendly image to potential students.

Implications and Recommendations for Carleton

Because basic retrofit schemes pay back within the timeframe specified in the climate action plan either for immediate implementation or consideration in most of the scenarios run in the model, we recommend that Carleton implements the energy saving alterations described in the audits (Carleton Climate Action Plan Steering Committee 2011). While these retrofits are associated with energy savings that would translate to negligible carbon savings with respect to Carleton's total greenhouse gas output, they represent easy, money saving investments, with the potential to create much more comfortable living conditions. Additionally, because these retrofits payback rapidly, it is our recommendation that Carleton pursue audits on more structures in order to identify buildings that would benefit from implementing similar upgrades. Pursuing campus wide audits and basic retrofitting would demonstrate Carleton's commitment to reducing carbon emissions potentially enhancing the school's green image.

Unlike the basic retrofit schemes, deep retrofits do not offer as much potential for implementation on Carleton's campus. Without a time constraint, these retrofits fail to pay back. Over the 50 year estimated lifetime of the projects, deep retrofits would represent a net present cost ranging from $158,997 to $276,698 in the Projected scenarios, on upfront costs of $206,164 to $343,768 (Table 6). However, despite the fact that these retrofits make little sense according to our economic model, as previously discussed, unquantified institutional benefits of green infrastructure and environmental values are both worth considering in determining whether to implement a deep retrofit. As Fred Rogers indicated, the school already considers institutional benefits of being green, and we can assume that when considering retrofits of this nature, the school would weigh these benefits as well (Rogers 2013). Because of this, an economic model to determine the payback time for deep retrofits can only provide a general threshold of values, since it is difficult to quantify such non-energy benefits accurately.

While the non-energy benefits that remained unquantified in this study may significantly impact payback times, this was not the case for the aesthetic value we did quantify. Despite the fact that our results indicate a willingness to pay for changes to Geffert and Dacie Moses and a willingness to pay to prevent changes to Nutting, none of these results had any serious implications on the payback times for the projects. Thus, our economic model alone would indicate that Carleton does not necessarily need to consider these changes when deciding whether or not to implement projects of the sort discussed in this paper.

Poor payback times for comprehensive deep retrofit projects explored in this study do not rule out the implementation of certain individual elements of a deep retrofit. For example, it may be more cost effective for a homeowner to replace all windows with triple paned windows, and bolster insulation surrounding the windows without the addition of additional wall insulation on the whole house. As previously mentioned, Minnesota has been demonstrated to have high potential for energy efficiency benefits associated with retrofits due to its extreme cold temperatures in the winter and heat in the summer (Polly et al. 2011). Thus, prior to implementing a deep retrofit upgrade, energy modeling could potentially lead to more cost effective retrofitting.

Similar to deep energy retrofits, the construction of net zero homes to replace the buildings examined in this study makes no economic sense according to our model. In all scenarios the construction of a net zero building would result in a net societal cost. In the projected scenario, these costs range from $1,039,250 to $2,437,829, on initial investments of $1,128,360 to $2,689,917 (Table 6). Thus, it is our recommendation that no functioning building should be torn down and replaced with a net zero energy structure for the perceived energy saving benefits. Additionally, because of the expensive nature of this type of construction, we do not believe that it should be implemented in new building projects in the near future as long as the current regulatory environment remains the same. However, as climate change become more pressing, building energy efficiency codes change to reflect climate change, and thus as the technology becomes more standard in buildings (and therefore cheaper), this type of construction should remain on Carleton's radar, especially once existing structures actually require replacement.

Implications beyond Carleton

Our modeling methodology has potential implications for small liberal arts colleges beyond Carleton. We can expect that similar schools would reach similar conclusions about the economic sensibility of these building projects. However, as institutional benefits beyond energy and carbon savings are likely to play a role in the decision making process, our research identified the quantification of these benefits as an important path for future research to better aid schools in making these decisions.

The variables that we incorporated in our model, as well as those that we were unable to quantify, and those that we speculate might have a large impact on payback times of retrofits, are all variables that similar educational institutions should consider in determining whether to pursue projects of this nature. Regardless of whether intangible variables are large enough to alter payback times, we have demonstrated that people care about the social and aesthetic value of buildings on campuses. Since people do care about the social and aesthetic value of buildings, college administrators need to consider how these variables matter on their campus in regards to building retrofits.

In all of our scenarios and across all of our houses, basic retrofits result in a positive net present value. We recommend that colleges investigate basic retrofit options purely from an economic standpoint. By focusing on isolated problem areas, energy efficiency can be improved without significantly altering the appearance of a building. Additionally, poor payback times for deep retrofits or net zero construction in our case study do not rule out the possibility of these same retrofits or parts of these retrofits paying back at other colleges.

Shortcomings

Energy modeling

The energy savings in our model are based on rough estimates determined from the square footage and footprint of each building. While these estimates provide reasonable values for our model, more precisely modeling the energy performance of each building before and after retrofits will allow for more accurate prediction of payback time, which would make this model more useful for colleges. Various building energy modeling software exists, including Sefaira and REM Design. While some of these programs are complex and require significant training, others can be utilized with little or no expertise in building modeling.

Definition of Carleton Community

For the purposes of our willingness to pay survey, we needed to define a sample group that could represent the overall opinions of the Carleton community. Due to the process of obtaining a random sample through the Office of Institutional Research and Assessment, we decided to restrict the sample to a snapshot of three groups within the Carleton community—students, staff, and faculty (over the age of 18) who were enrolled or employed during the 2012-2013 academic year. However, when the College makes large decisions such as those regarding renovation of facilities, there are other stakeholders that should be taken into account. Furthermore, not all stakeholders have an even proportion of decision-making authority; for instance, college administrators hold a much larger stake in decision making relative to other college staff. On a similar note, the Board of Trustees is not composed of employees of the College, so they would not have been included in any of our samples. Their primary mission is "policy making and responsibility for sound resource management of the College," including the operation of a Buildings and Grounds committee. Any decisions regarding the aesthetic changes shown in our survey would likely be passed by the Board, and their input could be different from that of our three sample groups (Carleton College 2010). Our interview with Vice President and Treasurer Fred Rogers attempted to account for this lack of "administrative" representation in our survey results.

Although there are alumni scattered among the staff and faculty at Carleton, alumni as a whole were not sampled. Alumni traditionally have a significant role in the funding of College operations and projects, through outlets such as capital campaigns, gifts to the endowment, and project grants, such as the Weitz family's contribution of 15 million dollars towards the completion of the Weitz Center for Creativity, and the Kracum family's contribution of the second wind turbine (Carleton College 2011c; b). However, sampling alumni includes such complications as determining which class year to use as the cutoff, obtaining correct, unbiased, and effective alumni contact information (versus the universality of carleton.edu emails for those currently employed and enrolled), and analyzing results from alumni who attended Carleton when some of these houses were not owned or run by the college.

The aesthetics of the houses studied also affect the opinions of visiting families and prospective students, and Northfield residents who live in the area or engage with the houses on a regular basis (for example, Northfielders are welcome at Dacie Moses Sunday Brunch even if they have no connection to the College). The influence and opinion of all of the previously mentioned groups that were excluded from our study could inform future studies on Carleton's decisions regarding facilities and houses, and more specifically, studies on the aesthetics of College owned buildings.

Definition of the Good

In order to perform a willingness to pay survey, one must define the good for which the participant is being asked to pay. In our study, the participant was asked whether they would pay a one-time specific amount to preserve the current appearance of the house or enact certain aesthetic changes associated with a deep retrofit. Our survey presented the participant with the before, during, and after exterior of a house that had undergone a deep retrofit, then asked them to imagine these same aesthetic changes taking place on our three Carleton-specific houses in order to conceptualize the good they were paying for. The most accurate way of demonstrating what the houses would look like during and after a deep retrofit would be to obtain house-specific architectural drawings, but our study was limited by the time and cost necessary to hire a professional and produce such detailed renderings (see Appendix 1 for survey details).

Future Research

Our research, modeling, and contextualizing interviews reveal that there are significant opportunities for future research, as well as opportunities to improve upon the accuracy of our methodology. Our methodology can be improved by quantifying intangible costs and benefits not included in our model, more accurately quantifying energy savings using modeling technology, and improving upon our willingness to pay methodology. Additionally, our research has raised various other questions concerning alternative retrofit schemes.

Quantifying Institutional Benefits of Green Building

Our research, in particular the elements beyond the cost benefit analysis, has demonstrated that Carleton and schools similar to it garner benefits beyond the energy savings and carbon reductions, including public relations and image improvements. However, our model, interviews, and qualitative survey questions failed to quantify these goods, thus preventing us from being able to incorporate them into the model. Quantifying these benefits associated with green building would enhance the efficacy of our model. Additionally, Carleton has demonstrated a willingness to pursue green building certifications, through our commitment to silver or higher LEED certification in all new campus construction (Carleton Climate Action Plan Steering Committee 2011). If Carleton were to pursue certification by a more rigorous metric such as the Passive House standard, there is potential to derive greater institutional benefits.

Thematic Retrofits

Another opportunity for future research is to explore the payback times of what we are calling thematic retrofit schemes. The cost benefit analysis in this research determines the payback times for comprehensive retrofits of a single building. These retrofits prohibit purchasing of materials in large quantities and require expensive designs to be produced for each house. Retrofitting costs could be reduced by conducting one type of retrofit on various buildings instead of various retrofits on one building. Such thematic retrofits have been proven to be cost effective. For instance, the Empire State building was able to reduce energy expenditures by 38 percent by installing better insulated windows, a large volume purchase that paid back in three years (Clinton 2011). A cost benefit analysis of thematic retrofit schemes, in which certain retrofit components are purchased at high volume for many campus buildings, may reveal quicker payback times than purchasing unique retrofit changes buildings at low volume.

CONCLUSION: METHODOLOGICAL AND SUBSTANTIVE RECOMMENDATIONS

After completing a contingent valuation of aesthetic value, a scaled assessment of relative valuation of non-quantifiable goods, interviews and historical analysis about campus buildings, and a cost benefit analysis model across three houses, four scenarios, and three types of retrofits, we have presented an interdisciplinary methodological approach for modeling the decision-making scenario faced by administrators at a small liberal arts college when determining the ideal investment level for retrofit projects.

Taking all of these factors into account, we can make several recommendations in relation to Carleton's retrofit opportunities. The model results for basic retrofits, with expected discounted payback times of 6-8 years for wood framed houses and 17 years for Nutting House (brick construction), lead us to recommend that basic retrofitting should be immediately undertaken as part of the Climate Action Plan for our study's houses. Models should be applied to other campus-owned wood framed houses to determine if similar payback times can be achieved. However, we conclude that deep retrofits and net zero building replacements are not economically feasible options for Carleton at this point (at net present costs of up to $276,698 and $2,437,829, respectively). Therefore, we do not recommend pursuing these options under current economic and regulatory conditions, though these conditions are likely to change in the future, potentially making more intense retrofitting more feasible. Furthermore, certain thematic aspects of deep retrofits may be applied to a subset of houses at reasonable payback times, and future models should target these aspects.

In order to identify similar cost saving opportunities while reducing fossil fuel consumption, small liberal arts schools—especially those that are seeking carbon footprint reduction as a part of the President's Climate Commitment—should consider conducting a similar cost benefit analysis. However, it should be noted that obtaining accurate values for un-quantified goods presents a particularly difficult challenge. While contingent valuation surveys offer one solution to this problem in the context of a small liberal arts school, schools should better determine a system for valuing these intangible, moral, and difficult to quantify values in the context of their own institutional needs.

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APPENDIX 1: SURVEY DETAILS

In order to carry out a campus-wide willingness to pay survey, we used the subscription-based service SurveyMonkey Pro (SurveyMonkey 2012). Each of the 10 surveys sent out had identical text, images, and structure, excluding the differences in values and housing order listed in Table 7 below. These differences in order and value were implemented to account for potential bias.

Table x. Survey orders and price values.

order of house presentation	WTP Values (in US dollars
1. Geffert 2. Dacie Moses 3. Nutting	30, 60, 90, 120, 150
1. Nutting 2. Dacie Moses 3. Geffert	30, 60, 90, 120, 150

The 10 surveys were each sent to 45 students, 10 staff, and 5 faculty from a total of 450 students, 100 staff, and 5 faculty. These random samples were obtained from the Carleton Department of Institutional Research; access to a full list of college contact information or a similar office at a different institution would be necessary to replicate the random sampling used in this survey. The survey opened on Tuesday, January 29 2013, and closed at 11:59PM on Monday, February 4 2013. The survey links were distributed solely by email to the participant's Carleton College email address, with an initial email sent on February 1, and two additional reminder emails sent on January 31 and February 4. We included a raffle for a $40 cash prize to be randomly distributed to one participant to provide incentive to participate and combat potential survey fatigue that members of a college community face. The survey emails were sent from a group member, rather than from the SurveyMonkey account.

Accurate architectural renderings of the three houses in the survey before, during, and after a deep retrofit would be the ideal types of images to define the good that participants are being asked to value. However, in the absence of such renderings, we presented the participant with the current aesthetic of the house, and images of a basic house before, during, and after a deep retrofit (Binsacca 2011).

Numbers related to Carleton's greenhouse emissions were obtained from the 2012 greenhouse gas inventory (Carleton College 2011a).

Email Number 1:

Subject: "Help with our Comps Project; Win 40 Dollars"

Hello,

We are senior students completing our Environmental Studies comprehensive project on hypothetical energy retrofits to buildings on Carleton's campus, and we would like for you to take our brief survey.

The survey will ask you questions regarding your willingness to pay for certain features of Carleton's buildings and structures.

The survey will take about 5 minutes of your time, and will be open until Monday, Feb. 4th at 11:59pm.

As compensation for completing the survey, you will be entered into a raffle to receive $40 in cash.

You were selected for this survey randomly from a list of members of the Carleton community. Your contribution will be valuable in informing our study and potential future College decisions regarding building construction and renovation.

Click here to take the survey: [unique survey link]

Thank you!

Greg Phillips, Jonathan Hillis, Ellen Farnham, Thomas Holmes

phillipg@carleton.edu, hillisj@carleton.edu, farnhame@carleton.edu, holmest@carleton.edu

Faculty adviser:

Professor Aaron Swoboda

aswoboda@carleton.edu

Reminder Email 1:

Hello,

This is a reminder that our comps survey will be open until Monday, February 4. Please take the time if you haven't already to answer our very short **12 multiple choice questions** and be entered into a raffle to **win $40!** Thank you to those who have already filled it out.

You can find the link here: [unique survey link]

If you are curious as to how your responses will inform our study, please feel free to come to the environmental studies comps symposium on April 16th at 5:15 in Weitz 236 (we know that is far in the future, but we thought we would give you a heads up).

Thank you,

Greg Phillips, Jonathan Hillis, Ellen Farnham, Tom Holmes

phillipg@carleton.edu, hillisj@carleton.edu, farnhame@carleton.edu, holmest@carleton.edu

Faculty advisor:

Professor Aaron Swoboda

aswoboda@carleton.edu

Reminder Email 2:

Subject: "Last Chance to Win $40; Help With Our Comps"

Hello,

This is a final reminder to take our brief survey if you haven't already in order to inform our comps project on energy efficiency at Carleton. The survey is only **12 multiple choice questions** and will take about **5 minutes.** The best part is that you will be entered to **win $40!** The survey will close tonight.

Thank you so much to those who have already taken the survey. We appreciate your contribution to our comps project.

You can find the link here: [unique survey link]

If you are curious as to how your responses will inform our study, please feel free to come to the environmental studies comps symposium on April 16th at 5:15 in Weitz 236 (we know that is far in the future, but we thought we would give you a heads up).

Thank you,

Greg Phillips, Jonathan Hillis, Ellen Farnham, Tom Holmes

phillipg@carleton.edu, hillisj@carleton.edu, farnhame@carleton.edu, holmest@carleton.edu

Faculty advisor:

Professor Aaron Swoboda

aswoboda@carleton.edu

Below is a sample of our full survey text and structure, using the Geffert, Dacie Moses, Nutting order with a value of $60 as an example**:**

Title: Carleton Retrofit Survey

Page 1: Institutional Review Board Consent Information

1. Please read the following information and ask any questions you may have before agreeing to be in this study.

We plan to use this survey information to inform our senior comps essay for our Environmental Studies major here at Carleton. Your identity will not be collected with your information. We will keep all facts about you private to the extent allowed by law. Your name and other facts that might point to you will not appear when we present this study or publish the results. You may request a copy of our paper when our research is complete. There are no particular risks to participating in this study as the questions are non-controversial and not personal.

Your participation is voluntary. Please share only what you are comfortable with sharing. You may decline to participate, or you may choose not to answer any particular question that I ask. If you change your mind about participating, you may stop the survey at any time.

Please feel free to contact us if you have any questions, concerns or comments about the project. If you have any questions or concerns regarding this study and would like to talk to someone other than the researchers, contact the Institutional Review Board for Research with Human Subjects at Carleton College, c/o Office of the Associate Dean of the College, Carleton College, One North college Street, Northfield MN, 55057; telephone (507) 222-4301.

By clicking "Continue" below, you agree to the following:

I have read the above consent information. If I have any questions or concerns about this survey, I have asked them and have received answers. I am at least 18 years old and I

consent to be surveyed for Jonathan, Ellen, Greg, and Thomas' Environmental Studies comps project on building retrofits.

☐ Continue

☐ I do not consent

Page 2: Survey Background Information

Recently, Carleton College conducted energy audits on a selection of Carleton owned houses. The audits were recommended by the President's Climate Action Plan in order to determine potential energy savings. Carleton is considering conducting comprehensive energy efficiency retrofits on some of these houses known as deep retrofits. Deep retrofits are capable of reducing the heating and cooling usage by 80%, but require aesthetic changes to the building. In this survey, we will be asking you about the potential aesthetic changes to the three houses pictured below: Geffert House, Dacie Moses House, and Nutting House.

Geffert House:

Dacie Moses House:

Nutting House:

Page 3: Deep Retrofit Information

Below are three pictures that represent a house before, during, and after a deep retrofit. Deep retrofits involve a total "re-skinning" and sealing of the the house in order to prevent air leakage. These retrofits require removing the outer layer of a house, adding insulation, and putting new siding on. In brick houses, because exterior walls cannot be expanded, interior walls must be thickened, reducing interior square footage. As a result of a deep retrofit, the following aesthetic changes are likely to occur:

-thicker exterior walls
-thicker window boxes and door frames
-new, triple paned windows
-heavier, windowless doors
-new siding on all exterior walls
-new roof
-fewer windows on the north side of the building

1950s-era Home: Before Deep Retrofit

1950s-era Home: During Deep Retrofit

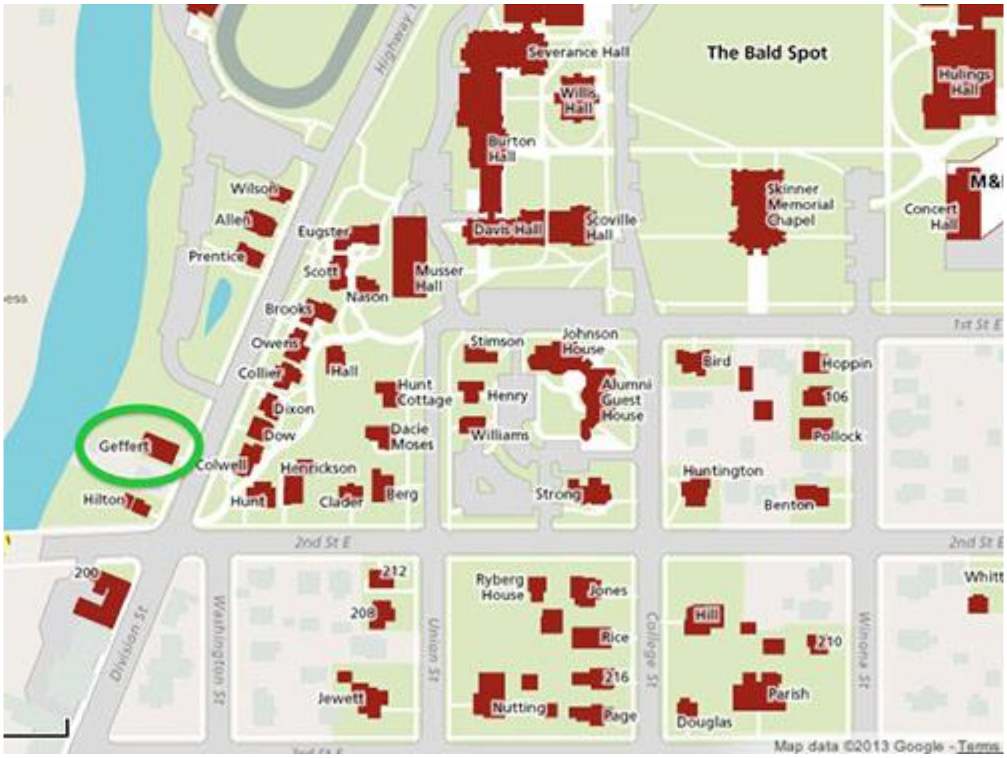
1950s-era Home: After Deep Retrofit

Page 4: Geffert House

The following questions pertain to Geffert House (pictured below). Geffert House has been the home for many interest-house groups at Carleton. Though it is unclear when the house was actually built, the Geffert family owned the property for 70 years. The house was sold to the Edwardsen family in 1990, and then by the Edwardsens to Carleton in 1999. Carleton renovated it and turned it into a student residence starting in 2002. It is located on Division Street, across from the townhouses.

Geffert House

Geffert House is located on Division street across from the townhouses.



Q: **Independent of energy savings, do you feel that the aesthetic changes associated with deep retrofits would:**

☐ improve the appearance of Geffert House.
☐ detract from the appearance of Geffert House.
☐ I have no opinion.

If participant selects "improve" option:
Page 5: (no title)

Q: **Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket for the aesthetic changes associated with the retrofits?**

☐ Yes
☐ No

If participant selects "detract" option:
Page 6: (no title)

Q: **Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket to prevent the aesthetic changes associated with the retrofits (keep Geffert House looking the same)?**

☐ Yes
☐ No

If participant selects "no opinion" option: survey skips to Page 7

Page 7: (no title)

Q: **The deep retrofits to Geffert will reduce carbon emissions due to heating and cooling by approximately 80% (6.9 tons annually of the 8.6 tons emitted by Geffert). To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.**

Which best describes the extent to which you believe this environmental benefit affects Carleton's image as a green institution?

significantly detracts — has no effect — significantly approves

☐ ☐ ☐ ☐ ☐ ☐ ☐

Q: **Net zero energy buildings employ efficiency measures and renewable energy technologies in order to utilize zero energy from non-renewable sources.**

If Carleton were to demolish Geffert House and replace it with a net zero energy building, it would eliminate 13.6 tons of carbon emissions annually due to heating, cooling, and electricity. To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.

Which best describes your willingness to allow this to occur:

Very unwilling — No opinion — Very willing

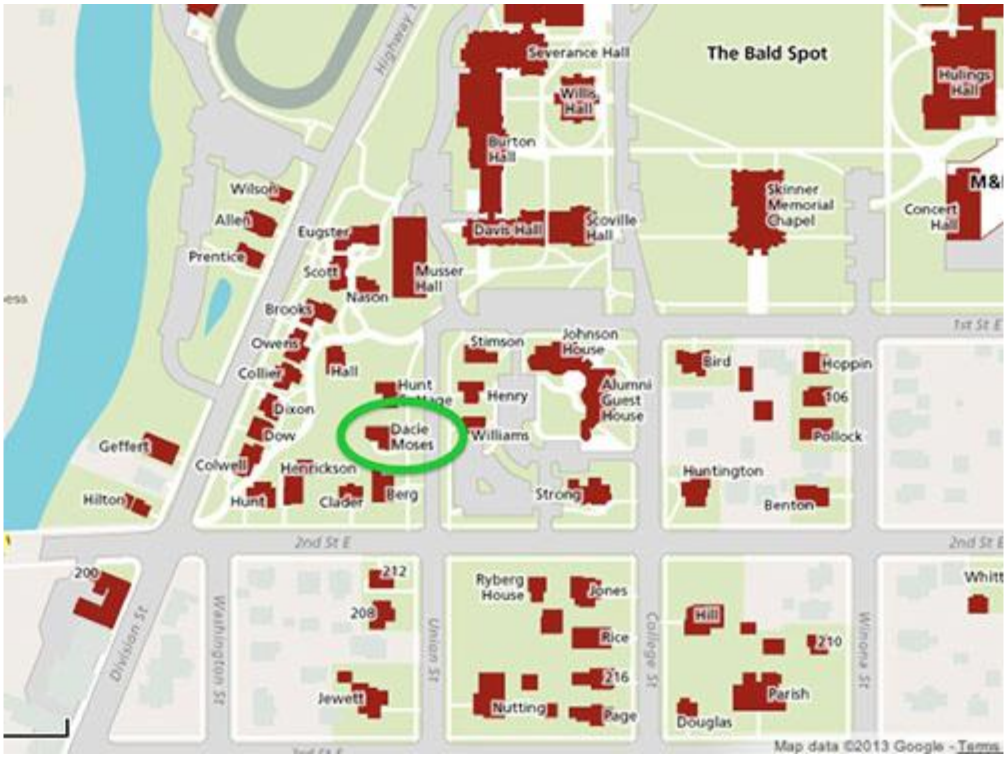
☐ ☐ ☐ ☐ ☐ ☐ ☐

Page 8: Dacie Moses House

The following questions pertain to Dacie Moses House (pictured below). Dacie Moses House is a student gathering place donated to the college by long-time staff member Dacie Moses in 1981. It was built in 1870 and purchased by Dacie Moses in 1922. It has since served as the location of Dacie's Sunday Brunch, acapella group practices, and a place for students to bake cookies. It is located half a block south of Musser Hall.

Dacie Moses House

Dacie Moses is located on Union Street between 1st and 2nd Streets.



Q: **Independent of energy savings, do you feel that the aesthetic changes associated with deep retrofits would:**

☐ improve the appearance of Dacie Moses House.

☐ detract from the appearance of Dacie Moses House.

☐ I have no opinion.

If participant selects "improve" option:

Page 9: (no title)

Q: **Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket for the aesthetic changes associated with the retrofits?**

☐ Yes

☐ No

If participant selects "detract" option:

Page 10: (no title)

Q: **Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket to prevent the aesthetic changes associated with the retrofits (keep Dacie Moses House looking the same)?**

☐ Yes

☐ No

If participant selects "no opinion" option: survey skips to Page 11

Page 11: (no title)

Q: **The deep retrofits to Dacie Moses will reduce carbon emissions due to heating and cooling by approximately 80% (6.4 tons annually of the 8.0 tons emitted by Dacie Moses). To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.**

Which best describes the extent to which you believe this environmental benefit affects Carleton's image as a green institution?

significantly detracts			has no effect			significantly approves
☐	☐	☐	☐	☐	☐	☐

Q: **Net zero energy buildings employ efficiency measures and renewable energy technologies in order to utilize zero energy from non-renewable sources.**

If Carleton were to demolish Dacie Moses House and replace it with a net zero energy building, it would eliminate 14.9 tons carbon emissions annually due to heating, cooling, and electricity. To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.

Which best describes your willingness to allow this to occur:

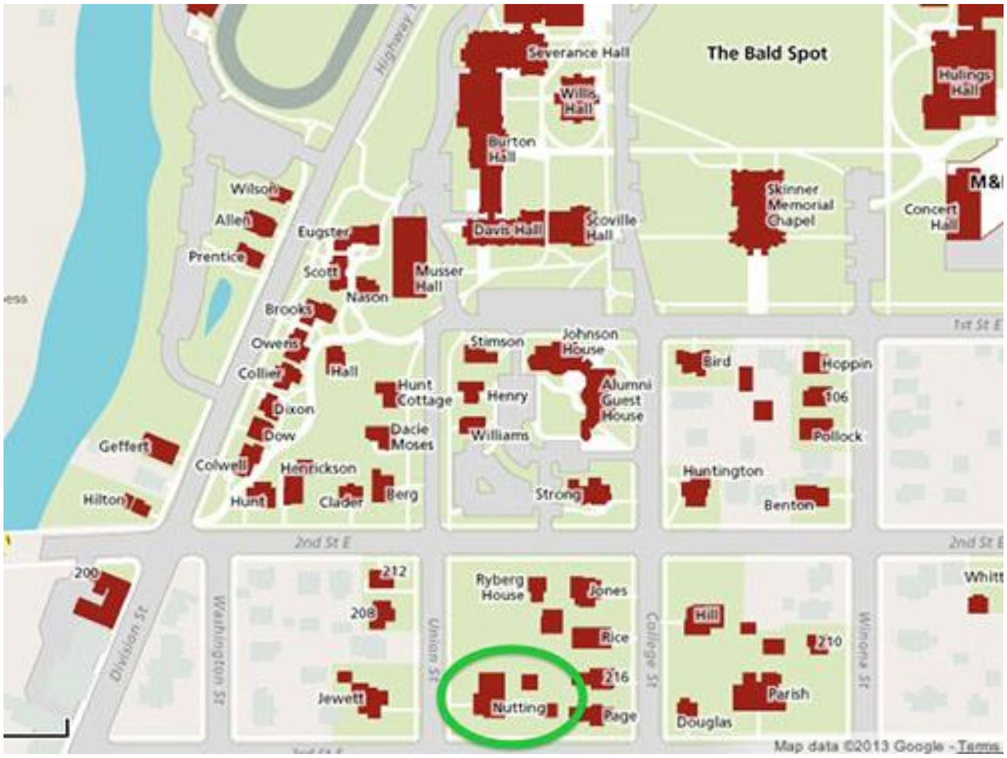
Very unwilling			No opinion			Very willing
☐	☐	☐	☐	☐	☐	☐

Page 12: Nutting House

The following questions pertain to Nutting House (pictured below). Nutting House currently serves as the President's House for Carleton College. It was built in 1888 by John C. Nutting, a college trustee and President of First National Bank. The house was given to the college--and designated to the National Register of Historic Places--in 1970. It is located two blocks south of Musser Hall.

Nutting House

Nutting is located at the corner of 3rd and Union, across from the northwest corner of the Weitz Center.



Q: **Independent of energy savings, do you feel that the aesthetic changes associated with deep retrofits would:**

☐ improve the appearance of Nutting House.
☐ detract from the appearance of Nutting House.
☐ I have no opinion.

If participant selects "improve" option:
Page 13: (no title)

Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket for the aesthetic changes associated with the retrofits?

☐ Yes
☐ No

If participant select "detract" option:
Page 14: (no title)

Independent of the energy savings, would you be willing to make a onetime payment of $60 out of your own pocket to prevent the aesthetic changes associated with the retrofits (keep Nutting House looking the same)?

☐ Yes
☐ No

If participant selects "no opinion" option: survey skips to Page 15

Page 15: (no title)

Q: **The deep retrofits to Nutting will reduce carbon emissions due to heating and cooling by approximately 80% (13.5 tons annually of the 16.9 tons emitted by Nutting). To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.**

Which best describes the extent to which you believe this environmental benefit affects Carleton's image as a green institution?

significantly detracts — has no effect — significantly approves

☐ ☐ ☐ ☐ ☐ ☐ ☐

Q: **Net zero energy buildings employ efficiency measures and renewable energy technologies in order to utilize zero energy from non-renewable sources.**

If Carleton were to demolish Nutting House and replace it with a net zero energy building, it would eliminate 49.3 tons of carbon emissions annually due to heating, cooling, and electricity. To put that number in context, Carleton emitted a total of 24,941 tons of carbon in 2012.

Which best describes your willingness to allow this to occur:

Very unwilling — No opinion — Very willing

☐ ☐ ☐ ☐ ☐ ☐ ☐

Page 16: (all optional demographic questions)

Q: **What class year or position do you hold on campus?**

☐ Freshman '16
☐ Sophomore '15
☐ Junior '14
☐ Senior '13
☐ Tenure track faculty
☐ Non-tenure track faculty
☐ Biweekly staff
☐ Salaried staff

Q: **What is your gender?**

☐ Female
☐ Male

Q: **[Students only] Do you live in campus housing?**

☐ Yes
☐ No

Q: **[Students only] What is your major?**

[open entry textbox]

Q: [**Faculty and staff only] How many years have you worked at Carleton?**
[open entry textbox]

Q: **Any other thoughts or comments in relation to this survey?**
[open entry textbox]

Q: **If you would like to be included in the drawing for the $40 cash reward for filling out this survey, please enter a valid email at which we can contact you. Your email address will in no way be associated with your survey responses.**
[open entry text box]

Participant clicks submit button; SurveyMonkey thanks participant, survey completed.

APPENDIX 2: RESULTS USING A 5.52% ANNUAL ELECTRICITY PRICE INCREASE

We made the decision to use the EIA's long term estimates for fuel price increases as they were the most reliable source that we could find for projections on the time scale we needed. However, it came to our electricity price increase history for the past 10 years from Xcel Energy which indicated that over the past decade prices have risen an average of 5.53% annually, far greater than the static electricity prices predicted by the EIA. These results are not long term predictions, nor were we able to find similar histories for natural gas prices paid by Carleton. Thus we were unable to use these percentages in our research. However, larger annual increases like these have significant implications. As demonstrated in the tables X and Y, retrofits that reduced electricity usage due to air conditioning or net zero construction resulted in less negative net present values after 50 year lifetimes, and eventually paid back despite discounting. This is most significant in deep retrofits to Nutting House which failed to pay back under the EIA predictive increase rates as well as net zero construction which also failed to pay back for all houses and scenarios in our main model. Had we been able to obtain the same information for natural gas, it is likely that retrofits to houses that only would reduce heating costs would potentially have drastically different results as well depending on the magnitude of the increase. Because of the lack of this information and the non-predictive nature of these increases, we omitted this data from our analysis, but present it in the following tables.

Table 7. Payback times for retrofits (years).

	House	Worst Case	Projected	Best Case	Environmentalist
Basic	Geffert	16	8	5	2
	Dacie Moses	15	6	3	1
	Nutting	54	17	9	4
Deep	Geffert	-	-	-	-
	Dacie Moses	-	-	-	-
	Nutting	-	131	85	110
Net Zero	Geffert	-	183	119	180
	Dacie Moses	-	153	102	150
	Nutting	-	119	83	117

Note: dashes indicate retrofits that never pay back due to discount rate or lack of electricity savings due to absence of air conditioning

Table 8. Net present value of retrofits after 50 year estimated lifetime ($). Positive net present values are blue while negative net present values are red.

	House	Worst Case	Projected	Best Case	Environmentalist
Basic	Geffert	1,200	4,300	9,300	13,300
	Dacie Moses	700	3,300	8,100	11,700
	Nutting	0	1,800	4,700	7,300
Deep	Geffert	-195,700	-186,000	-157,400	-135,300
	Dacie Moses	-184,000	-171,200	-150,300	-128,900
	Nutting	-301,822	-264,013	-205,520	-174,293
Net Zero	Geffert	-1,366,211	-1,316,120	-1,247,701	-1,258,540
	Dacie Moses	-1,052,352	-990,747	-909,883	-937,922
	Nutting	-2,396,662	-2,145,892	-1,833,053	-2,059,977

Appendix 3: Xcel Audit Reports

The following documents are the reports from the energy audits conducted on Geffert, Dacie Moses, and Nutting Houses. The audits were produced by the Neighborhood Energy Connection in conjunction with Xcel Energy. The Geffert House audit was produced on February 21, 2012 by auditor Steve Youlan. The audits for Nutting House and Dacie Moses House were conducted on November 15, 2012 by auditor Rick Cobbs. These audits were used to assess the energy efficiency of the buildings, as well as to produce the basic retrofit recommendations and cost estimates.

HOME ENERGY AUDIT REPORT

MINNESOTA

Xcel Energy
RESPONSIBLE BY NATURE™

Customer: Carleton College

Address: 112 Division St St S

Audit Date: 02-21-2012

Auditor: Steve Youlan

Phone: 651-221-4462x124

Thank you for participating in the Xcel Energy Audit program. A Home Energy Audit is the important first step toward achieving home energy efficiency. Read on to learn more ways to save with Xcel Energy's conservation programs.

Your audit was performed by the Neighborhood Energy Connection (NEC), a Minnesota nonprofit whose mission is to offer tools for energy-efficient living. It was our pleasure to visit your home to help you find ways to increase its comfort and energy efficiency. We hope that you found the audit informative and useful.

For follow-up questions about your auditor's recommendations please call your auditor, **Steve Youlan** directly at **651-221-4462x124** or contact the NEC at (651) 221-4462 ext. 145.

Thanks again for your interest in conserving energy. Your commitment to improving your home provides a better future for everyone.

Sincerely,

Jimmie Sparks

Residential Energy Program Manager
Neighborhood Energy Connection

OUR TOP RECOMMENDATIONS WERE:

Seal Attic Bypasses

Attic bypasses allow heated air to escape from your home's living spaces into the attic. Bypasses are hidden from view and commonly occur in the small spaces between the attic floor and attic penetrations such as plumbing stacks, electrical wiring, chimneys, ceiling light fixtures, heating or cooling ductwork, or kitchen and bathroom exhaust fans. Warm air in your attic can lead to moisture and condensation problems, rotten wood joists, and waterlogged, poorly performing insulation. Search out and seal attic bypasses with high quality caulk, polyethylene, foam, sheetrock, sheet metal, extruded polystyrene, or densely packed insulation.

Add Attic Insulation / Air Seal

Insulate your attic to R-50, taking care to seal all air leaks beforehand.

Replace water heater with power vented water heater

Power vent heaters use a fan to assist venting of combustion gases. Therefore they cannot backdraft while the burner is firing, improving health and safety for your home's occupants.

Weatherstrip Windows

Stop air infiltration by making your windows more airtight with weather stripping. When windows are closed, you'll feel fewer drafts.

Additional Auditor Recommendations

Attic: dense pack floor with cellulose.

□

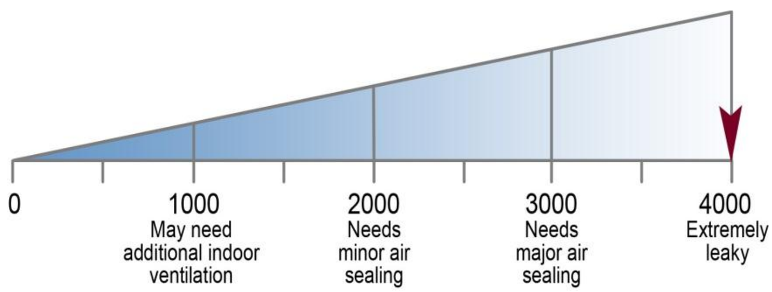
Stairwell: dense pack walls and under stairs.

MINNESOTA

HOME ENERGY AUDIT REPORT

Xcel Energy — RESPONSIBLE BY NATURE

Your blower door reading: 4050 cubic feet per minute (CFM) @ 50 Pascals (Pa).



We recommend air sealing in the following areas:

Attic: Access Door/Hatch, Chimney Flue, Plumbing Vent, walk-up stair well, bath fan vents
Living Areas:
Basement: basement windows, electric service

HOME PERFORMANCE SUMMARY

5 stars meets ENERGY STAR Federal Tax guidelines

Peak Attic: We recommend insulating your attic.		
Your attic's current R-Value:	12	
Recommended R-Value:	50	

Estimated Cost: $1,824.00 to $2,189.00 Estimated Annual Return on Investment: 7% to 11%

Walls: We do not recommend insulating your walls.		
Your wall's current R-Value:	11	
Recommended R-Value:	11	

Basement Rim Joist: We do not recommend insulating or sealing your basement rim joist.		
Your rim joist's current R-Value:	5	
Recommended R-Value:	5	

MECHANICAL SYSTEMS

Heating System: Boiler	
You heat your home with: Natural Gas	
Existing AFUE: 87	

Water Heating	
Existing: Standard Gas (0.52 or more)	

Air Conditioning	
Existing Air Conditioning: None	
Existing SEER:	

POTENTIAL UNSAFE CONDITION

Our auditor did not find any unsafe conditions.

DEFINITIONS

Savings figures are calculated independently of one another and should not be combined. R-value insulation ratings are used to measure insulation's ability to resist heat flow. The higher the R-value, the more effective it is. House insulation should be purchased based on its R-value, not thickness or weight. The "Rim Joist" is the piece of wood that sits directly on top of your foundation, connecting your floor joists. It is a common place for rim joist air leaks.

Annual Fuel Utilization Efficiency (AFUE) is a rating that reflects how efficiently a heating system converts fuel to energy. The higher the AFUE, the more efficient the heating system.

The Energy Factor (EF) indicates a water heater's overall energy efficiency based on the amount of hot water produced per unit of fuel consumed over a particular day. The higher the EF, the more efficient the water heater.

Seasonal Energy Efficiency Ratio (SEER) is a measure of the energy efficiency of an air conditioning system.

Customer: Carleton College

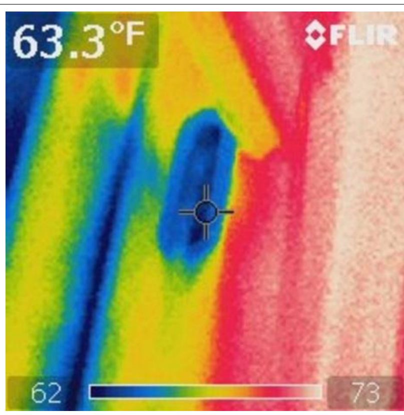
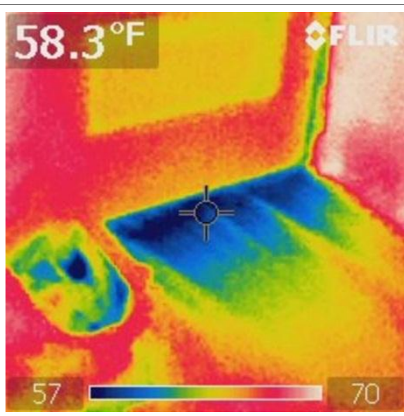
Audit Date: 02-21-2012

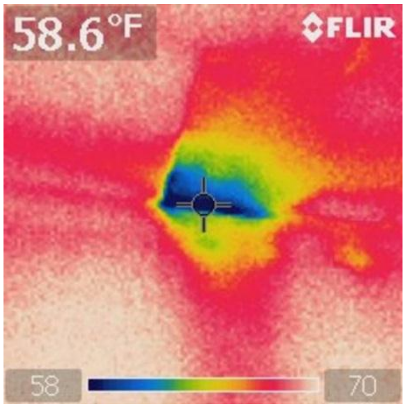
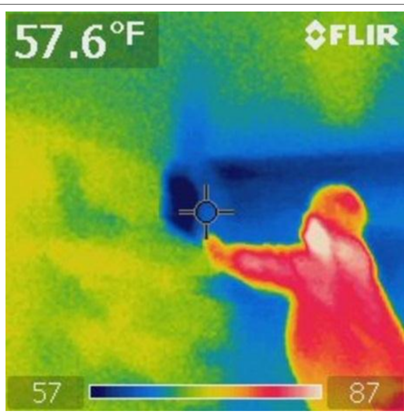
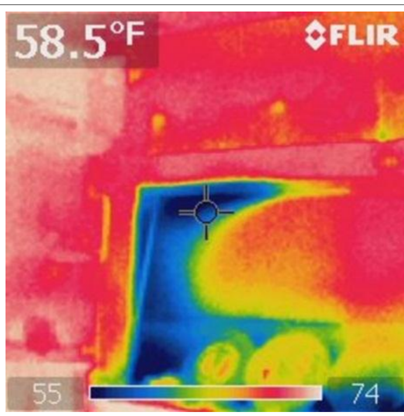
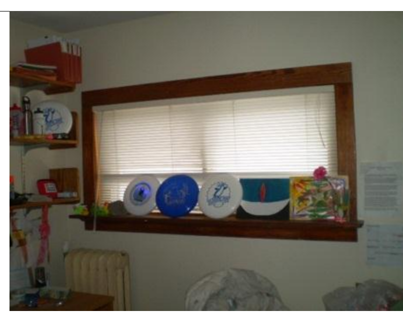
Auditor: Steve Youlan

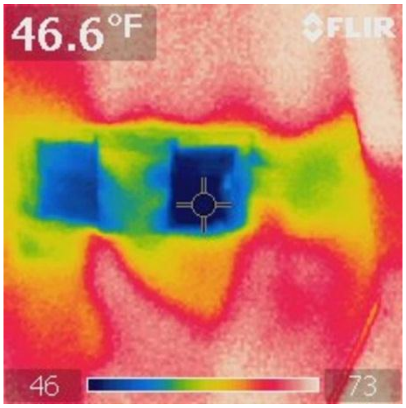
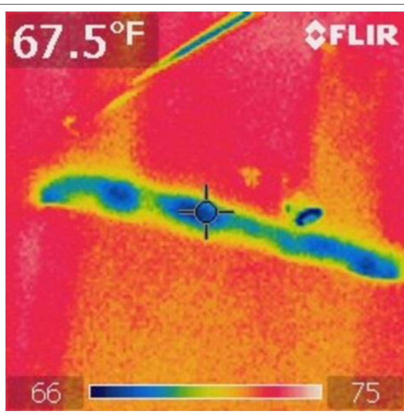
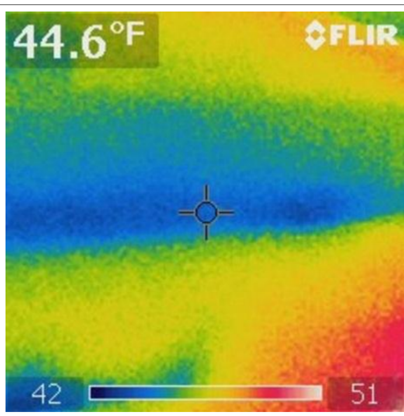
Phone: $<phone>

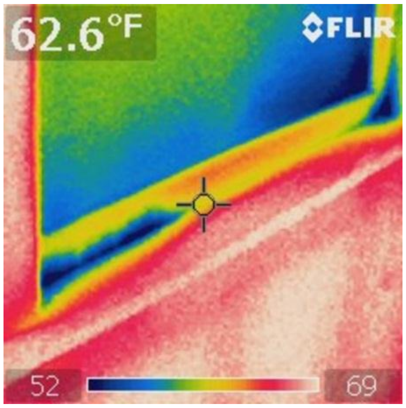
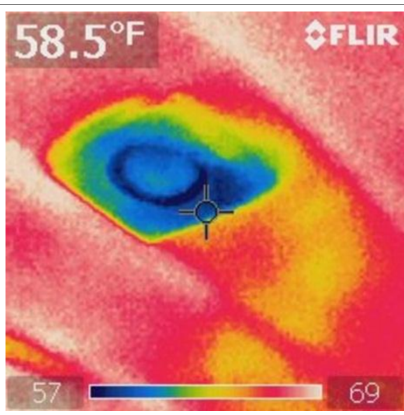
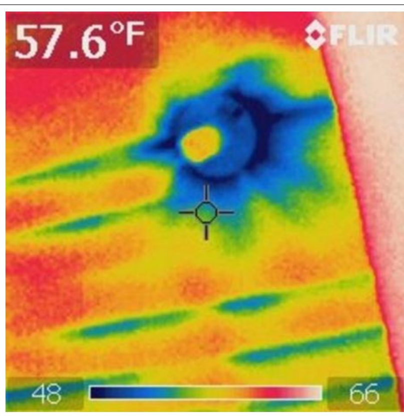
ABOUT INFARED IMAGES

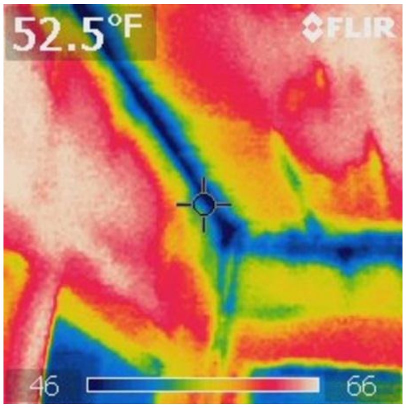
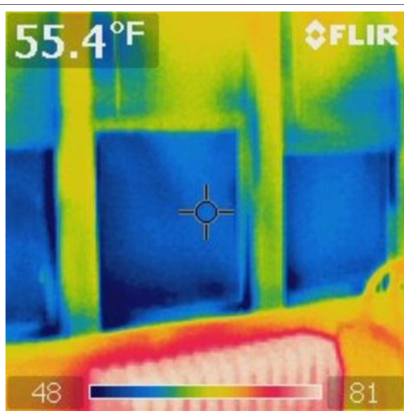
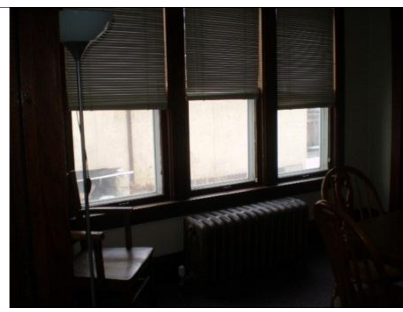
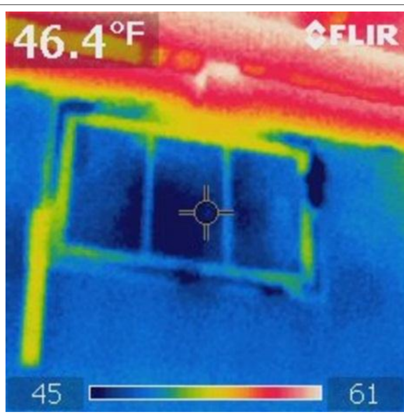
The infrared (IR) images show what the surface temperatures of wall and ceiling areas are relative to surrounding areas. The darker shades represent colder areas and could indicate framing and/or insulation voids or cold air coming in from outside. Following are infrared images next to standard digital photos of the same areas. Darker shades indicate cooler surfaces while lighter shades indicate warmer surfaces. These observations can only be confirmed with destructive investigation (i.e. drilling holes or removing sheetrock.)

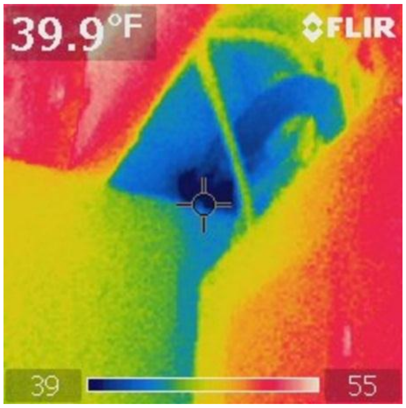
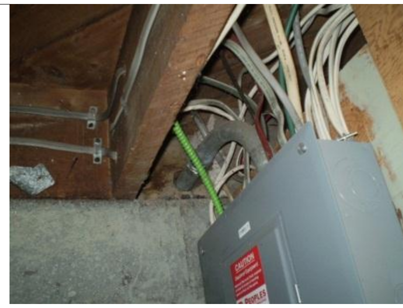
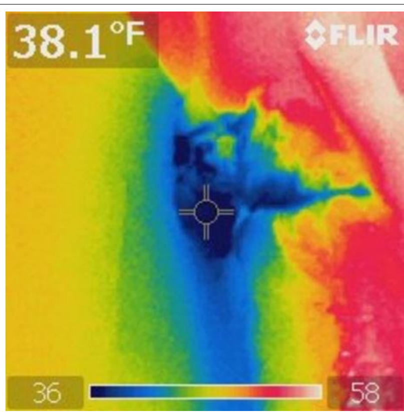
<table>
<tr><th>INFRARED IMAGES</th><th>DIGITAL IMAGES</th><th>COMMENTS</th></tr>
<tr><td>
</td><td></td><td>Air leakage at window rope pulleys. Seal gaps with pulley seals to reduce drafts and improve comfort.</td></tr>
<tr><td>
</td><td></td><td>Air leakage at door to attic. Insulate and weather strip door to reduce heat loss.</td></tr>
</table>

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		Air leakage at ceiling trim. Seal gaps at ceiling trim with caulk to reduce infiltration and minimize condensation.
		Cool air infiltration from air grille. Determine source.
		Loose fitting slider windows. Seal by weather stripping or removable caulk.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		Air leakage at ceiling bath fan. Seal gaps between fan housing and ceiling with caulk to reduce heat loss and minimize condensation.
		Air leakage where shower stall meets wall. Seal gap to reduce condensation and prevent damage to wall.
		Air leakage at window panes. Seal by re-glazing glass to reduce infiltration and improve comfort.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		Fixed window at stairs: seal gaps with clear caulk to reduce infiltration.
		Air leakage at fan/heat lamp. Seal gaps at ceiling to reduce heat loss and minimize condensation. Also seal gaps at exterior to stop infiltration of cool air.
		Air leakage at front "porch" ceiling. Seal all gaps to reduce heat loss.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		Air leakage at front porch ceiling trim. Seal with clear caulk.
		Cool windows. Close all storms and latch windows tightly for winter to reduce heat loss and improve comfort.
		Air leakage at basement windows and framing. Seal all gaps with caulk to reduce infiltration and raise temperature of main floor.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		Air leakage at electric lines. Seal with foam caulk.
		Air leakage at dryer vent. Seal gaps with foam to stop infiltration and improve comfort.

Xcel Energy Rebate Programs

Xcel Energy's rebate programs pay you to make your home more efficient. Based on your needs we recommend the following Xcel Energy rebate program(s):

THE HOME PERFORMANCE REBATE PROGRAM

Your home qualifies for the Xcel Energy Home Performance Rebate program which gives you the opportunity to save more energy and by doing more improvements at once, you receive larger rebates. You have completed the first step by receiving an energy audit. Now submit your sign up form and choose installers from the Preferred Contractor list. Your auditor can answer questions about this program.

Possible improvements for your home:

Required Items to Complete:	Rebate
Air Sealing & Weather Stripping	$60
Attic Insulation & bypass sealing	$350
CFLs – Total of 20	$40

Optional Items (choose two or more):	Rebate
Occupancy Sensor	$60.00
Water Heater - (0.67 EF)	$150.00

Home Performance Rebate with Energy Star

Take a whole-house approach to energy savings and home improvements. This program is ideal for homeowners who need to make multiple improvements to their home.

PROGRAM REQUIREMENTS

To participate, you must:

- Must be a residential natural gas and electric customer of Xcel Energy or be an all electric Xcel Energy customer with electric space heating
- Complete a Standard Audit ($60 fee) or Standard Audit with Infrared audit ($100 fee)
- Use an install contractor from our Participating Install Contractor List
- Implement at least five improvements—three mandatory and two optional
- Complete final inspection and provide all receipts to our partner, NEC
- Customers are not eligible to receive rebates from Home Performance and other Xcel Energy program for the same improvement
- Customer invoices/receipts must be dated *after their audit date* and *after the date of sign up* for the Home Performance program
- The test-out inspection must be satisfactorily completed
- Customers must meet all program requirements to be eligible for any of the Home Performance rebates
- All improvements must be completed by an Xcel Energy Participating Installation Contractor (PIC)
- Program is contingent on availability of funds and could be terminated at any time.
- Attic must have a pre R-value of 20 or less and a post R-value of 44 or greater.

Note: If you have already earned a rebate through a different Xcel Energy program, you cannot receive another rebate for the same improvement.

FIVE EASY STEPS:

1. Get a standard audit ($60 audit with a blower door test) or infrared audit ($100 audit).

2. Sign up for the program by calling our partner, the Neighborhood Energy Connection (NEC) at 651-221-4462 x136 or email the NEC at info@thenec.org. There is no obligation but signing up gets you the packet to get started.

3. Choose a participating contractor. Have a participating contractor install your recommended improvements. The NEC will mail you a list of participating contractors when you sign up, or you can click the link above.

4. Call the NEC at 651-221-4462 x 136, to come inspect and verify that the improvements have been installed which will give you peace of mind.
5. *NEC will collect your receipts and submit your rebate paperwork for you.*

Required Energy Conservation Improvements	Rebate*
o Air Sealing/Weatherstripping (20% of install cost up to rebate amount)	$60
o Attic Insulation (20% of install cost up to rebate amount)	$350
o CFLs	$40
Optional (choose at least two)	**Rebate***
o AC 14.5 SEER	$250
o AC 15 SEER	$350
o AC 16 SEER	$475
o Clothes Washer	$50
o Dishwasher	$15
o ECM Fan	$100
o Furnace 90%	$150
o Furnace 92%	$225
o Furnace 94%	$300
o Furnace 96%	$325
o Boiler – 84%	$250
o Occupancy Sensor	$60
o Refrigerator	$15
o Programmable Thermostat	$10
o Wall Insulation (20% of install cost up to rebate amount)	$400
o Water Heater – Tankless (0.82 EF)	$450
o Water Heater – (0.67 EF)	$150
o Water Heater – (0.80 EF)	$250
o Refrigerator Recycling	$35

*Certain restrictions and criteria do apply in order to be eligible for these rebates criteria do apply in order to be eligible for these rebates.

PRE-EXISTING EQUIPMENT OR CONDITION

Pre-Existing condition refers to equipment or insulation that you have already installed, prior to your audit and prior to signing-up for Home Performance with ENERGY STAR. Certain pre-existing equipment can be counted towards your Home Performance requirements; however, you are **not** eligible to receive our rebate for that specific equipment. CFLs are allowed as pre-existing equipment and you may also have one optional improvement designated as a pre-existing equipment condition.

MINNESOTA

HOME ENERGY AUDIT REPORT

Customer: Carleton College

Address: 110 Union St

Audit Date: 11-15-2012

Auditor: Rick Cobbs

Phone: 651-328-6311

Thank you for participating in the Xcel Energy Audit program. A Home Energy Audit is the important first step toward achieving home energy efficiency. Read on to learn more ways to save with Xcel Energy's conservation programs.

Your audit was performed by the Neighborhood Energy Connection (NEC), a Minnesota nonprofit whose mission is to offer tools for energy-efficient living. It was our pleasure to visit your home to help you find ways to increase its comfort and energy efficiency. We hope that you found the audit informative and useful.

For follow-up questions about your auditor's recommendations please call your auditor, **Rick Cobbs** directly at **651-328-6311** or contact the NEC at (651) 221-4462 ext. 145.

Thanks again for your interest in conserving energy. Your commitment to improving your home provides a better future for everyone.

Sincerely,

Rebecca Olson, Residential Energy Program Manager
Neighborhood Energy Connection

OUR TOP RECOMMENDATIONS WERE:

Insulate Crawl Space

Rooms can lose heat through their floor when they have an uninsulated crawl space below them. Like any other insulated space, air leaks should be addressed before insulating.

Add Attic Insulation / Air Seal

Insulate your attic to R-50, taking care to seal all air leaks beforehand. Insulation keeps your home warm in the winter and cool in the summer. When correctly installed with air sealing, insulation can deliver comfort and lower energy bills during the hottest and coldest times of the year. Insulation performance is measured by R-value — its ability to resist heat flow. Higher R-values mean more insulating power. Insulation works best when air is not moving through or around it. So it is very important to seal air leaks before installing insulation to ensure that you get the best performance from the insulation.

Weatherstrip Windows

Stop air infiltration by making your windows more airtight with weather stripping. When windows are closed, you'll feel fewer drafts.

Weatherstrip Doors

A 1/8" space between a standard exterior door and its threshold is equivalent to a two square inch hole in the wall. Installing a sweep at the door's bottom threshold and weather stripping around the perimeter keeps cold winter air and hot summer air outdoors where you want it.

Air Seal and Re-Insulate Rim Joists

Rim joists insulated with certain products can become a moisture issue if not air sealed properly. Air leaks can diminish effectiveness of insulation. Remove existing insulation from rim joists, air seal and re-insulate.

Additional Auditor Recommendations

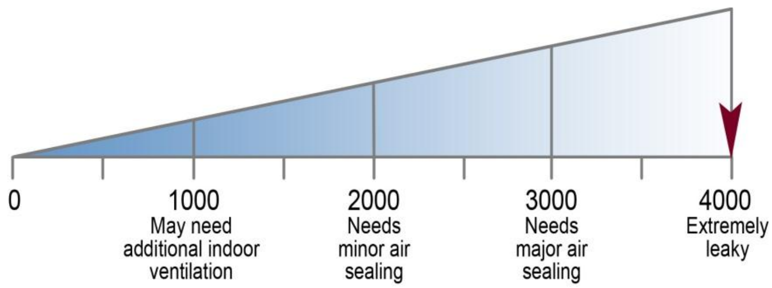
Attic insulation estimated, resident didn't want it accessed. Assuming insulation is needed because joists were visible with camera. Crawl space wall insulation is a priority and dirt in crawl space should be covered with plastic to minimize radon.

HOME ENERGY AUDIT REPORT

MINNESOTA

Xcel Energy® RESPONSIBLE BY NATURE™

Your blower door reading: 6106 cubic feet per minute (CFM) @ 50 Pascals (Pa).



We recommend air sealing in the following areas:

Attic:	Access Door/Hatch
Living Areas:	Doors, Windows, Electric Outlets, Switches
Basement:	Rim Joist, Crawl Space walls

HOME PERFORMANCE SUMMARY

5 stars meets ENERGY STAR Federal Tax guidelines

Peak Attic: We recommend insulating your attic.		
Your attic's current R-Value:	19	★★
Recommended R-Value:	50	★★★★★

Estimated Cost: $868.00 to $1,042.00 Estimated Annual Return on Investment: 4% to 13%

Walls: We do not recommend insulating your walls.		
Your wall's current R-Value:	11	★★★
Recommended R-Value:	11	★★★

Basement Rim Joist: We recommend insulating and sealing your basement rim joist.		
Your rim joist's current R-Value:	0	★
Recommended R-Value:	10	★★★★

Estimated Cost: $250.00 to $300.00 Estimated Annual Return on Investment: 13% to 19%

MECHANICAL SYSTEMS

Heating System: Boiler	
You heat your home with: Natural Gas	
Existing AFUE: 87	★★★★

Water Heating	
Existing: Standard Gas (0.52 or more)	★★★

Air Conditioning	
Existing Air Conditioning: None	
Existing SEER:	★

POTENTIAL UNSAFE CONDITION

Our auditor did not find any unsafe conditions.

DEFINITIONS

Savings figures are calculated independently of one another and should not be combined. R-value insulation ratings are used to measure insulation's ability to resist heat flow. The higher the R-value, the more effective it is. House insulation should be purchased based on its R-value, not thickness or weight. The "Rim Joist" is the piece of wood that sits directly on top of your foundation, connecting your floor joists. It is a common place for rim joist air leaks.

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MINNESOTA

HOME ENERGY AUDIT REPORT

Xcel Energy® RESPONSIBLE BY NATURE™

Customer: Carleton College

Audit Date: 11-15-2012

Auditor: Rick Cobbs

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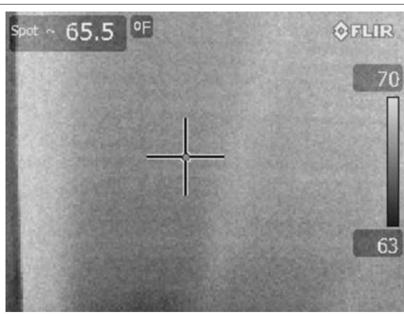
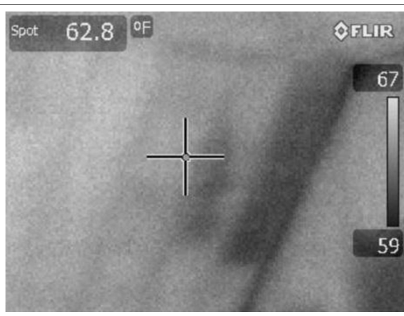
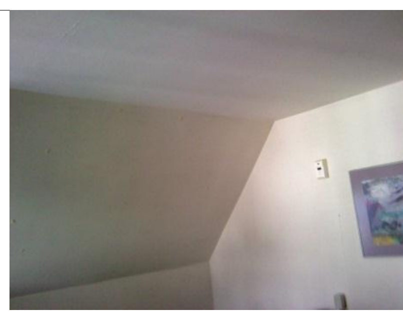
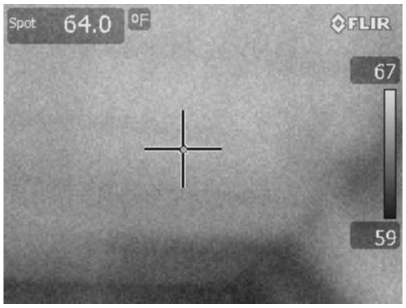
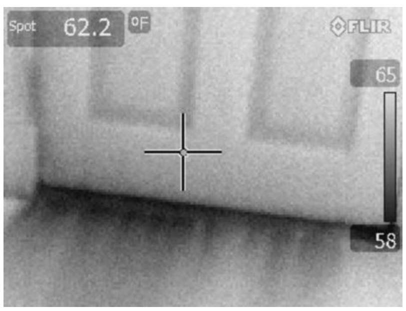
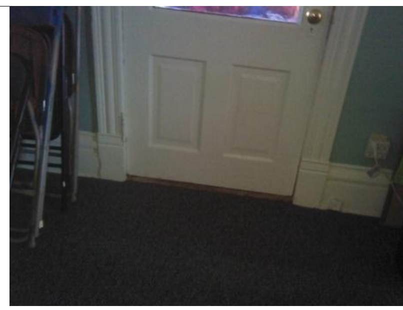
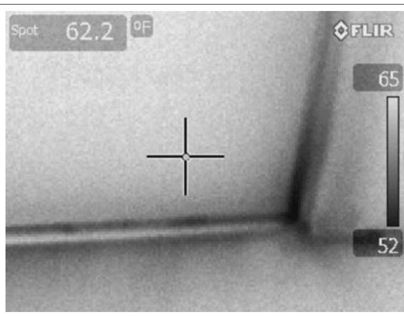
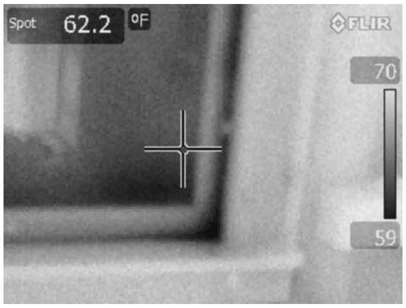
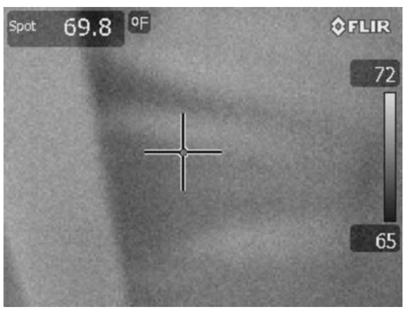
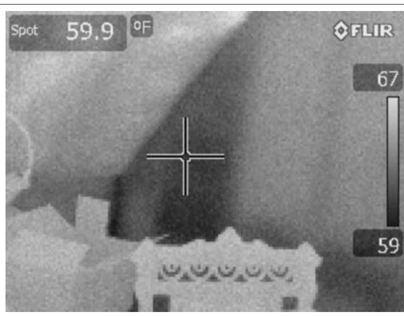
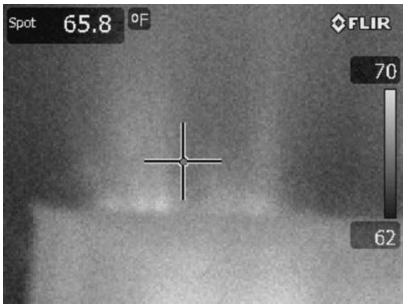
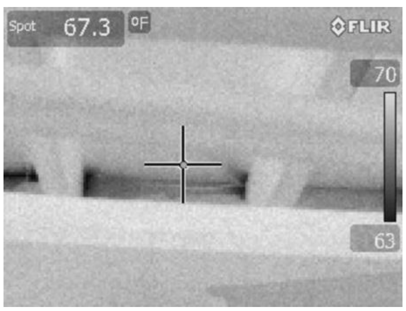
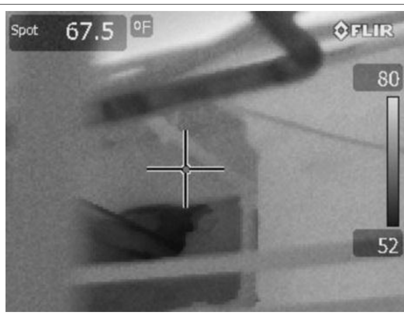
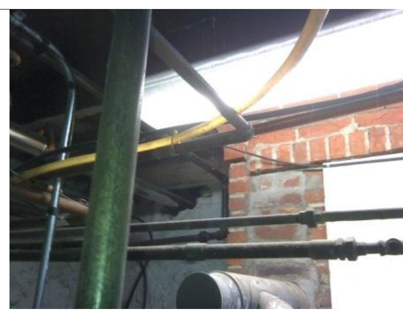
<tr><td>
</td><td></td><td>This picture shows a slant that appears to be insulated. This was typical of most slants in the house.</td></tr>
<tr><td>
</td><td></td><td>This picture shows an insulated slant with an insulation void. The dark area shows what appears to be a missed area of the slant.</td></tr>
</table>

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This picture shows the peak attic. The joists in the attic are barely visible. This appears to be because there is some insulation in the attic but not enough to cover the joists.
		The following pictures were taken with the blower door running to show air leakage. This is air leakage from an outside door. Recommend weatherstripping the doors and installing sweeps.
		This is another door that is allowing cold air infiltration.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This window was not closing properly and was allowing in outside air. Recommend having windows fixed or replaced so that both the storms and the windows can be closed easily.
		This picture shows the attic hatch. Recommend weather stripping the hatch to minimize air leakage to the attic.
		This picture shows what appears to be an empty wall cavity. This appears to have been missed when the walls were insulated.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This picture shows air leakage from around the back door frame. Recommend caulking around the door trim.
		This picture shows air leakage around the rim joist. Recommend installing rigid foam and sealing all four sides with spray foam.
		This picture shows air-infiltration from the crawl space. Recommend insulating the crawl spaces walls and rim joists with foil faced rigid foam and sealing all joints or gaps with spray foam.

Xcel Energy Rebate Programs

Xcel Energy's rebate programs pay you to make your home more efficient. Based on your needs we recommend the following Xcel Energy rebate program(s):

THE HOME PERFORMANCE REBATE PROGRAM

Your home qualifies for the Xcel Energy Home Performance Rebate program which gives you the opportunity to save more energy and by doing more improvements at once, you receive larger rebates. You have completed the first step by receiving an energy audit. Now submit your sign up form and choose installers from the Preferred Contractor list. Your auditor can answer questions about this program.

Possible improvements for your home:

Required Items to Complete:	Rebate
Air Sealing & Weather Stripping	$60
Attic Insulation & bypass sealing	$350
CFLs – Total of 20	$40

Optional Items (choose two or more):	Rebate
Boiler 84%	$250.00
Occupancy Sensor	$60.00
Programmable Thermostat	$10.00

Home Performance Rebate with Energy Star

Take a whole-house approach to energy savings and home improvements. This program is ideal for homeowners who need to make multiple improvements to their home. You can receive expert home efficiency improvements – and up to $1,200 in rebates.

PROGRAM REQUIREMENTS

To participate, you must:

- Be a combined residential natural gas and electricity customer of Xcel Energy in Minnesota.
- Complete a Standard Audit ($60 fee) or Standard Audit with Infrared audit ($100 fee).
- All improvements must be completed by an Xcel Energy Participating Installation Contractor (PIC).
- Implement at least three required **and** two optional improvements (see back of this sheet).
- If the attic has a pre R-value of 20 or less, it must have a post R-value of 44 or greater;
- If the attic has a pre R-value greater than R-20, the installer must add at least R-25.
- Customer invoices/receipts must be dated *after their audit date* and *after the date of sign up* for the Home Performance program.
- Customers must meet all program requirements to be eligible for any of the Home Performance rebates.
- Customers are not eligible to receive rebates from Home Performance and other Xcel Energy programs for the same improvement.
- Program is contingent on availability of funds and could be terminated at any time.
- Rebates are issued after our partner, The Neighborhood Energy Connection (NEC), verifies that the improvements were done properly and then processes your rebate paperwork.

Note: If you have already earned a rebate through a different Xcel Energy program, you cannot receive another rebate for the same improvement.

FOUR EASY STEPS:

1. Sign up for the program by calling our partner, Neighborhood Energy Connection (NEC), 651-221-4462 x136. You may also sign up through email: mailto:info@thenec.org.

2. Choose a participating contractor (the list will be sent to you.) Have a participating contractor install your recommended improvements. Note: All measures must be installed by a participating contractor except those noted. See the next page for a list of the required and optional conservation improvements.

3. Call NEC at 651-221-4462 ext.136 after the improvements have been installed, and they will come to inspect and verify that the improvements have been completed.

4. *NEC will collect your receipts and submit your rebate paperwork for you.*

REQUIRED ENERGY CONSERVATION IMPROVEMENTS	REBATE
o Air Sealing/Weatherstripping	20% up to $60
o Attic Insulation – Must choose a contractor from the Participating Contractor List. – If existing R-value is 20 or less, must increase to R 44 – If existing R-value is 21 or more, must increase by R 25	20% up to $350
o Up to 20 High Efficiency Lights (CFL's) – Can be pre-existing in the home*	$2/bulb up to $20
OPTIONAL (CHOOSE AT LEAST TWO)	**REBATE**
CENTRAL AIR – Must choose a contractor from the participating list	
o AC 14.5 SEER	$250
o AC 15 SEER	$350
o AC 16 SEER	$475
APPLIANCES – Must be ENERGY STAR qualified	
o Clothes Washer	$50
o Dishwasher	$15
o Refrigerator	$15
CONVENIENCE ITEMS	
o Occupancy Sensor	$60
o Programmable Thermostat	$10
o Refrigerator Recycling	$35
HEATING – Must choose a contractor from the participating list	
o Furnace 90%	$150
o Furnace 92%	$225
o Furnace 94%	$300
o Furnace 96%	$325
o Boiler – 84%	$250
WALL INSULATION – Must choose a contractor from the participating list	
o Wall Insulation – Existing R-Value must be 0. Must insulate to R-13.	20% up to $400
WATER HEATER – Must choose a contractor from the participating list	
o Water Heater – Tankless (0.82 EF)	$450
o Water Heater – (0.62 EF)	$50
o Water Heater – (0.64 EF)	$70
o Water Heater – (0.67 EF)	$150
o Water Heater – (0.80 EF)	$250.00

* Certain pre-existing equipment can be counted towards your Home Performance requirements; however, you are not eligible to receive our rebate for that item. Only one item from the optional improvements may be counted as pre-existing. CFLs can also be pre-existing.

HOME ENERGY AUDIT REPORT

MINNESOTA

Customer: Carleton College

Address: 217 Union St

Audit Date: 11-15-2012

Auditor: Rick Cobbs

Phone: 651-328-6311

Thank you for participating in the Xcel Energy Audit program. A Home Energy Audit is the important first step toward achieving home energy efficiency. Read on to learn more ways to save with Xcel Energy's conservation programs.

Your audit was performed by the Neighborhood Energy Connection (NEC), a Minnesota nonprofit whose mission is to offer tools for energy-efficient living. It was our pleasure to visit your home to help you find ways to increase its comfort and energy efficiency. We hope that you found the audit informative and useful.

For follow-up questions about your auditor's recommendations please call your auditor, **Rick Cobbs** directly at **651-328-6311** or contact the NEC at (651) 221-4462 ext. 145.

Thanks again for your interest in conserving energy. Your commitment to improving your home provides a better future for everyone.

Sincerely,

Rebecca Olson, Residential Energy Program Manager
Neighborhood Energy Connection

OUR TOP RECOMMENDATIONS WERE:

Add Attic Insulation / Air Seal

Insulate your attic to R-50, taking care to seal all air leaks beforehand. Insulation keeps your home warm in the winter and cool in the summer. When correctly installed with air sealing, insulation can deliver comfort and lower energy bills during the hottest and coldest times of the year. Insulation performance is measured by R-value — its ability to resist heat flow. Higher R-values mean more insulating power. Insulation works best when air is not moving through or around it. So it is very important to seal air leaks before installing insulation to ensure that you get the best performance from the insulation.

Air Seal and Re-Insulate Rim Joists

Rim joists insulated with certain products can become a moisture issue if not air sealed properly. Air leaks can diminish effectiveness of insulation. Remove existing insulation from rim joists, air seal and re-insulate.

Weatherstrip Doors

A 1/8" space between a standard exterior door and its threshold is equivalent to a two square inch hole in the wall. Installing a sweep at the door's bottom threshold and weather stripping around the perimeter keeps cold winter air and hot summer air outdoors where you want it.

Put stereos, TVs, computers, chargers on Power strips and turn off strip when not in use

These electronic items draw a lot of power even when turned off. A power strip cuts off the power to these items, which avoids "phantom load."

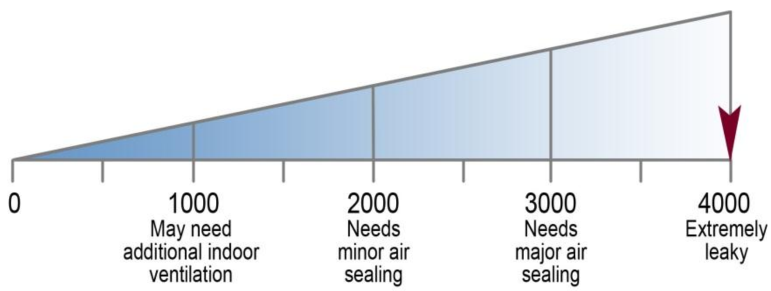
Replace Refrigerator with ENERGY STAR model

ENERGY STAR qualified refrigerators are required by the U.S. Department of Energy to use 20% less energy than conventional models. Choose an ENERGY STAR qualified model and cut your energy bills by $165 over the lifetime of your fridge.

Additional Auditor Recommendations

Attic has air leaks between wall sections,and around plumbing pipes. The thermal boundary of the attic should be decided. The air handler ducts should be insulated with blown insulation on the attic floor.

Your blower door reading: 9100 cubic feet per minute (CFM) @ 50 Pascals (Pa).



We recommend air sealing in the following areas:

Attic:	Kneewalls, Walltops between sections of house
Living Areas:	Doors, Door Trim
Basement:	Rim Joist, Basement windows

HOME PERFORMANCE SUMMARY

5 stars meets ENERGY STAR Federal Tax guidelines

Peak Attic: We recommend insulating your attic.		
Your attic's current R-Value:	30	★★★
Recommended R-Value:	50	★★★★★

Estimated Cost: $1,632.00 to $1,958.00 Estimated Annual Return on Investment: 2% to 3%

Walls: We do not recommend insulating your walls.		
Your wall's current R-Value:		The insulation levels could not be assessed.
Recommended R-Value:	14	The insulation levels could not be assessed.

Basement Rim Joist: We recommend insulating and sealing your basement rim joist.		
Your rim joist's current R-Value:	0	★
Recommended R-Value:	19	★★★★★

Estimated Cost: $275.00 to $330.00 Estimated Annual Return on Investment: 16% to 23%

MECHANICAL SYSTEMS

Heating System: Forced Air	
You heat your home with: Natural Gas	
Existing AFUE: 92	★★★★

Water Heating	
Existing: On Demand	★★★★★

Air Conditioning	
Existing Air Conditioning: Central Air	
Existing SEER: 13	★★★

POTENTIAL UNSAFE CONDITION

Our auditor did not find any unsafe conditions.

DEFINITIONS

Savings figures are calculated independently of one another and should not be combined. R-value insulation ratings are used to measure insulation's ability to resist heat flow. The higher the R-value, the more effective it is. House insulation should be purchased based on its R-value, not thickness or weight. The "Rim Joist" is the piece of wood that sits directly on top of your foundation, connecting your floor joists. It is a common place for rim joist air leaks.

Annual Fuel Utilization Efficiency (AFUE) is a rating that reflects how efficiently a heating system converts fuel to energy. The higher the AFUE, the more efficient the heating system.

The Energy Factor (EF) indicates a water heater's overall energy efficiency based on the amount of hot water produced per unit of fuel consumed over a particular day. The higher the EF, the more efficient the water heater.

Seasonal Energy Efficiency Ratio (SEER) is a measure of the energy efficiency of an air conditioning system.

MINNESOTA

HOME ENERGY AUDIT REPORT

Xcel Energy® RESPONSIBLE BY NATURE™

Customer: Carleton College

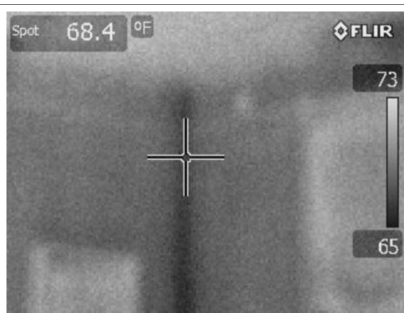
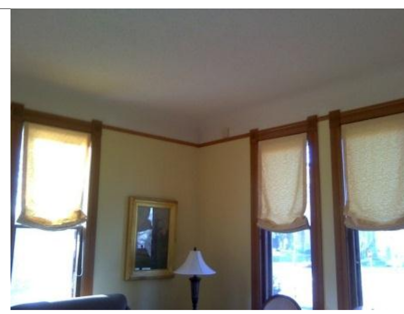
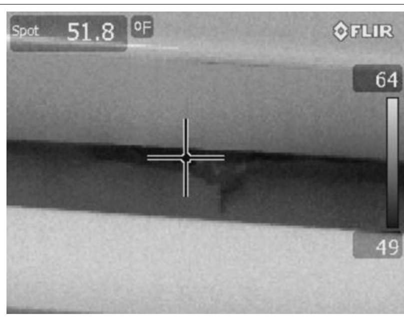
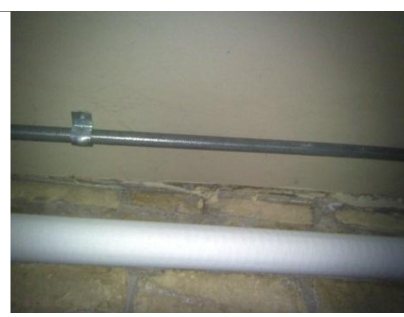
Audit Date: 11-15-2012

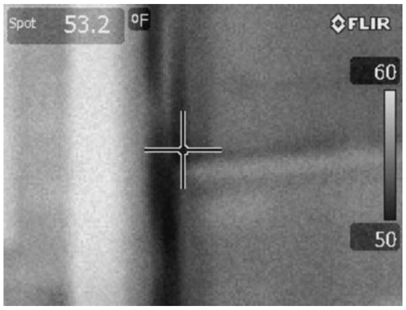
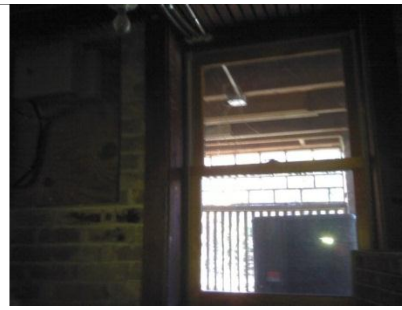
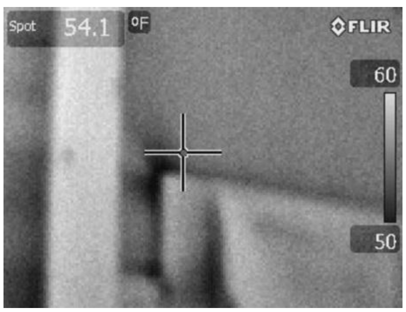
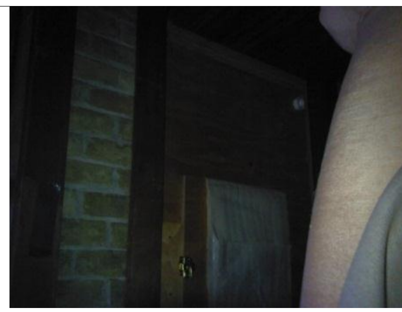
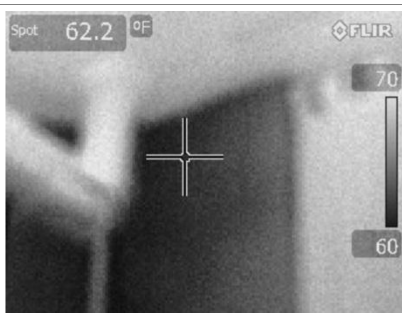
Auditor: Rick Cobbs

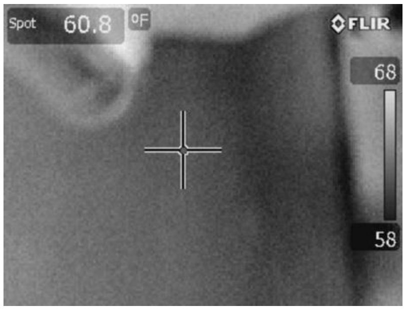
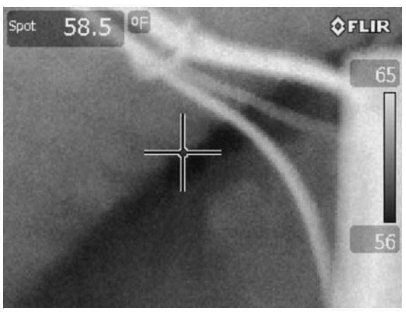
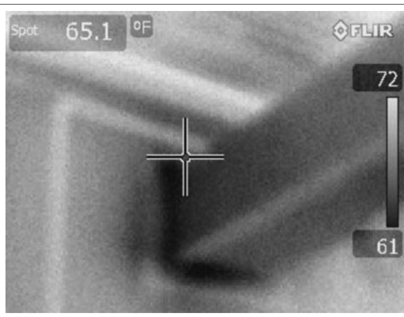
Phone: 651-328-6311

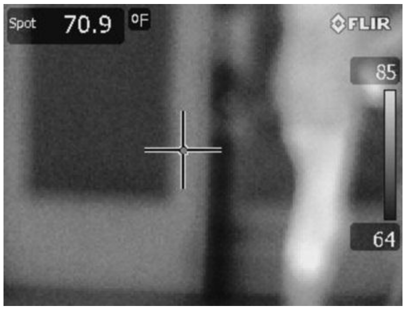
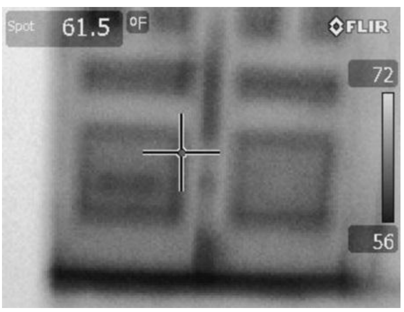
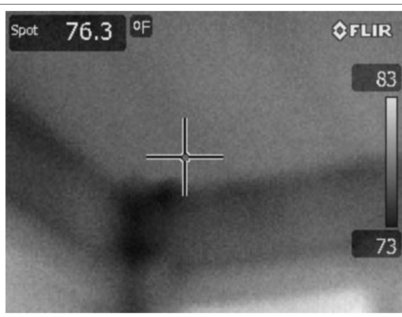
ABOUT INFARED IMAGES

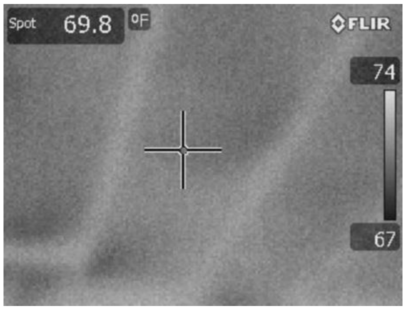
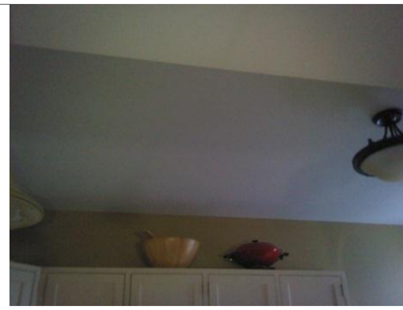
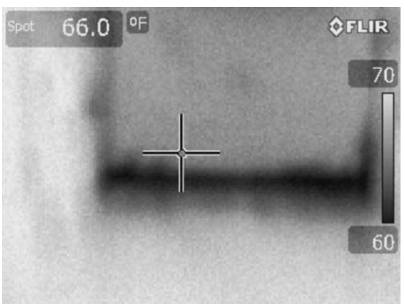
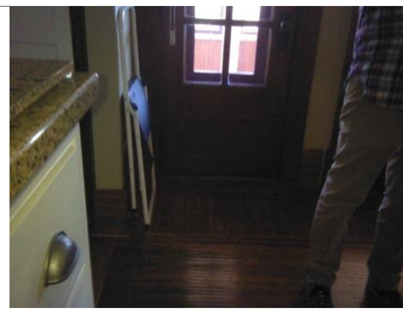
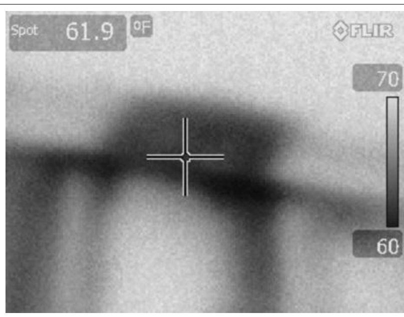
The infrared (IR) images show what the surface temperatures of wall and ceiling areas are relative to surrounding areas. The darker shades represent colder areas and could indicate framing and/or insulation voids or cold air coming in from outside. Following are infrared images next to standard digital photos of the same areas. Darker shades indicate cooler surfaces while lighter shades indicate warmer surfaces. These observations can only be confirmed with destructive investigation (i.e. drilling holes or removing sheetrock.)

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This picture shows the outside walls. It cannot be determined if the outside walls are insulated. This picture makes it appear that they are not insulated. This was typical of all the outside walls.
		This picture shows cold air infiltration which appears to be coming from the rim joist above the drywall. Recommend air sealing and insulating the rim joist.

<table>
<tr><th>INFRARED IMAGES</th><th>DIGITAL IMAGES</th><th>COMMENTS</th></tr>
<tr><td>
</td><td></td><td>This picture shows cold air coming around the basement window sash. Recommend weather stripping the window with sash inserts, covering with plastic or replacing the window.</td></tr>
<tr><td>
</td><td></td><td>This picture shows cold air coming around the old dog door. Recommend sealing the door tight and insulating the door with rigid foam.</td></tr>
<tr><td>
</td><td></td><td>This picture shows a very big cold area above the basement ceiling at the south end of the basement. Recommend removing the drywall, investigating and fixing the problem.</td></tr>
</table>

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This is a similar cold area on the same end of the basement.
		This picture shows some leaks in the brick in the furnace room. Recommend sealing any gaps with spray foam.
		This picture shows air leakage around the beam in the basement. Recommend sealing all 4 sides of the beam with caulk.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This picture shows air-infiltration around the french doors at the back of the house. Recommend weather stripping the doors.
		This picture shows air-infiltration around the front doors. Recommend installing weather stripping and an adjustable threshold to minimize air leaks.
		This picture shows air-infiltration around the ceiling ducts for the air conditioner. Recommend sealing around the ducts at the attic floor and making sure the ducts are completely sealed within the attic.

INFRARED IMAGES	DIGITAL IMAGES	COMMENTS
		This picture shows the attic floor joists from the ceiling below. Recommend adding more insulation to act as a thermal break above the joists.
		This is another door that could use weather stripping.
		This appears to be an area with no insulation between two wall sections. Recommend air sealing the wall tops and adding insulation to the attic.

Xcel Energy Rebate Programs

Xcel Energy's rebate programs pay you to make your home more efficient. Based on your needs we recommend the following Xcel Energy rebate program(s):

THE HOME PERFORMANCE REBATE PROGRAM

Your home qualifies for the Xcel Energy Home Performance Rebate program which gives you the opportunity to save more energy and by doing more improvements at once, you receive larger rebates. You have completed the first step by receiving an energy audit. Now submit your sign up form and choose installers from the Preferred Contractor list. Your auditor can answer questions about this program.

Possible improvements for your home:

Required Items to Complete:	**Rebate**
Air Sealing & Weather Stripping	$60
Attic Insulation & bypass sealing	$350
CFLs – Total of 20	$40

Optional Items (choose two or more):	**Rebate**
Boiler 84%	$250.00
Furnace 92%	$225.00
Programmable Thermostat	$10.00
Water Heater - Tankless (0.82 EF)	$450.00

Home Performance Rebate with Energy Star

Take a whole-house approach to energy savings and home improvements. This program is ideal for homeowners who need to make multiple improvements to their home. You can receive expert home efficiency improvements – and up to $1,200 in rebates.

PROGRAM REQUIREMENTS

To participate, you must:

- Be a combined residential natural gas and electricity customer of Xcel Energy in Minnesota.
- Complete a Standard Audit ($60 fee) or Standard Audit with Infrared audit ($100 fee).
- All improvements must be completed by an Xcel Energy Participating Installation Contractor (PIC).
- Implement at least three required **and** two optional improvements (see back of this sheet).
- If the attic has a pre R-value of 20 or less, it must have a post R-value of 44 or greater;
- If the attic has a pre R-value greater than R-20, the installer must add at least R-25.
- Customer invoices/receipts must be dated *after their audit date* and *after the date of sign up* for the Home Performance program.
- Customers must meet all program requirements to be eligible for any of the Home Performance rebates.
- Customers are not eligible to receive rebates from Home Performance and other Xcel Energy programs for the same improvement.
- Program is contingent on availability of funds and could be terminated at any time.
- Rebates are issued after our partner, The Neighborhood Energy Connection (NEC), verifies that the improvements were done properly and then processes your rebate paperwork.

Note: If you have already earned a rebate through a different Xcel Energy program, you cannot receive another rebate for the same improvement.

FOUR EASY STEPS:

1. Sign up for the program by calling our partner, Neighborhood Energy Connection (NEC), 651-221-4462 x136. You may also sign up through email: mailto:info@thenec.org.

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3. Call NEC at 651-221-4462 ext.136 after the improvements have been installed, and they will come to inspect and verify that the improvements have been completed.

4. NEC will collect your receipts and submit your rebate paperwork for you.

MINNESOTA

HOME ENERGY AUDIT REPORT

REQUIRED ENERGY CONSERVATION IMPROVEMENTS	REBATE
o Air Sealing/Weatherstripping	20% up to $60
o Attic Insulation – Must choose a contractor from the Participating Contractor List. – If existing R-value is 20 or less, must increase to R 44 – If existing R-value is 21 or more, must increase by R 25	20% up to $350
o Up to 20 High Efficiency Lights (CFL's) – Can be pre-existing in the home*	$2/bulb up to $20
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CENTRAL AIR – Must choose a contractor from the participating list	
o AC 14.5 SEER	$250
o AC 15 SEER	$350
o AC 16 SEER	$475
APPLIANCES – Must be ENERGY STAR qualified	
o Clothes Washer	$50
o Dishwasher	$15
o Refrigerator	$15
CONVENIENCE ITEMS	
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HEATING – Must choose a contractor from the participating list	
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