Cognitive Barriers to Energy Efficient Decision Making in US Coast Guard Facility Management

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science

In

Civil Engineering

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7 Dec 2016
Blacksburg, VA

Keywords: facility management, government, energy reduction, cognitive bias, choice architecture

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ABSTRACT

Government agencies have attempted to reduce energy consumption using executive orders, mandates, and agency policies. Despite these efforts, overall energy consumption of government facilities has not experienced significant energy reductions. Why haven't these efforts succeeded? The premise is that energy consumption decisions and their unintended outcomes contribute to this problem, and in this manuscript research focuses on cognitive bias, choice architecture, and decision making in relation to energy decisions answer this question. Potential impacts cognitive bias has on the decision maker is examined, and if it is possible to design better decision environments to account for cognitive bias and help decision makers maximize benefits (utility). This manuscript first examines the literature of cognitive bias, choice architecture, and government energy management, especially how these topics relate to meeting the country's energy goals. The next chapter examines cognitive bias that government facility managers encounter using qualitative analysis. In this study, the research indicates facility managers encounter loss aversion, risk aversion, choice overload, and the status quo bias during energy decisions. The last chapter examines applications of choice architecture, specifically attribute framing, to emphasize the utility maximizing choice of long term energy reductions over initial cost. This study found that decision makers did not see the utility of the energy efficient option without an intervention to draw their attention to the long term savings. Once the decision makers became aware of the potential savings, they chose the most efficient (and utility maximizing) option.

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GENERAL AUDIENCE ABSTRACT

Government agencies have attempted to reduce energy consumption using executive orders, mandates, and agency policies. Despite these efforts, overall energy consumption of government facilities has not experienced significant energy reductions. Why haven't these efforts succeeded? The premise is that energy consumption decisions made by facility managers, and their unintended outcomes, contribute to this underestimating of energy savings. This manuscript research focuses on how decisions can vastly effect energy efficiency, and how the structure of decisions can assist facility managers to make decisions which result in energy efficiency. This manuscript first examines the literature decision making in government energy management. The next chapter examines cognitive bias, which inhibits decisions that maximize benefits, that government facility managers encounter using interviews and survey results. In this study, the research indicates facility managers would rather avoid a loss of revenue than risk a potential gain in revenue, and are overwhelmed by the options of energy efficiency products and services available. The last chapter examines how to make the decisions easier for facility managers, by drawing attention to the benefits of long-term energy efficient products and services over initial (high) costs of products and services. This study found that decision makers did not see the benefit of the energy efficient products and services without an intervention to draw their attention to the long-term savings. Once the decision makers became aware of the potential savings, they chose the most efficient option.

ACKNOWLEDGEMENTS

I would like to wholeheartedly thank my advisor Dr. Tripp Shealy. His knowledge and encouragement to explore new and different ideas, and genuine desire for positive change, greatly assisted my efforts and enhanced my work. His generous availability, feedback, and mentorship instilled in me a deep appreciation for research, and a desire to continue down this path of behavior science. I greatly look forward to applying the lessons I have learned working with him to my professional career.

Additionally, I would like to thank my committee members, Dr. Annie Pearce and Dr. Michael Garvin. Their feedback on my proposal greatly improved my final thesis, and their mentorship throughout this process has been essential to any success I have had at graduate school.

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INTRODUCTION

In 2008, a study was done by a professor at the University of Wisconsin-Madison and the US Navy to examine the energy compliance of newly constructed Navy buildings certified LEED silver or better. Executive Order 13423 mandated that all new government construction had to achieve at least LEED silver certification, and agencies must reduce energy consumption by 30% by the year 2015. The objective of the study was to determine if the US Navy LEED certified buildings achieved the goals set forth by EO 13423. Surprisingly, this research team found that out of the eleven LEED buildings examined, nine of these buildings did not achieve 30% reduction in electricity, and when the LEED buildings were compared to buildings of similar construction but without any LEED certification, they actually used more electricity (Menassa et al. 2011).

While the reasons for these perplexing conclusions aren't immediately apparent, we can generally understand the idea that despite best efforts, energy reductions have been baffling engineers and researchers for the past 30 years. Efforts to adhere to standards do not indicate success in reaching these benchmarks. What can be done? This idea will be explored in the following chapters as the growing field of behavior science and choice architecture is explored, potential of these less than conventional methods to help us achieve our energy reduction goals is demonstrated.

Current State:

The US Coast Guard wants to reduce energy usage and greenhouse gas emissions (Alford 2015), but is currently missing greenhouse gas (GHG) emission goals by 17%. This is because the US Coast Guard facility managers encounter a complex decision environment due to the delicate balance of multiple command control measures, a budget-centric culture, shrinking resources, increased facility ownership, and growing administrative responsibilities. This decision environment results in decisions where the potential outcome for energy efficiency is unclear and thus risky for the facility manager.

We respond to risk and uncertainty by acting conservatively, whereas if we have already experienced loss, we are more likely to take risks in our decisions to recap some of those losses (Kahneman and Tversky 1979). Cognitive bias explains many of our decisions under risk, especially when there exists a potential for loss. The following chapters will attempt to demonstrate that risky decisions effect Coast Guard facility managers, and that understanding how risk and loss affects our decisions may help us design a decision environment friendlier to the participant.

Objectives:

The following chapters explain behavior science and choice architecture, and demonstrate examples where these aspects effected decisions in other fields. This manuscript researched and tested Coast Guard facility managers specifically on the effects of risk on their decisions, by using decision scenarios and attribute framing on engineering students. Additionally, potential cognitive bias that impact CG facility managers are identified, which may result in designing better choice environments for energy reductions.

The contribution of this study is to assist facility managers in their organization so that the decisions they make can result in substantial energy reductions. Additionally, if we can begin to show how a better decision environment could effect facility managers, this could be applied beyond the facility manager to the user, owner, and other stakeholders.

Layout of Chapters:

The following chapters are organized as such: Chapter 1 is a literature review of the current body of knowledge in the field regarding cognitive bias and facility management. Chapter 1 extensively reviews research on cognitive bias, risk, loss, and tools of choice architecture to help overcome the aforementioned decision barriers. Chapter 1 also introduces us to government facility management, the challenges that facility managers encounter, and their potential impact on energy consumption.

Chapter 2 is a research paper focused on identifying cognitive bias in facility managers' decisions. Chapter 2 explains the role of the Coast Guard facility manager, their challenges, and attempts to answer the question: how can energy efficient decisions be made easier for the facility manager? Facility managers were surveyed and interviewed to determine if their decisions are bounded by their response to loss and risk.

Chapter 3 is a research paper focused on framing the energy scenarios to emphasize the benefit of long term savings over short term losses. In this study, we predict that framing outcomes and gains in energy savings can overcome potential losses from the initial cost of the energy product. Engineering students were given scenarios to test their responses to energy questions without framing effects, and with framing effects to focus on long term savings.

LITERATURE REVIEW PAPER--Opportunities for Greater Energy Efficiency in Government Facilities by Aligning Decision Structures with Advances in Behavioral Science

Intended Outlet for Publication:

Renewable & Sustainable Energy Reviews

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Abstract

In 2007, Executive Order 13423 mandated 30% energy and emission reductions for all government facilities by 2015. Unfortunately, the government fell short of their goal by 9%. Their approach through mandates and federal legislation focused predominantly on new construction and major retrofits to existing facilities. To meet future energy and emission reduction goals, more emphasis on facility management will be encouraged. The government manages over 370 million square feet of facilities each year. The daily decision process for government facility managers is full of competing interests, such as maintenance needs (preventative and corrective), limited operating budgets, time constraints to make decisions, and bounded rationality about energy consumption and savings. By understanding how these decisions are made and the cognitive bias that may occur, advances in facility management decision making can be made to reduce energy consumption. Cognitive biases to the decision making process such as loss aversion, anchoring, and status quo bias, and present one approach to overcome them through restructuring the decision environment, a tactic called choice architecture. Examples of choice architecture, such as, enabling procurement systems to query green products, changing default settings in mechanical systems, and requiring the use of pay back period calculators to account for cognitive limitations of the decision maker, are suggested and supported by behavioral science research to help direct facility managers towards energy efficient choices. This approach, through choice architecture, holds potential to yield relatively low-cost solutions (they do not require new mandates or laws) to support greater energy reduction in government facility management. This merging of literature from behavioral science to facility management is meant to open new avenues of interdisciplinary research.

1.1 Introduction

The federal government is the largest user of electricity and fuel in the country, accounting for 1.5% of the nation's annual energy consumption (EIA 2014). In 2007, Congress passed legislation to reduce its energy use 30% from 2003 levels by 2015 (Rahall 2007). New programs for facility management like Freeze the Footprint (EIA 2014) were enacted and major retrofits to existing facilities were completed (Menassa 2011). Unfortunately, the federal government fell short of their goal by 9% (EIA 2014). Today, federal agencies continue to pursue measures to reduce energy consumption through new executive orders (e.g. EO 13514) and recognized financial incentives (EIA 2014). However, in spite of these efforts, buildings still consume 34% of all the energy used by the government (EIA 2014), partially because many government facilities are old and not built with efficiency in mind. In addition, major retrofits completed during Executive Order 13423 are not as efficient as expected (Menassa 2011). This paper explores the decision making process and potential cognitive biases that prevents greater energy reduction to enable the government to meet its future goals.

The focus of this paper is decisions made during the operations and maintenance phase of government facilities, because buildings consume more energy during the operations and maintenance phase than during any other life cycle phase (Wu et al. 2012). Also, government facility managers face constant and significant challenges to energy reduction decisions. For example, government facility managers typically transition jobs, on average, every three years, which could lead to myopic decisions that discount future return on investments. These same managers are lauded during yearly job evaluations for reducing operation budget expenditures, possibly deterring the purchase of more expensive products that save energy over time. Additionally, during retrofits, facility managers are frequently not part of the design team making the decisions that influence daily operations and maintenance and related energy use (Hodges 2005).

The paper begins with an overview of government energy decisions and the role of facility management. The purpose of this section is to illustrate the gap in research related to behavioral and decision sciences to better inform facility managers' decisions about energy. The next section provides the theoretical perspective of how decisions, of all types, are made. The premise is decision makers do not always have the appropriate time and information to make the best decisions, and choices should be structured to account for these shortcomings. The third section introduces cognitive biases relevant to facility management. This includes how cognitive biases impact various fields from law to engineering and how to improve decision making through an approach called choice architecture. The final section offers opportunities for choice architecture within government facility management to aid in decision making for future energy reduction. The purpose of this review is to expose new avenues of research related to decision making for energy reduction. The focus here is specifically about government facility management, but the concepts and theories are applicable to many sectors.

1.2 Government Facility Management and Energy Decisions

To explain how government employees make decisions about energy, decision tools and policies are split into two categories: market-based and command control processes. The market based instruments are programs that produce rebates for energy efficient products and induce pollution charges, taxes, and permits that regulate energy and environmental harm (Jaffe et al. 2002). Command control instruments are items that force the government to enact regulations by setting performance and technology standards (Jaffe et al. 2002). Command control measures are intended to be carried out regardless of cost. Listed in this section are a mix of decision support tools that represent both market based approaches and command control measures for energy efficiency and facility management by the government.

1.2.1 Executive Orders

Executive orders (EO) act as command control measures for decision making. Enacted in 2007, EO 13423 required a 30% reduction in energy consumption in all federal government buildings by 2015 (*Exec. Order No. 13423* 2007) and more recently EO 13514 pushed for strict energy measures by 2020, including greenhouse gas emission reductions. EO 13514 was recently replaced by EO 13693, which calls for a 2.5% annual decrease in energy intensity until the end of fiscal year 2025 (*Executive Order (EO) 13693* 2015), as seen in Table 1.1.

Table 1.1: Executive Orders that Mandate Energy Efficiency

Executive Order	Energy Mandate	Status
EO 13423	30% energy reduction in government buildings by 2015	Short of goal by 9%
EO 13514	Meet GHG emission reduction goals 1&2 by 2020*	Replaced with 13693
EO 13693	2.5% annual decrease in energy until 2025	Current

GHG 1 & 2: Reduce GHG emissions by 25% relative to a 2008 FY baseline (Alford, 2015).

The problem of command control measures like EOs is that firms often place more consideration on meeting the mandate and less importance on long term benefits due to the uncertainty of determining future gains (Hassett & Metcalf 1995). Contract firms often believe the best way to achieve these mandates is to adopt a new technology, which can disproportionately add to the delivery cost of the project (Jaffe et al. 2002). While EOs help reduce energy consumption, they alone are not enough (seen in Table 1.3) to meet the large energy reduction goals set by the government. Market based approaches are also needed.

1.2.2 Leadership in Energy and Environmental Design

An example of a market based approach is the rating system Leadership in Energy and Environmental Design (LEED). LEED certified buildings lease for a higher price per square foot and at a higher occupancy rate (Blumberg 2012; Dermisi 2009) suggesting a demand in the market for more sustainable buildings. The government also mandates that all newly constructed government owned facilities meet at least LEED Gold certification ("LEED Building Information" 2016; Menassa et al. 2011). However, LEED as a decision support tool may result in anchoring on required mandates leading to lower energy performance in buildings (Klotz et al. 2010). Likewise, just certifying a government building with LEED does not equivocally correlate with increased energy efficiency (Scofield 2009, 2013). In fact, energy consumption in 9 out of 11 US Navy LEED certified buildings did not meet the required 30% energy reduction mandated by EO 13423. These buildings consume more electricity than the national averages published by the commercial building energy consumption survey (Menassa et al. 2011).

Even if LEED could guarantee energy reduction, the number of government facilities already online and not retrofitted are considerably more than the number of new or recently retrofitted government buildings. Therefore, small, day-to-day facility level decisions hold potential to influence a large number of buildings unaccounted for by LEED. Day-to-day facility maintenance decisions involve preventive maintenance, corrective maintenance, and in some cases, deferred maintenance (Chandrashekaran & Gopalakrishnan 2008). The majority of these maintenance items involve electrical, mechanical, and structural elements of the facility. This includes procurement decisions as related to the operations and maintenance of the facility (United Nations Environment Programme (UNEP) 2007). Facility managers are responsible for decisions about what parts to replace, which appliances to purchase, and in what order. These decisions range from $200,000 HVAC systems to $10 light bulbs. The next section describes the many mandates that currently affect product purchases in the federal government.

1.2.3 Government Facility Management Mandates

Information about product purchases in the federal government is disseminated amongst different acts and statutes that can be confusing and difficult to implement. For example, there are ENERGY STAR purchasing requirements for energy related products and services (*Energy Policy Act of 2005* 2005). There are requirements to purchase premium efficient motors for devices with electric motors up to 500 horsepower. There are also requirements to purchase alternative or synthetic fuels, which stipulates that agencies compare greenhouse gas emissions when using conventional types of fuel (Rahall 2007).

There are also dozens of mandates governing building energy use buried within U.S. energy code. There are mandates which involve building energy intensity reduction for agencies to reduce intensity in existing buildings, conduct better facility assessment benchmarking, improve evaluation of systems, improve training for facility managers, reduce energy use in leased buildings, evaluate new construction agency procedures, and monitor energy for contractor operated facilities. Additionally, there are requirements for energy efficiency, life cycle costs, net zero, fossil fuel reduction, metering, and renewables (*Energy Policy Act of 1992* 1992, *Energy Policy Act of 2005* 2005, *Exec. Order No. 13423*2007; Rahall 2007).

These mandates are in place to help the government meet over-arching goals of reducing greenhouse gas emissions. But when it comes to government employees making decisions, identifying and complying with every command control measure can become cognitively overwhelming. There is an opportunity to better align advances in behavioral sciences to reduce the cognitive burden, making decisions about energy efficiency easier for facility managers.

1.2.4 Facility Management Literature Review

Much of the literature devoted to facility management focuses on sustainable needs, reducing risk, and uncertainty that contributes to ineffective project management (See Table 1.2). The solutions presented in the literature frequently involve increased public participation, training, and new policies for environmental protection (Khalil et al. 2011). However, when facility managers attempt to meet energy reduction demands and mandates from the government, the uncertainty in products and effectiveness can lead to more risky decisions, not less (Hassett & Metcalf 1995). Table 1.2 provides a summary of research about facility management decision making. This list is not exhaustive, but indicative of the research found that pertains to this study of facility management decisions about energy. Note both the lack of distinction in papers between government and private facility management and the lack of research connecting facility management to behavioral sciences.

Behavioral science research can help explain how cognitive biases influence decision making. For example, the EOs increase the risk of decision making by stipulating a LEED score which acts as an anchoring bias for facility managers. Additionally, the sorts of risks facility managers encounter in regards to sustainability are well researched but solutions to best correct them are often not provided (Hodges 2005; Jackson 2010; Khalil et al. 2011; de Zwart 1995). Facility managers, for example, cannot make energy reduction decisions appropriately if they do not consider long term costs – inadvertent loss aversion in facility management which prevents energy savings (Hodges 2005). Another example, facility managers have the potential to reduce energy consumption but are often cut out of the conversation resulting in decisions that do not maximize utility due to imperfect information (bounded rationality) during design and construction.

Table 1.2: Gap in Research Connecting Behavioral Science to Facility Management Decision Making

	Behavioral Science	Procurement	Innovation	Energy Efficiency	Risk
Chandrashekaran & Gopalakrishnan, 2008		X		X	
de Zwart, 1995			X		
El-Haram & Agapiou, 2002		X	X	X	X
Hodges, 2005		X		X	X
Jackson, 2008	X	X		X	X
Khalil et al, 2011				X	X
Perrenoud et al., 2014		X		X	X
Pitt & Tucker, 2008		X	X	X	X

The next section provides a theoretical perspective that is then applied to energy decision making for facility managers. The premise is that facility managers, like other decision makers, are bounded by rationality and prone to errors during decision making, which leads to less than optimal (at times irrational) outcomes.

1.3 Utility to Prospect Theory

Utility theory states decision makers select goods or services that meet their highest preferences. However, utility theory is not always consistent with observed behavior (Kahneman & Tversky 1979). Decision makers do not always understand the outcome of each choice (Simon 1957) and therefore, at times, choose options with less than optimal outcomes (Friedman 2002).

For example, providing too much information can overwhelm a decision maker leading to decision paralysis, a cognitive barrier called choice overload (Iyengar & Lepper, 2000; Johnson et al. 2012; Madrian and Shea 2000). Indeed, reducing the number of choices for a decision maker, opposite of what utility theory would recommend, can increase decision makers' satisfaction (Iyengar and Lepper 2000). Cognitive errors like choice overload in utility theory are numerous because cognitive and environmental barriers restrict rational choice, known as bounded rationality. These barriers abound, including lack of information and cognitive processing ability, (Simon 1955) and conflicting short term gains with long term benefits (Benartzi and Thaler 1993).

When decision makers are faced with alternatives that involve risk and the probabilities of outcomes are unknown, prospect theory can predict decision outcomes that utility theory fails to consider (Kahneman and Tversky 1979). Decision makers often downplay outcomes that contain risk and overly weigh outcomes that include certainty (Kahneman et al. 1991; Kahneman and Tversky 1979). This is because potential losses provoke greater degrees of discomfort than potential gains provide satisfaction (Kahneman and Tversky 1984; Schwartz 2000). To overcome a potential loss, the gain must be roughly twice as great (Benartzi and Thaler 1993). Decision makers, however, are not always risk averse. If a decision maker recently experienced a loss, the amount of risk they are willing to accept increases, in hopes to return to net zero or positive outcome (Tversky and Kahneman 1981).

Prospect theory explains why homeowners selling in a down market may insist on a higher asking price (Genesove and Mayer 2001), why investors sell profitable stocks too soon and retain losing stocks too long (Odean 1998), and why consumers generally hold failing assets longer than winning assets (Carmon and Ariely 2000; Cummings et al. 1986; Knetsch 1989).

Prospect theory is applied to make accurate predictions about risk seeking or averse behavior in politics (Patty 2006), international relations (Berejikian 2002) and public support for military intervention (Nincic 1997). Framing military involvement as a protective mediation to avoid geopolitical loss (i.e. framing to avoid loss) is viewed more favorable by the general public than a proactive intervention explained as benefiting foreign policy (i.e. framing to gain) (Nincic 1997).

Framing choices as losses or gains in value is often more influential in decision making than the resulting end point (Kahneman and Tversky 1979) because even when two presentation formats are formally equivalent, each may give rise to different psychological processes (Thaler et al. 2010). Decision makers do not immediately know the right choice, but rather perform an informal reasoning process referred to as preference construction. For example, medical patients given a choice between surgery or radiation preferred surgery when described as having a 90% survival rate. However when the surgery was described as having a 10% mortality rate the preference for surgery was much lower (McNeil et al. 1982).

The same type of preference construction is likely true for facility managers about energy. Framing effects that over emphasize immediate rather than long-term savings may lead to sub-optimal decisions. The next section expands on cognitive biases that prevent rational choice: loss aversion, endowment effect, choice overload, discounting, status quo, anchoring, and heuristics in decision making. These cognitive biases are presented because previous research across disciplines, with various demographics and scenarios, conclude similar findings. The list of cognitive biases based on prior literature also relate to energy decisions. This list is not comprehensive due to the expansive, and growing, body of literature about cognitive biases. The review focuses on seminal works that led to advances in behavioral science. The list is meant to illustrate the vast research opportunity to improve energy related decisions for government facility management.

1.4 Cognitive Biases

The following section summarizes how cognitive biases affect people in all fields and professions. There are many cognitive biases, such as extremeness aversion (Houde and Todd 2010), reciprocity (Gneezy et al. 2003), alternative overload (Cronqvist and Thaler 2004), naïve allocations (Fox and Langer 2005), among many others. Table 1.3 is not extensive but rather based on selected biases that appear well defined, occur in overlapping fields with regularity, and are deemed relevant to facility management. For more extensive lists and descriptions of cognitive bias in energy see (Gillingham et al. 2009), (Houde and Todd 2010), and (Wilson and Dowlatabadi 2007); about infrastructure see (Shealy and Klotz 2014), and for other general lists see (Johnson et al. 2012) and (Sunstein 2013).

Table 1.3: Select Cognitive Biases

Cognitive Bias	Definition	Relevant Literature
Loss Aversion	To avoid loss; loss provokes greater degrees of discomfort than a win provides satisfaction.	(Benartzi & Thaler, 1993; Kahneman & Tversky, 1984; McGraw et al., 2010)
Endowment Effect	Placing more value on goods or services owned than non-owned.	(Knetsch, 1989; Kahneman, Knetsch & Thaler, 1991)
Choice Overload	Overwhelming the decision maker with too many choices.	(Johnson et al., 2012; Cronqvist & Thaler, 2004; Schwartz, 2014)
Discounting the future	Evaluation of options based on immediate gain rather than long term gains.	(Shamosh & Gray, 2008; Shiv et al., 2005; Weber et al., 2006)
Status Quo Bias	When overwhelmed or lacking time, the decision maker overly weights previous decisions to inform current decision.	(Kahneman, Knetsch & Thaler, 1991; Samuelson et al., 1988)
Anchoring Bias	Rely on previous information (the anchor) to make current decision.	(Klotz, 2010; Jacowitz & Kahneman, 1995; Tversky & Kahneman, 1974)

Heuristics	Decision short-cuts when faced with difficult choices (i.e. 'rule of thumb').	(Beamish and Biggart, 2012; Tversky & Kahneman, 1974)

1.4.1 Loss Aversion

Losing something of value provokes more discomfort than a gain of something equal in value provides satisfaction (Tversky and Kahneman 1991). Loss aversion is a decision maker's tendency to avoid options that would result in loss (and associated discomfort). Loss aversion is prevalent when situations could result in certain or probable loss. In these scenarios, decision makers generally prefer options with certainty not to lose (Kahneman and Tversky 1984).

To address the consequences of loss aversion when making policy decisions, researchers suggest bundling policies together that involve both losses and gains to offset costs while maintaining their net benefits (Milkman et al. 2012). Another real world example of loss aversion influencing motivation is teachers given a monetary bonus in advance and asked to give back the bonus if their students did not improve test scores, which led to a greater increase in scores compared to when teachers were promised the same bonus but not given the money upfront (Fryer et al. 2012).

1.4.2 Endowment Effect

The endowment effect occurs when decision makers over emphasize the value a good or service as compared to the market value (Kahneman et al. 1991). Often, endowment effect is explained by the disparity between the willingness to accept (WTA) and willingness to pay (WTP) behaviors that consumers display. Buyers tend to focus on their sentiment to forgo the good or service while sellers focus on the benefits of retaining the item. The WTA is generally twice as great as the WTP (Kahneman et al. 1990); although, it can be as much as 14 times greater depending on how much attention is drawn to the benefits of possessing the good or service (Carmon and Ariely 2000). The seminal study on the endowment effect gave a group of students a coffee cup and another group a candy bar and asked both groups if they would like to trade for a candy bar or coffee cup. In both exercises, approximately 90% chose to retain their original object, suggesting the value of the object they owned was greater than that of the object up for trade (Knetsch 1989).

1.4.3 Choice Overload

A commonly held belief is that happiness increases with the number of choices available, which is true in some scenarios (i.e. having more than one car option to purchase, or more than one college to attend). More options present more opportunities for the consumer's needs to be met, but too many options can create a cognitive burden for the decision maker because each option must be considered (Schwartz 2004). A familiar example is a restaurant menu with too many dinner options. Reviewing all of the options requires more time to make a decision. Decision makers can feel dissatisfaction and regret with their choice as a result of too many original options (Iyengar and Lepper 2000). Balancing the number of choices with decision makers' preferences can improve not only decisions about food purchases, but more serious decisions such as financial investments (Cronqvist and Thaler 2004).

1.4.4 Discounting the Future

Discounting the future explains why eating healthy foods to prevent disease, saving money for retirement, and using energy efficient products are difficult to implement (Weber 1997). Delayed benefits are processed as losses and accelerated benefits are processed as gains (Hardisty and Weber 2009).

Discounting the future prevents immediate action on long term challenges like climate change (Messner and Weinlich 2015). Action to prevent climate change is asymmetric, with high, certain upfront costs and delayed, probabilistic benefits. Future damages of climate change have almost no effect on current decisions (Karp 2005). To aid in such decisions about climate change, researchers suggest to place both options in the distant future rather than only one option. For instance, $100 now or $105 in a year, most decision makers will choose the immediate option but if the choice is between $100 in 20 years or $105 in 21 years the cost of waiting an additional year does not seem as great. For climate change, this means that polices that force future greenhouse gas restrictions are easier to adopt than current restrictions (Karp and Tsur 2011).

1.4.5 Status Quo Bias

In any decision, there is typically the option to take no action, to remain at the current state or unchanged status. Consider the fact that incumbents usually win elections, consumers consistently buy the same toothpaste brand, or a company maintains a policy using the rationale 'that's how it's always been done' (Eidelman and Crandall 2012). This is known as status quo bias, the fact that decision makers are not likely to override current decisions and are likely to implement past strategies (Samuelson and Zeckhauser 1988).

In fact, loss aversion can reinforce the status quo bias because the risk of loss due to change can be unattractive to the decision maker (Kahneman et al. 1991). Samuelson and Zeckhauser (1988) conducted an experiment by presenting participants a financial situation, where participants had inherited a portfolio from a family member. The majority of participants preferred keeping the status quo investment option over making a change. Similarly, status quo bias may influence government facility management decisions where institutional barriers reinforce previous choices (Beamish and Biggart 2012).

1.4.6 Anchoring Bias

Anchoring bias occurs when decision makers choose options based on previously established standards, despite its significance (Jacowitz and Kahneman 1995; Strack et al. 1988). Anchoring bias is prevalent in estimation tasks, even if people are given arbitrary anchors. In one example, a number wheel (0 to 100) was rigged to select either 10 or 65. When the wheel was spun, participants were asked to estimate the number of African countries in the United Nations by moving upward or downward from the number selected by the wheel. For groups that landed on 10, their estimate was about 40% less than the group given the anchor of 65 (Tversky and Kahneman 1974). Similarly, random anchors can affect engineering decisions about energy in buildings. Simply anchoring decision makers to a random but high number led to an increase in perceived achievement in LEED rating system from building professionals (Klotz et al. 2010)., demonstrating that their estimations can be greatly skewed (Jacowitz and Kahneman 1995).

1.4.7 Heuristics

Heuristics are shortcuts that decisions makers can take when presented with complex choices. These are often described as “rules of thumb,” decisions based on experience (Gigerenzer 2007), and intuition (Dijksterhuis 2004; Newell and Shanks 2014). Heuristics are categorized by representative and availability mental models. Stereotypes are an example of representative mental model (Gilovich and Savitsky 2002) and past experiences are an example of the availability model (Gilovich et al. 2002; Schwarz et al. 1991). Errors in decision making occur when either model does not align with reality. For example, assuming a business venture will fail, simply because other similar businesses have failed is a symptom of availability heuristics, which can lead to quick judgments and wrong decisions (Gilovich et al. 2002). Smart structuring of decision environments can better anticipate when heuristics, or other cognitive biases, are likely to be used and help correct for them if needed. The next section explains one approach to account and correct for these cognitive biases.

1.5. Accounting for Cognitive Biases in Decision Making

Choice architecture is a method used to account for cognitive biases and improve decision making. The principle of choice architecture is that decisions can be structured to focus decision-makers on the information that matters most. For example, when presented with miles per gallon (mpg) metric, consumers wrongly assume that increases in mpg have a linear effect in fuel use and CO_2 emissions, suggesting that an increase from 10 to 20 mpg has the same benefit as going from 40 to 50 mpg. However, this is not true. The shift from 10 to 20 mpg reduces fuel use by 50%, whereas from 40 to 50 mpg, fuel use is reduced by only 20%. Restructuring the information as a linear metric, such as gallons per mile, improves decision makers ability to pick the most efficient option (Larrick and Soll 2008). Similar choice architecture, that more closely aligns decision structures with psychological processes, is improving fields from medicine (Johnson and Goldstein 2003) to finance (Fox and Langer 2005), to insurance (Johnson 1993).

The objective is to illustrate the possible advances to reduce energy consumption in government facilities by connecting choice architecture literature to decision making for facility management in the government. The choice architecture approaches, listed in Table 1.4, are those that appear relevant to facility management. These approaches were chosen because of the breadth of results from different fields with overlapping results. By no measure, is this list exhaustive, for more information see (Johnson et al. 2012).

Table 1.4: Select Choice Architecture That Appear Relevant to Decision Making in Facility Management

Choice Architecture	Example	Relevant Literature
Defaults	Automatic choices, such as automatic 401k enrollment for new employees.	(Cronqvist & Thaler, 2004; Johnson et al., 2005; Weber & Johnson, 2009; Johnson et al., 2012; Sunstein, 2013)
Framing	Presentation of information, such as saying yogurt is 20% fat free versus 80% fat.	(Gillingham, 2009; Johnson, 2009; Kahneman & Tversky, 1981)
Reducing Choices	Narrowing options, such as giving seniors 3 Medicare options instead of hundreds.	(Johnson et al., 2012; Schwartz, 2014)
Labeling	Using visual aids to make information easier to process, such as ENERGYSTAR labels on appliances.	(Johnson et al., 2012; Peters et al., 2009)

1.5.1 Defaults

Defaults influence decision making in three ways: creating a reference point, providing an endorsement, and reducing effort to make a decision (Dinner et al. 2010). Creating a reference point frames other outcomes as a loss or gain and this framing impacts the decision (Dinner et al. 2010). Car buyers first shown the “fully loaded” package perceive lesser models as having missing features. Meanwhile, car buyers first shown the base model perceive those same features as add-ons (Park et al. 2000). Providing an endorsement means decision makers perceive the default as the recommended option because it is the most commonly chosen or fits within the social norm (Brown and Krishna 2004; McKenzie et al. 2006). Organ donation rates are twice as high when the default option is to be a donor (opt-out) compared to non-donor default, likely because the default endorses a social norm (Johnson and Goldstein 2003). Effort references the cognitive energy exerted to make a decision. Sweden implemented a default social security savings program and after 4 years 92% of people in the program were using the newly created default plan and saving more money than managing their funds on their own. The default option reduced the effort required to pick a program, and likely also provided an endorsement (Cronqvist and Thaler 2004).

1.5.2 Framing

Framing is presenting the same information but in a positive, negative, or neutral tone. There are two types of framing: attribute and goal framing (Heath et al. 1999; Krishnamurthy et al. 2001; Levin et al. 1998) . The difference between attribute and goal framing is the object being highlighted. In attribute framing, the frame is focusing on the characteristic of an option or choice. The example presented earlier about describing the success rate of surgery as positive (90% survival rate) or negative (10% mortality rate) is an example of attribute framing. Attribute framing is usually more effective when framed positive (Levin and Gaeth 1988). Goal framing relates behavior to obtaining the goal (Heath et al. 1999). For example, framed positive, “If you get a mammogram, you take advantage of the best method for early detection of breast cancer” compared to a negative frame, “If you don’t get a mammogram, you fail to take advantage of the best method for early detection of breast cancer.” Surprisingly, attribute framing is most effective with a positive frame whereas goal framing is most effective as a negative frame (Krishnamurthy et al. 2001).

1.5.3 Reducing choices

Reducing the number of choices a decision maker must consider is an effective method to mitigate choice overload. Some states offer seniors over 100 choices of Medicare drug plans, which can be overwhelming. Removing options can increase the number of Medicare patients willing to make a decision and improve the outcome (Kling et al. 2008). There is not a clear and concise recommendation for the correct number of options for different decisions but the general rule is to include enough options that preserve the decision maker's values (Johnson et al. 2012).

1.5.4 Labeling

Labels provide a visual or graphical method for evaluation that is often beneficial when decision makers must otherwise process large amounts of numerical information (Peters et al. 2009). Decision-makers can consider more options when numbers are broken into categories, such as grades, or if they have endpoints labeled as poor or excellent. Labels also decrease the time of information processing by allowing effective responses to be accessed more quickly (Johnson et al. 2012). Newell and Siikmaki (2013) applied these techniques to increase consumer purchases of energy efficient household appliances. By modifying the appliance labels, they were able to nudge consumers towards energy efficient product options. Similar approaches are used to influence diet choices (Sunstein 2013), car choices (Schwartz 2000), and other forms of energy use (Wilson and Dowlatabadi 2007). For buildings, rating systems like LEED and Energy Star provide labels or categories such as Certified or Platinum. These labels can drive the decision process during design and construction (Corbett and Muthulingam 2007; Leland et al. 2015; Matisoff et al. 2015).

Defaults, framing, reducing options, and labeling are examples of passive interventions to the decision making process (Thaler and Sunstein 2008). Active interventions refer to mandates and policies as described in the previous section about government facility management. Both passive and active choice interventions can help overcome bounded rationality when making "upstream" decisions about civil infrastructure systems and energy use in buildings that require active tradeoffs with multiple variables and uncertain consequences. The next section summarizes recent advances connecting design engineering to behavioral science.

1.6 Cognitive Biases in Civil Infrastructure Systems and Building Energy Decision Making

Previous research in cognitive biases that influence civil infrastructure systems and building energy related decision making, are included as part of the conceptual merging of behavioral science and facility management. Only studies about decision making in these fields, grounded in behavioral science also relevant to industry are presented. This includes papers on energy efficiency, choice architecture, and cognitive bias. To begin, we will discuss the cognitive bias of loss aversion, status quo bias, anchoring and heuristics in decision making about energy and infrastructure.

In the same way loss aversion may influence gambling decisions, loss aversion effects engineering decision making about infrastructure. Simply re-framing points in rating systems for sustainability as a loss in achievement rather than a gain in achievement significantly improved engineers' consideration towards sustainability. Engineers endowed points in the Envision Rating System ("Envision™ Sustainable Infrastructure Rating System" 2012), and set a 15% higher goal for energy and water reduction than when no points were endowed (Shealy et al. 2016). Such an increase could drastically effect possible outcomes. For example, if endowed points for rating systems could be applied to all U.S. infrastructure, a 15% reduction in greenhouse gas emissions would result in a reduction of over 2 billion tons of CO_2 (Shealy and Klotz 2015). Of course, infrastructure decisions are subject to varying constraints, goals, and resources with different stakeholder schedules, agendas, mandates, and budget cycles. However, decisions about infrastructure are made in groups. A similar study investigates the effect of choice architecture on group decision making and found parallel results to individual decision making (Shealy et al. 2016). These results align with previous research that suggests experts are just as likely to be influenced by choice architecture interventions as novices are (Englich et al.

2006; Northcraft and Neale 1987).

Restructuring the decision environment can also reduce the effects of cognitive biases during contract structuring for infrastructure development. Status quo bias led to underestimating the project costs and overestimating financial returns on investment for a capital project between the Dutch Highway and Waterways Agency and a Dutch contractor. Redirecting biases towards improved performance instead of the price of managerial intervention helped remove the status quo bias which led to more realistic expectations and more opportunities for financial gains (van Buiten and Hartmann 2013).

Likewise, anchoring bias can surface during the design process for buildings. Professionals who help set energy performance goals for U.S. buildings were shown a series of questions helping them set either a 90% energy reduction goal or set one for 30% energy reduction goals. Participants exposed to the 90% anchor afterwards set higher energy performance goals than respondents exposed to the 30% anchor (Klotz et al. 2010). This is important because attainable goals may actually empower, or anchor, lower achievement. One method to help overcome low achievement are role model projects that exemplify high levels of sustainability. Engineering professionals presented with an example which scored high sustainability ratings set 34% higher goals for their own projects than those not presented with an example project (Harris et al. 2016).

Anchoring bias and status quo bias may be a result of heuristics to reduce complexity of decision making during engineering design and construction delivery. An observed heuristic is the default-design heuristic, a shared set of standards and practices that dictate a “good” building design. Default design can lead architects to repeatedly use templates, i.e. commercial buildings that are rectangular with windowed, executive offices around the perimeter (Beamish and

Biggart 2012). Related is the value-added heuristic, which means that designers may short-cut decisions to maximize the function and flexibility of the building (so that future owners can make use of it) over performance and profit. Another is a shared rule of thumb to maximize investment potential by designing the safest and most attractive investment option for owners (Beamish and Biggart 2010). These heuristics reduce coordination time, help maintain order among practitioners, and are reinforced by social accountability. However, these heuristics can become harmful when they are not shared by the client or project delivery team and can lead to wrong assumptions without proper communication and conscious consideration for how these assumptions influence project delivery (Gigerenzer and Selten 2002).

Building owners and occupants are also influenced by cognitive biases and heuristics. Information about energy efficiency is often presented in kilowatt hours, a unit that means little to the utility customer (Kempton and Montgomery 1982). In fact, even those knowledgeable of sophisticated energy equations did not use said methods, instead used simple monetary conversions considering pay back periods (Kempton and Montgomery 1982). Companies like Opower help customers realize their energy consumption by providing a benchmark to their neighbors (Allcott and Mullainathan 2010). By reframing the message from kilowatt hours to their neighbors energy use, Opower provided social pressure for change leading to over 6 billion kWh of electricity saved, equal to $700 million in cost savings (Laskey and Kavazovic 2010).

Social pressure through comparison, however, may not always be the correct intervention. Wilson and Dowlatabadi (Wilson and Dowlatabadi 2007) caution that great care must be taken when deciding what kind of intervention to use and that the intervention must address either the psychological or economic driver behind the behavior to effectively reduce energy consumption. The specific behavior (i.e. choice overload, loss aversion, heuristics) must align with the appropriate intervention (i.e. policy, framing, default) to influence behavior change.

Our list is by no means exhaustive of the methods to reduce cognitive biases to improve consideration for energy efficiencies. For more see (Chai and Yeo 2012; Gillingham et al. 2009; Wilson and Dowlatabadi 2007). The difference between these lists and our list is the focus on "upstream" decisions during design that appear susceptible to the same cognitive biases that influence consumers' decisions. Interventions that target facility managers may have a similar and complementary effect to help reduce energy consumption as interventions that focus on building occupants, infrastructure and building designers. The next section proposes new opportunities to employ choice architecture to influence facility management.

1.7 Opportunity for Choice Architecture in Facility Management

The purpose of this section is to illustrate the many opportunities for choice architecture that complement command control and market based approaches to reduce energy in government facilities. Ultimately the objective is to make similar advances in government facility management through choice architecture as seen in retirement savings (Goldstein et al. 2008), vehicle emissions (Larrick and Soll 2008), and others (Sunstein 2013). Given the opportunities for choice architecture, the examples below are meant to provoke consideration for more research, to encourage choice architecture approaches that accelerate energy reduction in government facility management decisions.

1.7.1 Reducing Procurement Choices to Energy Efficient Products

The procurement process for government facility managers is complex due to executive orders and institutional barriers that over emphasize upfront cost against long term savings

(Jackson 2008). This often leads facility managers to make decisions that are not the most sustainable (Jackson 2010). Using choice architecture to design a better choice environment via reducing choices or using defaults holds potential to better assist facility managers.

A successful example of utilizing defaults to assist in energy efficiency is the Department of Energy Waste Isolation Pilot Plant (WIPP). Reports showed that only 16% of WIPP purchases were "green products," indicating that the WIPP purchase program did not assist facility managers in making sustainable decisions. Managers had to select a product first to learn if the product was environmentally or sustainably better than other products, which hindered sustainable purchase. In response to E.O. 13514, (the goal to reduce GHG emissions by 2020 to a certain benchmark) the WIPP modified their procurement system to allow querying capabilities to better track progress, and added a field to indicate products with green alternatives (among other measures) (Dion 2012). The new field allowed decision makers to query just green and energy efficient products, which reduced the number of options and the cognitive burden to make a decision. To go further, the WIPP procurement systems could add energy efficient default options for products ordered most frequently, further promoting decisions that lead to energy savings.

1.7.2 Framing Energy Efficiency

Framing effects can help make energy efficiency decisions more favorable to the decision maker. The Federal Energy Management Program's (FEMP) Buy Energy-Efficient Products guide is designed to support federal buyers in the purchase of energy and water efficient products (Bunch 2016). Before a facility manager makes a purchase, they can check the FEMP guide, which also provides an energy and cost calculator. However, the facility manager must willingly check the FEMP guide, which adds an elective burden to the decision making process. Rather than expecting the facility manager to check the guide before making a selection, defaults and framing can be used to encourage the decision maker by including a question in the procurement form asking if the product meets FEMP standards. Another approach is to ask facility managers to list the return on investment using the FEMP calculator, forcing the cognitive effort rather than leaving the decision maker with an elective burden. Including these elements may help shift the emphasis from short term savings to long term savings both in energy and financial cost.

1.7.3 Benchmarks and Feedback Loops that Expand Bounded Rationality

By introducing feedback loops and benchmarks, the decision maker is assisted in making decisions when they don't have all of the necessary time and information to make the utility maximizing decision. A naval base in San Diego reduced their energy consumption through an energy feedback program centered on gathering energy information and distributing that information monthly. Energy cost and consumption of the current month was compared to the same month in the prior year and displayed in relation to year-to-date data. The reports were e-mailed to over 40 ships and departments (Dion and Duke 2012). The feedback approach creates a benchmark that helps to better assess energy reduction.

1.7.4 Default HVAC Temperatures

Defaults need to make sense in the physical and workplace contexts in which they are used; a single default setting may be inappropriate for an entire building or organization. For example, the same temperature setting may result in different levels of comfort on north versus south facing sides of buildings or in workspaces where occupants are sedentary versus active. Facility managers could widen the temperature range and give occupants control. Occupant control and varying default energy settings across building zones leads to overall lower energy demand, higher staff satisfaction, and ease of operation (Kemp-Hesterman et al. 2014). The U.S. Postal Service enacted a similar default change by making the off position the default setting for their mechanical heating and cooling systems in unused indoor spaces, saving nearly $41 million (Dion and Shiof 2012).

1.8 Conclusion

The government currently uses policy and mandates to improve energy efficiency in facilities, with relatively little implementation of behavioral science research (Sunstein 2013; Thaler and Sunstein 2008). Opportunities exist for government agencies to adopt choice architecture as a method to encourage and meet energy reduction goals. Increased awareness of cognitive biases, plus the implementation of choice architecture, is leading to advances in engineering for sustainability (Shealy et al. 2016), and energy reduction in residential buildings (Wilson and Dowlatabadi 2007). Similar research is needed to merge behavioral science to facility management to help reduce energy consumption in buildings.

The decision making process for government facility managers is complex and often encourages immediate savings over long term savings. Provided for discussion are potential cognitive biases such as status quo bias, anchoring, and loss aversion that prevent facility managers from making choices that result in energy reduction. Use of framing effects, role models, defaults, and labels can help reduce cognitive barriers. For example, endowing design engineers with sustainability points on a rating system like Envision frames the decisions about energy and water reduction as a loss in points instead of a gain in points towards certification. Role model projects can illustrate feasibility of high achievement, which can encourage engineers to consider similar methods toward energy and water reduction. Rewording contract structures can help remove status quo bias leading to more accurate estimation of project costs.

I provide examples of similar choice architecture that could be expanded in the government applications. For example, reducing procurement choices by allowing facility mangers to query green or efficient products in one Department of Energy facility helped reduce the cognitive burden of decision making and led to more energy efficient purchases. Another forced facility managers to check certain product guides or use pay back period calculators prior to selecting a product. This approach accounts for loss aversion, the endowment effect, and cognitive limitations of the decision maker, forcing the use of a decision tool before making a purchase.

While this review aims to increase consideration for energy reduction during decision making for facility management, there are also opportunities within choice architecture to improve energy prediction models for buildings. In a 1991 study of loss aversion, Kahneman, Thaler and Knetsch wrote that "…models that ignore loss aversion predict more symmetry and reversibility than are observed in the world, ignoring potentially large differences in the magnitude of responses to gains and to losses." Facility mangers control lighting, ventilation, air temperature and equipment maintenance. Not accounting for the decision variables of facility managers may contribute to the variance in modeled energy consumption and actual energy consumed in buildings (Hodges 2005). This is an area of research needed to bridge facility decisions with energy modeling.

Energy policy and products receive the most attention, despite the fact that most life cycle costs for a building occur during the operations and maintenance phase. Despite such influence over building performance, facility managers often do not optimize potential energy savings because they are not informed of management goals and often make decisions without consideration of long term life cycle costs. Ultimately, aligning decision environments with behavioral science and using choice architecture while placing greater emphasis on energy efficiency can contribute to meeting future energy reduction goals.

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CONFERENCE PAPER—Cognitive Barriers to Energy Efficient Decision Making in US Coast Guard Facility Management

Intended Outlet:

ASCE Sustainable Infrastructure Conference

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Abstract:

The U.S. Coast Guard is the largest energy consumer within the Department of Homeland Security, and established an energy reduction goal of reducing CO_2 emissions by 25% from a 2008 baseline. Unfortunately, the Coast Guard continues to fall short of CO_2 emissions goals by approximately 49 million tons. This study investigates how framing effects in energy efficiency decisions can help the US Coast Guard achieve energy reduction goals in the future. Our empirical study investigated participants' myopic bias to focus on upfront gain over long term benefits when making decisions about upgrades to facility machinery. A mixed methods approach was used to determine if decisions are suboptimal and if upstream decisions can be optimized for energy efficiency. Coast Guard facility managers participated in an energy use survey and interview to determine which barriers they encounter during decision making. Engineering students were given decision scenarios to determine if framing could impact their energy decisions. Our study found that US Coast Guard facility managers encounter risk aversion, loss aversion, choice overload, and status quo bias in daily decision making activities. This study also found that engineering students' decisions were not impacted for efficient options that dealt with a smaller order of magnitude (less than $6000 of upfront costs) but the decision framing was more effective and the students selected the more efficient option when dealing with costs in the $200k range, and when using CO_2 emission calculations. This has implications for future use, including how knowledge of barriers to decisions can help us design decision aids for facility management procurement, and design better choice environments to meet the organization's goals.

2.1 Introduction

The US Coast Guard is the largest energy consumer and producer of CO_2 emissions within the Department of Homeland Security (DHS) (Alford 2015), and has thus set goals to reduce CO_2 emissions by 25% by 2020 from a 2008 baseline. By 2014, CO_2 emissions had reduced by 13% from that initial baseline, but were still short of annual milestones. To continue reducing emissions at the same rate, the Coast Guard aligned with the DHS Strategic Sustainability Performance Plan (Alford 2015) and is complying with Executive Order (EO) 13423, which states that new government construction projects over $5 million must obtain LEED Gold certification or better (*Exec. Order No. 13423* 2007).

Unfortunately, focusing on new construction might not be enough to continue reducing emissions at the same rate because most Coast Guard facilities are already constructed. More over, engineering and construction firms often place more consideration on meeting the mandate for LEED and less importance on long term benefits due to the uncertainty of determining future gains (Menassa et al. 2011). Approximately 90% of a buildings life cycle emissions come from the operations and maintenance phase, therefore, construction is a small part of the total life cycle (Sartori and Hestnes 2007). The Coast Guard, and other government agencies, stand to benefit more from efforts to reduce energy intensity of existing facilities.

The focus of this is paper is decision support for energy reduction of existing Coast Guard facilities that complements the existing executive orders and mandates. Government facility managers face constant and significant challenges to energy reduction decisions. For example, Coast Guard facility managers typically transition jobs, on average, every 3 to 4 years, which may cause myopic decisions leading to discount future return on investments.

Furthermore, these same managers are praised during annual job evaluations for reducing operation budget expenditures, possibly deterring the purchase of more expensive products that save energy over time. Additionally, during retrofits, facility managers are frequently not part of the design team making decisions that influence daily operations and maintenance and related energy use (Hodges 2005).

The research presented is a mixed methods approach to identify both the barriers and solutions to better decision making for energy and CO_2 reduction. The paper begins with an overview of facility management in the Coast Guard, exploring the decision making process, potential barriers that prevent greater energy reduction, and concludes with suggestions for meeting the Coast Guard's CO_2 goals. While the focus here is the Coast Guard, the solutions proposed are likely applicable to other government and non-government decision making during facility management.

2.2 Background

2.2.1 Facility Management in the Coast Guard

Thirty-nine bases in the Coast Guard are managed by a facility manager and his or her staff. Their responsibilities include facilities, grounds, preventative, corrective maintenance, and improvement projects in their regional areas. These facility managers and staff must constantly make decisions about lighting, plumbing maintenance, HVAC maintenance, and corrective or preventative maintenance on large scale items such as building renovations. These decisions directly impact the energy footprint of their facility and are paid for through tax payer money (Chandrashekaran and Gopalakrishnan 2008). Figure 2.1 demonstrates the layout used for the background of the paper.

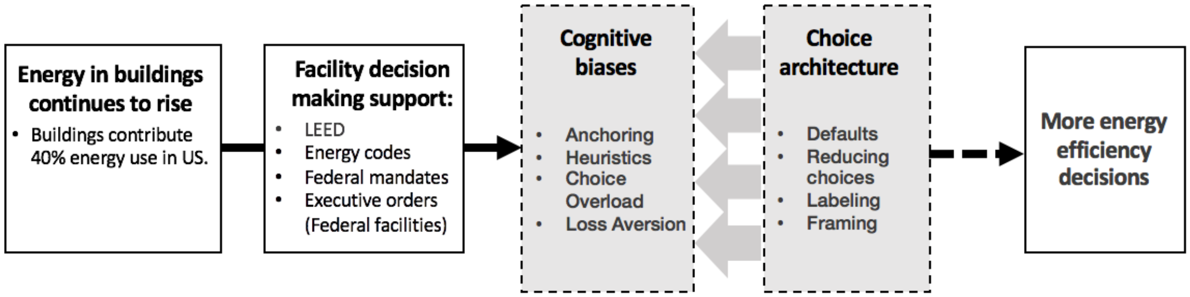

Fig. 2.1. Layout of Research Background

Facility managers do not always have the appropriate time and information to make the best decisions. They must often balance shrinking budgets, high operational tempo, lack of human resources and growing administrative tasks. They are relied upon for engineering expertise, but are pulled in dual directions due to administrative and operational requirements. Literature on facility managers often focuses on risk management (El-Haram and Agapiou 2002), energy savings (Hodges 2005), and policy (Khalil et al. 2011), yet there is a noticeable lack of research bridging decision making and facility management for energy savings (Jackson 2010). To enable better decisions that lead to long term reduction in energy consumption, choices should be structured to account for these shortcomings. The next section describes the possible shortcomings when facility managers must act without complete information, negotiate with limited funds and numerous policies and mandates, and a growing responsibility for energy management.

2.2.2 Decision Bias Preventing Energy Reduction in Facility Management

Cognitive biases occur when decision makers encounter barriers to rational decisions, meaning decisions that lead to optimal outcomes. Sometimes bias can result in good decisions made quickly in the form of heuristics (Gigerenzer 2007), however they can also contribute to cognitive errors in judgment due to uncertain or incomplete information (Kahneman and Tversky 1979).

Decisions under risk and uncertainty are often influenced by cognitive biases, and decisions about energy efficiency are not exempt. For more than three decades, behavioral science has demonstrated that people do not consistently make decisions that maximize benefits (Kahneman and Tversky 1979). For example, decision makers downplay options that contain risk, and overly weight options that contain certainty (Kahneman et al. 1991). However, if a decision maker recently experienced a loss they are likely more willing to accept a risk. This helps explain why investors might hold onto failing stocks hoping for a turn around (Carmon and Ariely 2000).

Prospect theory provides a framework for decision making under uncertainty, which states that decision makers try to avoid losses at the expense of potential gains. More exact, the potential gain needs to be at about 3 times more than the perceived loss (Benartzi and Thaler 1993). On the other hand, Utility theory assumes the frame of loss or gain does not matter, rather decision makers with each decision work to maximize their benefits, or utility. Because future energy reduction is not certain and decision makers do not have all the information and time to analyze potential utility for each choice, the theoretical perspective about decision making for this paper is prospect theory. Prospect theory can predict outcomes that utility theory does not consider, and explains how people respond to risk and loss depending on the circumstance.

To enable better decisions, behavioral scientists use choice architecture, which is the intentional design of choices to align with the decision makers goals and objectives accounting for potential cognitive biases and environmental mental constraints (Sunstein 2013). Choice architecture has improved decision environments for retirement plans, Medicare plans, and financial investments (Cronqvist and Thaler 2004; Johnson et al. 2005; Tversky and Kahneman 1981). An example of the impact of choice architecture is framing. Choices framed as losses or gains in value can often influence decisions much more than the intended outcome (Kahneman and Tversky 1979), even if the two options presented are equivalent in value. The decision maker will undergo a different emotional response (positive or negative) (Thaler et al. 2014). Framing effects have been applied in household emissions (Gifford and Comeau 2011), disease testing (Spence and Pidgeon 2010), and food labeling (Levin et al. 1998). When medical patients were given a choice between surgery or radiation, more preferred surgery when the option was described as having a 90% survival rate. Conversely, preference for the surgery option was much lower when the survey was described with a 10% mortality rate (McNeil et al. 1982).

The Coast Guard focuses on mitigating risk and maximizing budget, but does not mention how decisions are impacted by risk in official publications (Alford 2015). Although research has been completed in the field of energy efficiency, prospect theory, choice architecture, and facility management, few published papers were found which overlaps all of these topics. Choice architecture has the potential to help the Coast Guard meet and reach its energy goals. Behavioral science literature suggests that cognitive bias prevents us from maximizing utility (Kahneman and Tversky 1979), and choice architecture can help us make better decisions (Johnson et al. 2012). The Coast Guard can capitalize on potential gains in energy reduction informed by Prospect theory and aligning facility management choices framed to encourage more consideration for energy reduction.

This study first assesses how energy decisions are made by Coast Guard facility managers, and then tests framing scenarios with engineering students. Studying facility managers in the federal government and the impact of choice architecture on their decisions has implications for further, widespread application. Also addressed is the relatively sparse body of knowledge on facility management and decision making under uncertainty to help government entities like the Coast Guard bridge the energy efficiency gap through less than conventional behavioral approaches.

2.3 Research Objective and Questions

Related to the overall objective to make energy reduction decisions easier for Coast Guard facility managers, there are two research questions:

1. What cognitive barriers exist for Coast Guard facility managers when making decision about energy reduction?

The hypothesis is that facility managers are averse to upfront economic loss leading to discounting future gains and overly focusing on short term losses (i.e. initial cost). Meaning, facility managers make decisions the meet short term utility objectives but fail to provide long term benefits compared to other choice options. This is measured by facility managers downplaying options with risk (i.e. potential energy savings using an unknown or new product) and overly weighing outcomes that include certainty (i.e. products purchased before, status quo).

2. Can framing energy decisions as gains in value help overcome loss aversion in facility managers and enable a shift towards choices that lead to long term energy reduction benefits?

The hypothesis is that framing decisions to emphasize long-terms gains can help the decision maker. In other words, framing helps the facility manager make decisions that result in energy reductions. Framing effects help decision makers focus on different attributes of the decision. Therefore, reframing choices to focus on potential gains of the energy efficient product will influence the decision. The gain measured is money saved from energy efficient products, and the loss is the initial cost of the equipment or product.

2.4 Methodology

Our research method is a mixed methods explanatory design beginning with qualitative survey and semi-structured interviews followed by simulated decision interventions about energy use in facility management. The purpose of the survey and interviews with Coast Guard facility managers was to determine barriers to energy efficiency.

2.4.1 Coast Guard Survey

A survey was distributed to Coast Guard facility engineers to collect information regarding how energy decisions are made, common barriers, and their perception of the current state of energy reduction in the Coast Guard, see Appendix C for more details. The survey was designed to address research question one: what cognitive barriers exist in decision making for energy efficiency in the Coast Guard? Additionally, a series of likert scale questions based on a previous study of public sector barriers to green buildings were developed (Pearce et al. 2007).

Survey respondents were Coast Guard facility managers between the ages of 25-34 years old with approximately 3-10 years of experience in civil engineering, and ranks of Chief Warrant Officer, Lieutenant, Lieutenant Commander, and General Schedule (civilian pay grade) 12 & 13. For more specific description of how the survey was designed please see Appendix A.

2.4.2 Coast Guard Interview

In the Coast Guard survey, participants were asked if they were willing to be interviewed regarding daily energy decisions. Three volunteers were interviewed from the seven facility managers who completed the Coast Guard survey. Previously developed interview strategies for effective semi-structured procedures were followed (Schwarz and Oyserman 2001). The interview questions were developed based on the results of the survey. Questions probed about their daily energy decisions managing a Coast Guard facility. The semi-structured approach led to questions not being asked in the same order and varied slightly from each participant, but each participant was asked the following questions:

1. What are the Coast Guard's energy reduction goals?
2. What are your responsibilities as a Facility manager?
3. What do you consider energy efficient?
4. How are facility systems monitored and benchmarked?
5. Do you think other Facility Mangers make similar decisions to you?
6. Do you see utility bills for your facility?
7. What efforts are made to educate base personnel on energy usage?
8. Can you describe the organizational structure of the facility management office?
9. Can you describe your interactions with the regional energy manager in the last 6 months?
10. Can you describe the maintenance process for equipment or energy efficient upgrades to the building?
11. Can you describe the procurement process?
12. When do you consider energy use when making purchases for equipment?
13. How would you recommend making energy efficient decisions easier for facility managers?

Once the interviews were completed the transcripts would be coded for forms of cognitive bias and tallied up for analysis.

2.4.3 Decision Scenarios with Engineering Students

To answer research question two: can framing energy decisions as gains in value help overcome loss aversion in facility managers and enable a shift towards choices that lead to long term energy reduction, decision scenarios were developed (see Appendix A for details). Decision scenarios were modelled after typical procurement decisions that a facility manager makes for HVAC, lighting, and galley equipment (Alford 2015). In these decision scenarios, facility-related procurement decisions were imitated that focused on upfront cost. The first option was introduced with only specification sheets, expecting that decision makers would prefer the low upfront cost due to loss aversion. However, the low cost option also has a higher energy output, and to simulate real-life options the options gradually become more energy efficient, but also more expensive. The options were crafted so that pay back periods (if calculated) would become more favorable as the options became more efficient.

There were four options that started as the lowest cost but highest energy usage (conventional), and the options gradually increased in cost and decreased in energy usage (most efficient). The option between those (efficient, less efficient) were found by interpolating between the conventional and most efficient option. In the scenario options were listed as Option A, B, C, & D, however they were randomized within the scenario prevent students from detecting a pattern, except for Option A, which was always the conventional option to keep pay back period calculations simple, see Appendix A for survey calculations and Appendix D for the decision scenarios.

The test was developed to understand what decision makers would choose: the low cost option (but high energy) or the higher upfront cost option (with more long term savings), because the information to make the utility maximizing choice was available. A ‘rational’ option was identified, the choice that the decision maker should make if trying to minimize long term costs and maximize energy savings. This option had the best pay back period and lowest energy usage, but was the most expensive upfront. Because shifting the mental model for decision makers to select the utility maximizing (energy efficient) choice was the intent, the second scenario introduced a prompt in the form of pay back period calculations or CO_2 emissions.

The decision scenario calculations would give the decision makers time to rethink their initial decision once they see how factors such as energy usage (in kwh/yr) and long term costs (money saved by using a more efficient product) add up, the assumption being that decision makers wouldn't normally see the best choice without this information being pointed out to them. Shifting the model of long term gains as a more favorable option than short term losses, intended to create a decision environment where the utility maximizing choice (long term gains) was preferred.

The decision scenarios were developed and tested with engineering students. A small group (n=9) checked for face validity following a think aloud protocol. The questions were intended to imitate typical real world decisions about facility upgrades that often lack complete information about future energy savings. Students (n=24) were given specification sheets about products (i.e. HVAC, galley freezer) and made decisions about which was most appropriate for a mock facility. During the experiment, choices were framed as either probability of gains or certainty of loss, and the anticipated result was the framing of chance rather than certainty influences their decision. Long term gains or short term losses do not always correspond with maximizing utility. Therefore, the intervention measured was whether framing helped overcome the loss aversion encountered in energy decisions.

The difference in responses between the conventional questions (initial price and annual electricity use), and the intervention that required participants to calculate annual electricity costs, pay back period, and CO_2 emissions was measured. Also measured were the differences in outcomes when decision makers were given economic impacts versus CO2 emissions of their choices. For example, one decision simulation asked engineering students to make a procurement related decision on an HVAC system without requiring them to calculate the pay back period. The next decision simulation required the engineering students to calculate the CO2 emissions (and others the payback period) before selecting an option.

2.4.4 Statistical Analysis

The survey questions followed Likert scale and are reported in a descriptive format. Interviews were recorded, transcribed, and coded. Researchers coded responses using the MAXQDA12 software. The text was uploaded and then scanned for question responses and then tallied for frequencies of responses that correlated with cognitive bias using inductive reasoning.

The decision scenario questions were multiple choice and the results were categorical. A scale was assigned to the categorical data, based on the pay back period of each choice, giving the choice with the lowest pay back period a value of "1" and the longest pay back period a value of "4." The response options were equally distributed, meaning that the difference between a 3 and 4 is equal to the difference between 1 and 2. Thus, the data was ordinal and we evaluated responses based on percent frequency and to show a significant difference in response based on the framing intervention using a Wilcoxon Ranks Sum test.

2.5 Results & Discussion

2.5.1 Coast Guard Survey

Coast Guard facility managers indicated that the primary barriers to energy savings are: lack of available funds, lack of time, procurement process, lack of resources, and lack of necessary knowledge. Additionally, write in responses indicated a lack of emphasis on energy savings within the Coast Guard, lack of control over the savings from energy efficient equipment, and maintenance staff. Respondents were less likely to indicate command emphasis on initial cost savings, existing procedures/standards, lack of management buy in, risk of failure, and perceived economic impacts as primary barriers. The survey asked questions intended to also assess facility manager’s attitudes and perceptions towards energy efficiency. Results indicate that facility managers believe climate change is effecting the planet adversely but are split on organizational response to address climate change. Facility managers could not agree about valuing energy efficient products that may cost more over upfront versus products that are less expensive.

2.5.2 Interview Findings

Three interviews were conducted with Coast Guard facility managers to understand what prevents a facility manager from achieving their energy efficiency goals. Responses included time to consider alternative options, emergency situations requiring emergent solutions, varying priorities, and lack of personnel resources and funds. These responses seem to align respectively with behavioral literature as choice overload (too much information or choices to process), status quo bias and heuristics (relying on previous information or choices to make decisions), risk aversion (varying priorities to account for certainty), and loss aversion (due to lack of funds).

The interviewees described decisions are made primarily by considering if the work is corrective or preventative. Corrective work means something has broken unexpectedly and more immediate action must be taken. Corrective work was a prevalent theme in the discussion with the facility managers. Preventative work does not require immediate action, for example, restocking supplies, recurring maintenance, or replacing a product before the service life ends or product failure.

Each of the facility managers interviewed mentioned numerous difficulties they encounter to maintain and operate their facilities. In one case, the facility manager had not seen energy savings realized from LED lighting upgrades and installation of efficient hot water heaters. And the monitoring equipment installed did not translate into an easily readable dashboard and reports for the facility manager to review, or publish to the base on their energy performance.

The monitoring equipment installed in their facilities is a result of the Coast Guard's attempt to comply with Executive Order 13514, which calls for an energy management database and monitored equipment. However, facility managers must manually enter data into a database and build their own charts to monitor trends during the development process for the new energy management system. Based on the interviews, this manually intensive process to monitor progress seems to deter facility managers because of the demand on their time.

The three facility managers interviewed agreed that it is difficult for them to consider energy efficiency with every maintenance decision because the funding and procurement process creates a burden to new or innovative technologies. They commented that purchasing or following previous decisions (status quo) is the easiest path to task completion. The facility managers interviewed were aware of the Coast Guard's overarching energy and sustainability goals but could not accurately describe the goals. The facility managers were able to describe how to achieve energy reductions but did not provide a clear method to track progress and report it over time.

The interview transcripts were coded to assess how responses relate to behavioral or cognitive barriers to making energy efficient decisions such as risk aversion, loss aversion, status quo bias, and choice overload. For example, in response to asking what prevents energy efficient implementations, one of the facility manager's said, "I think time's a big one. It's harder to do an analysis and really brainstorm what we could be doing for greater energy efficiency… whether it's worth it or not, I [do] not have the resources to pursue." Because of the words "whether it's worth it or not" and "I do not have time to pursue" this response was coded as aversion to risk. Meaning, they did not want to invest the time and effort to generate alternative options because they doubt or are uncertainty of the potential energy savings.

After coding the interview and survey responses, the number of responses connected to each cognitive barrier, such as, risk aversion, loss aversion, status quo bias, and choice overload were tallied. The frequency of described cognitive bias are listed in results can be seen in Table 2.1. Table 2.1 also represents the survey responses and what cognitive bias was encountered.

Table 2.1: Survey and Interview Responses

Type of Cognitive Bias Encountered	Survey Responses[1]	Interview Response[2]
Loss Aversion	69%	32%
Risk Aversion	56%	57%
Choice Overload	63%	N/A
Status Quo Bias	63%	11%

Survey Responses is what facility managers marked as barriers to energy efficient decisions
[2] Coded answers corresponding to cognitive biases in the three interviews totaled to 47

The most common and frequent responses from the interviews was that decisions about energy are not a high priority. They would rather expend resources on other priorities (such as emergencies) and minimize time needed to make decisions. Respondents suggested using the new energy monitoring systems to publish information on energy usage is not a good use of their time. In general, facility managers are pulled across many responsibilities and the belief of the three interviewed is that spending so much time on energy efficiency is risky. And that the chain of command enables energy efficiency to become, as quoted by one of the facility mangers, ‘someone else’s responsibility’ in the future (see Appendix B for detailed survey and interview responses). These responses seem to indicate an aversion to energy efficiency because of risk. Basically, energy efficiency would require exerting time and resources without known benefits.

The facility mangers interviewed repeatedly indicated a lack of time to make all necessary facility decisions, which frequently led to choosing options that were previously in place. The lack of time to consider options led to heuristics to keep the status quo. Evidence of myopic decision making surfaced when facility managers described the Coast Guard’s procurement process. Facility manager’s staff request products from contracting officers who are in charge of purchasing. Staff requests are often changed if less expensive (but not equivalent) alternatives are available. But the same product switch does not occur for energy efficient products. The facility managers interviewed seemed to believe energy efficiency was only a consideration when there are left over funds at the end of the fiscal year.

2.5.3 Decision Scenarios with Engineering Students

Decision making scenarios were conducted with civil engineering students to simulate choice interventions with facility managers. The purpose of these decision scenarios was to test methods to overcome cognitive biases observed in survey and interview results with facility managers. More specifically, test whether framing options to focus on long term gains could reduce the effects of loss aversion and risk aversion in facility procurement decisions.

The pay back period was calculated by a series of simple calculations meant to imitate an informal decision process. Decision makers are less likely to use expert calculations (meaning time value of money, involved life-cycle cost analysis) than back-of-the-napkin ‘folk’ equations, even when educated on how to do so (Kempton and Montgomery 1982). Essentially, the decision maker took the difference in initial costs between the evaluated option and baseline option, and divided that by the electrical cost difference between the evaluated and baseline option. For example, if the baseline option cost $30 upfront, but cost $45 to maintain every year, and the evaluated option cost $50 upfront, but cost $25 to maintain every year, we would take the difference between the initial costs ($50-$30) and divide that by the difference in electrical maintenance costs ($45-$25) to reach an informal payback period for the evaluated option (in this case, 1 year).

The first decision simulations asked engineering students to make a procurement decision on lighting without requiring them to calculate pay back period. The second lighting question required students to calculate payback period before making a selection. The results indicate no significant difference (p=0.3) in choice outcomes as a result of framing intervention, demonstrated in Figure 2.1. Prior to calculating pay back period, 14 of 24 students selected the most efficient option. After calculating pay back period, 15 of 24 students selected the most efficient option.

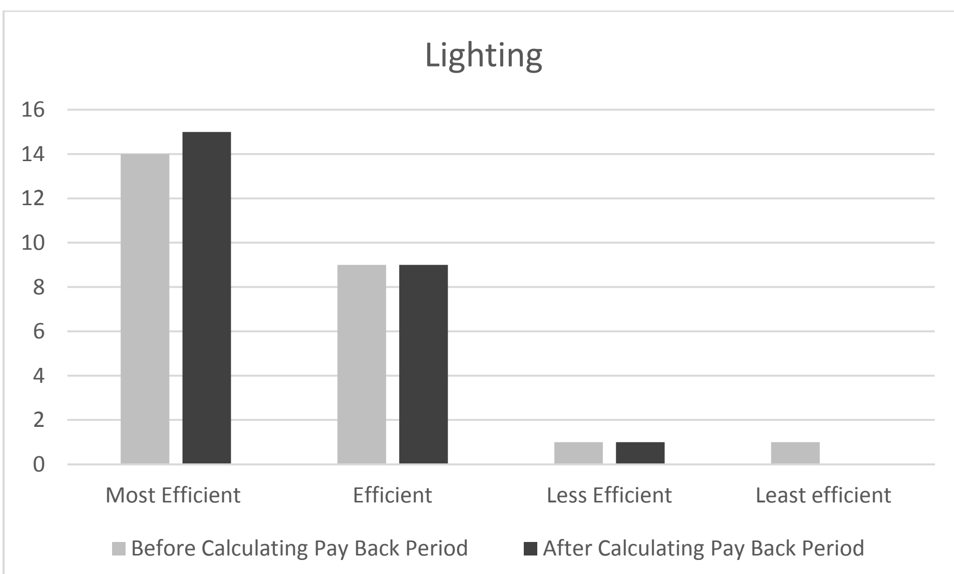

Fig.2.2. Respondents chose most efficient at a similar rate without requiring payback calculation.

The second set of decision scenarios, similar to the lighting, asked students to choose between HVAC system options. Of the four options presented, one option was the most efficient and yielded the quickest pay back period of 3.99 years and expended 50% less CO_2 emissions than the conventional HVAC option. The first HVAC decision scenario was asked without requiring CO_2 emission calculations. The next HVAC decisions scenario required CO_2 emissions calculations before an option could be chosen. Requiring them to calculate, in this scenario CO_2 emissions, did in fact influence the decision making (using a Wilcoxon Rank Sum Test, $p=0.001$). In this scenario, 7 of 24 students selected the most efficient option before calculating CO_2 emissions, and after calculating CO_2 emissions, 19 of 24 students selected the most efficient option. Additionally, before calculating CO_2 emissions, 8 of 24 selected the 'efficient' option (the second best option) and that number decreased to 4 of 24 after the CO_2 emission intervention. Similarly, the 'less efficient' and 'least efficient' options experienced decreased selections following the CO_2 intervention. This revealed that an intervention did impact the method and frame decision makers used to evaluate the choices, and allowed them to see the utility maximizing choice more clearly, as seen in Figure 2.2.

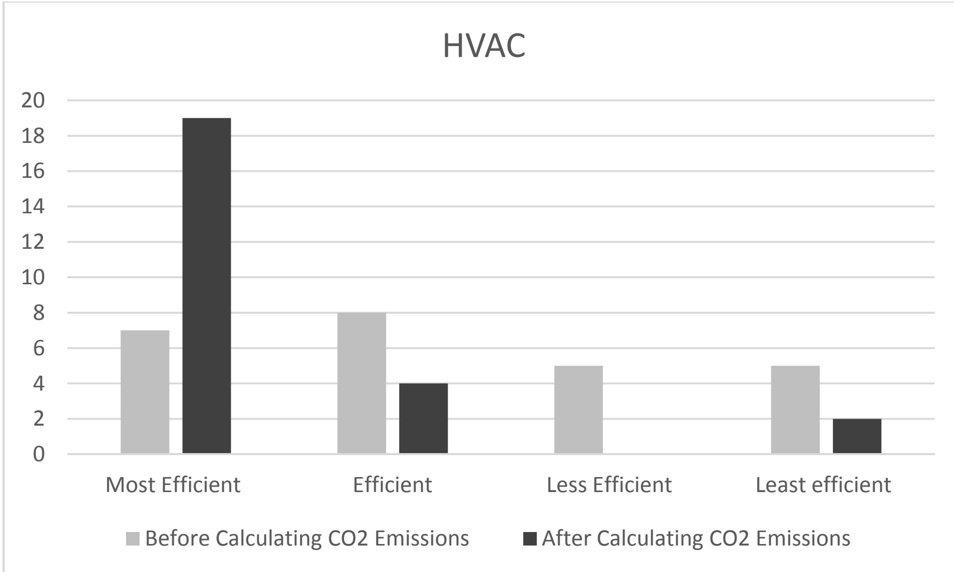

Fig. 2.3 Respondents chose the most efficient option after calculating CO_2 Emissions.

In the freezer scenario, students were not presented with a conventional decision choice first, they were instead given a prompt (pay back period) from the start, and compared those answers with another prompt (CO_2 emissions). This test resulted in almost no significant difference (using a Wilcoxon Rank Sum Test, $p=0.307$) between the two interventions, 17 of 24 students selected the most efficient freezer after calculating pay back period, and 21 of 24 students selected the most efficient freezer after calculating CO_2 emissions. In this scenario most students selected the most efficient freezer from the first scenario which required calculating pay back period, and the next scenario which required calculating CO_2 emissions noticed a slight increase in selections, see Figure 2.3.

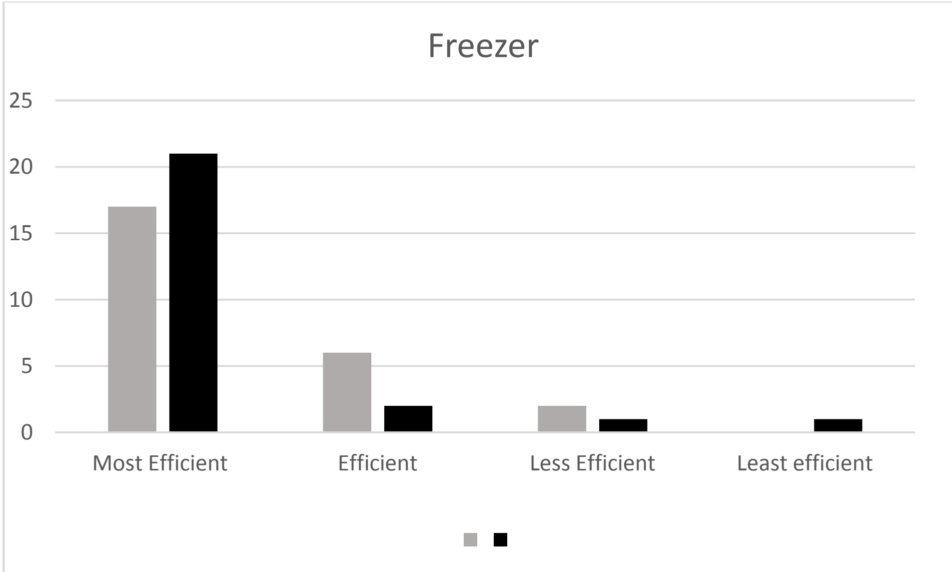

Fig. 2.4. Respondents chose the most efficient option for both pay back period and CO2 emission calculations.

2.5.4 Discussion of Decision Scenarios

The interventions tested in the decision scenarios were developed to help decision makers make the utility maximizing decision in energy efficient decisions. The intervention appeared to influence students' decisions about HVAC ($100,000) but not lighting. One reason could be the order of magnitude between the two scenarios. The payback period for lighting is less than one year and HVAC is just under four years for the most efficient option. Additionally, for the lighting options the hypothetical pay back periods were similar (0.44 yrs, 0.38 yrs, and 0.36 yrs) and the HVAC pay back periods were higher (4.55 yrs, 4.4 yrs, and 3.99 yrs). Cumulative Prospect theory may also provide some explanation, which states that overweighing of extreme events occurs more frequently than the overweighing of small probability events (Tversky and Kahneman 1992). The lighting scenarios involved lighting pay back periods so short the decision maker might not encounter many barriers to choosing the most efficient option initially. Also, lighting had products of smaller value, the 'loss' being the conventional product value of approximately $1200 and a 'gain' of approximately $4200 (the difference between the most efficient and least efficient product). This level of magnitude (in $1000s) is much less than HVAC valued around $200,000 for the initial price. The HVAC questions introduced a situation without a frame, and a CO_2 emission frame to help the decision maker chose the more efficient option. Students' decision appeared to shift after the CO_2 intervention and pay back period calculations were introduced, indicating that when much higher order of magnitude (100,000 as opposed to 1000), and CO_2 emissions are used, framing can be effective. Additionally, benefits are not as easy to mentally calculate with higher numbers.

Because multiple frames and interventions were used in congruence with each other we cannot say that CO_2 emission framing alone, or dealing with pay back period in a certain order of magnitude alone is enough to design a better decision environment for the decision maker. Choosing which is the most effective attribute to use is dependent on the situation, different attributes could be effective in different energy efficiency decision scenario. In this situation of a controlled experiment with engineering students, CO_2 emissions and a high order of magnitude were attributes used which changed the outcome of the decisions.

However, the implications of this initial study can help us answer the questions posed in the hypothesis section: what cognitive barriers exist for facility managers regarding energy reduction, and can framing energy decisions as potential gains help overcome loss aversion in facility energy decisions? It was determined that cognitive barriers such as loss aversion, risk aversion, choice overload, and status quo bias exist for facility managers from the interviews and surveys completed with the Coast Guard facility managers. According to our decision scenario, students' decisions were susceptible to long term energy benefit framing when making energy decisions for items of greater value (i.e., HVAC). This is a significant first step towards understanding how facility managers want to make the best decisions for their organizations, but are often held back by cognitive barriers to energy efficiency. Additionally, we are closer to understanding how to best design choice environments for those operating around cognitive barriers such as loss and risk aversion, and adapting past research on cognitive bias to the field of facility management within the built environment.

2.5.5 Limitations

The decision scenarios should be replicated with historical decision data with actual facility managers completing decision scenarios to further validate results. This experiment attempted to replicated issues within the Coast Guard but faced challenges of low participation. The Coast Guard is the smallest uniformed service, and has less of a population to sample when it comes to facility managers. This experiment, however, could be repeated with a larger number of facility managers in similar uniformed services or government agencies.

When developing the decision scenarios, assumptions were made to compare different types of HVAC units, freezer units, and lighting choices. Survey energy assumptions did not take into account the time value of money. It was assumed that decision makers were making pay back period calculations with cognitively simple equations, and not equations that took into account, inflation, cash flows, depreciation, and salvage value. The decision scenarios should also be isolated to try different interventions with different populations so that the same population is not exposed to a multitude of intervention types (for example, used were order of magnitude, CO2 emissions, and pay back period to frame the utility maximizing option as the favorable option). While scenarios were combined with different orders of magnitude, pay back period, and CO2 emissions, these interventions should be tested again individually. For example, one test developed could test a population with just one scenario: choosing an HVAC unit conventionally (without calculating anything beforehand), and choosing an HVAC unit after pay back period is calculated.

2.6 Conclusion

The U.S. Coast Guard is the largest energy consumer within the Department of Homeland Security, and established an energy reduction goal including reducing CO_2 emissions by 25% from a 2008 baseline. Unfortunately, the Coast Guard continues to fall short of their goal by approximately 49 million tons of CO_2. The results suggest one reason is Coast Guard facility managers lack time as a major barrier to considering more energy efficient products. The same facility managers recognize the Coast Guards goal of energy efficiency but are unable to provide sufficient details and suggest energy efficiency is not a high priority. To help shift priorities, we tested whether prompting consideration for energy and CO_2 emissions can help reframe facility management decisions. The results were not conclusive but results requiring more consideration for pay back period and CO_2 emissions prior to making a final decision may help shift decision outcomes to more efficient options.

The results suggest Coast Guard facility managers navigate difficult decision environments and better choice environments may lead to improved outcomes for energy reduction. There are dozens of federal rules and mandates, laws, statutes, and departmental guidance which all compete for space in a facility manager's consciousness. Couple that with budget constraints, increased administrative responsibilities, shrinking workforces, and broken equipment, and the result is facility managers, like others, are likely to take shortcuts to make decisions. One possible choice architecture intervention to test is reducing the number of choices and parameters decision makers must consider. Instead of saddling more responsibilities that require more effort, we need to create systems that are easier to use, read, and disseminate. Defaults are an example that could potentially be used in procurement decisions. Making energy efficient options the default could not only make decisions easier for facility managers, but can also help the Coast Guard reach emission goals. Reducing choices could narrow down the potential options for facility managers to consider. Better labelling on products helps inform decision makers about actual benefits or drawback to a potential product or appliance. Energy dashboards enable dissemination of information, better tracking, accountability, and can offer nudges whenever energy usage goes above goals to keep facility managers on track. A tool that automatically calculates pay back period or CO_2 emissions for proposed products on the procurement form can help facility managers make decisions without requiring additional time.

In 2014 there was a 17% gap between how much CO_2 emissions the Coast Guard wants to emit, and how much they are actually emitting (Alford 2015). Better understanding of decision environments can help reduce CO_2 emissions by easing the decision making process for facility managers. This research provides a proof of concept for potential methods to frame decisions for facility management that help reduce emissions. While this study focused on those making facility purchases, similar advances are likely possible for stakeholders and occupants, resulting in even greater energy consumption reductions beyond what a facility manager can achieve on their own.

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RESEARCH PAPER: Framing Energy Efficiency with Pay Back Period: An Empirical Study to Increase Energy Consideration During Facility Procurement Processes

Intended Outlet for Publication:

Journal of Performance of Constructed Facilities—American Society of Civil Engineers (ASCE)

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Abstract

The federal government is the largest energy user in the country and government facilities are responsible for 40% of their total energy emissions. Unfortunately, traditional methods to improve energy efficiency are not reducing emissions to meet the federal government's goal of 2.5% reduction per year. To complement more traditional approaches like executive orders, congressional acts, and mandates, the focus here is facility management. Specifically, the procurement process for government facility equipment (e.g. HVAC, lighting systems). Based on behavioral science research, decision makers do not always immediately understand, or know, the outcome of each possible choice due to lack of time, information or processing capability. What is more, cognitive biases, such as loss aversion, anchoring, and status quo bias, may further reduce consideration for energy efficient options. The hypothesis is that choice architecture, meaning the way in which procurement options are structured, influence facility management procurement decisions. To test this hypothesis, engineering and building science students (n=56) were presented with three procurement scenarios. Each scenario provides four product choices at varying cost and energy efficiency. Half of the participants randomly received the normal procurement form and the other half received a modified form asking first to calculate the pay back period (PBP) of each option compared to the baseline option. The results indicate a statistically significant difference (p=0.0003) between participants in the control who did not choose the more expensive but more efficient product option and students in the intervention group who more frequently chose the most expensive upfront but more efficient option. These results demonstrate one of many potential applications for choice architecture to improve "upstream" decisions for energy reduction in facility management. If applied to all government facilities the savings would be approximately $1.2 trillion; obviously, not all government

facilities are equivalent nor are they being upgraded all at once but simply adding a prompt to government procurement forms asking users to calculate pay back period before making a procurement decision appears to hold potential benefits without requiring additional acts of congress, executive orders, or mandates. Ultimately, better understanding of how facility decisions are made can help the federal government more quickly meet their energy efficiency goals. This study offers a new approach bridging behavioral decision making research to facility management for energy efficiency.

3.1 Introduction

The federal government is the largest energy user in the country and government facilities are responsible for 40% of their total energy emissions (George and Joyce 2015). As a result, Executive Order 13693 was signed to reduce energy and green house gas emissions within federal facilities. Mandates within federal agencies now require Leadership in Energy and Environmental Design (LEED) in new construction ("LEED Building Information" 2016), and federal acts like the Energy Independence and Security Act were put in place (Rahall 2007). However, these traditional methods to improve energy efficiency are not reducing emissions at the federal government's goal of 2.5% annual reduction (Gillingham et al. 2009; U.S. Department of Energy 2013).

Cognitive biases to energy and emission reduction may help explain why reaching such energy reduction goals are challenging, even with executive orders, mandates, and decision tools like LEED (Sorrell 2015; Weber 2015; Wilson and Dowlatabadi 2007). For example, facility level decision makers may not have the information or time to make decisions for energy reduction, a result of bounded rationality (Friedman 2002). Or facility managers might be overly burdened with choices and options, and unsure which is the better product for energy efficiency, a scenario best described as choice overload (Schwartz 2004). This paper examines how facility level energy decisions, specifically government facility level decisions, are influenced by choice architecture to encourage more consideration for energy efficiency. Choice architecture is the careful design of the environment in which people make choices (Thaler et al. 2014). Whether intentional or not choice architecture is inherently present when making decisions about facilities, the design of buildings, or retrofits. Therefore, choice architecture can help alleviate or reduce the effects of cognitive biases during decision making (Shealy and Klotz 2016; Thaler et al. 2014). More purposely, the tested choice architectures are government procurement decisions: whether modifications to the procurement form may alleviate cognitive bias that hinders selecting the most energy efficient product options during facility upgrade.

This paper begins with a short literature review of government facility management decision making, then shifts to cognitive biases in behavioral decision making and tools from choice architecture to overcome or alleviate these biases. The next section reviews specific methods to test framing effects on loss aversion about energy efficiency decisions, followed by the methods used to empirically test framing effects on facility management decision making in the federal government procurement process. The paper ends with a discussion of the implication of the findings with next steps and opportunities for future research to explore behavioral decision making and choice architecture relevant to energy efficiency in “upstream” decisions about constructed government facilities.

3.2 Background

3.2.1 Energy Efficiency in Government Facilities

Decisions about energy use in government facilities are often influenced by government regulations. There are many regulations that must be considered, such as, EO 13432, 13693, and the Energy Independence and Security Act of 2007. Additional government requirements mandate considerations for energy efficiency, life cycle costs, net zero, fossil fuel reduction, metering, and renewables (*Energy Policy Act of 1992* 1992, *Energy Policy Act of 2005* 2005, *Exec. Order No. 13423* 2007; Rahall 2007).

One of the frameworks required by the government for energy efficiency consideration is Leadership in Energy and Environmental Design (LEED), which helps prioritize energy efficiency during new construction and renovations. LEED is a rating system that seeks to implement sustainable measures and has market value (Blumberg 2012). In the commercial sector, for example, buildings that have LEED certification set a higher asking price and frequently have a higher occupancy rate (Dermisi 2009). LEED Gold and Platinum certified buildings have reduced building energy intensity compared to similar conventional buildings (Scofield 2013), however most government buildings still in operation are not LEED certified (Menassa et al. 2011).

Another measure used to increase consideration for energy efficient in government facilities are energy codes and congressional acts, such as the Energy Policy Acts of 1992 & 2005, and the Energy Independence and Security Act of 2007. These acts are intended to reduce energy level throughout the government by introducing alternative energy tax credits and breaks, encouraging solar, wind, and ocean energy as energy sources, reducing fossil fuel use, and provide metering for customers on request. Similarly, there are federal mandates to reduce energy use such as requiring ENERGY STAR purchases (Rahall 2007), encouraging alternative energy sources (*Energy Policy Act of 2005* 2005), and motor efficiency standards (*Energy Policy Act of 1992* 1992). These efforts are intended to reduce the burden on energy consumers and promote energy independence, and have resulted in a 32% increase in alternative energy consumed since 2011 levels in all sectors, but overall building energy consumption failed to decrease by 30% from 2008 levels as stated in E.O. 13432 (EIA 2014).

Finally, executive orders influence government energy use by setting standards, for example to reduce greenhouse gas emissions 2.5% each year until 2025 (*Executive Order (EO) 13693* 2015). However, executive orders do not state how to achieve the reductions or overcome the challenges that surround energy efficiency. Energy efficiency goals are well documented through the legislative history and EO’s, but setting a standard and not providing methods or resources to achieve such standards may be counter productive due to the cognitive burden placed on decision makers (Iyengar and Lepper 2000). Simply put, these conventional methods used by the government to instigate increased energy efficiency are providing marginal improvements, but not enough to meet energy goals (EIA 2014).

3.2.2 Cognitive Bias

Thirty years of research in behavioral sciences provides evidence that the decision environment influences the outcome. Behavioral science research helps explain, for example, why homeowners selling in a down market may insist on a higher asking price (Genesove and Mayer 2001), why investors sell profitable stocks too soon and retain losing stocks too long (Odean 1998), and why consumers generally hold failing assets longer than winning assets (Carmon and Ariely 2000; Cummings et al. 1986; Knetsch 1989). There are numerous ways in which the decision environment influences the behavioral response: anchoring to decision tools, heuristics during complex decision tasks, numerous design options leading to an overload of information, and undervaluing gains because of loss aversion. This is not a complete list and more examples can be found in (Johnson et al. 2012; Weber and Johnson 2009). The purpose here is to illustrate varying types of cognitive biases and how they connect to complex decisions in facility management.

Decision makers are frequently influenced by previously established standards, despite significance, and rely on such anchors to make decisions. For example, anchoring decisions to random (but high) numbers led to an increase in perceived achievement in LEED rating systems from building professionals (Jacowitz and Kahneman 1995; Klotz et al. 2010). Similarly, when decision makers encounter complex choices they often rely on a ‘rule of thumb’ or heuristic (Gigerenzer 2007). A heuristic occurs in situations where patterns, stereotypes, and preconceived notions guide decision and behavior. Heuristics can be helpful when making snap decision, but harmful when the decision is complex and requires more consideration. At times decision makers can be overwhelmed by options to consider, and encounter choice overload. Often times choice overload is cognitively overwhelming for the decision maker because they cannot weigh the costs and benefits of every option within the time allotted, and are dissatisfied with the outcome (Iyengar and Lepper 2000).

Loss aversion, another cognitive bias, is frequently observed when decision makers under value potential gains because of a fear of losing. In general, losses provoke greater degrees of discomfort than potential gains of similar value provide satisfaction (Kahneman and Tversky 1984; Schwartz 2000). Overcoming potential loss bias usually requires gains twice as great (Benartzi & Thaler, 1993); although, the gain required has been observed as 14 times as much (Carmon and Ariely 2000). To address the consequences of loss aversion when making policy decisions, researchers suggest bundling policies together that involve both losses and gains (Milkman et al. 2012). Loss aversion is broadly applicable among fields; helping make accurate predictions about risk seeking or averse behavior in politics (Patty 2006), international relations (Berejikian 2002) and public support for military intervention (Nincic 1997). Framing military involvement as a protective mediation to avoid geopolitical loss (i.e. framing to avoid loss) is viewed more favorable by the public than a proactive intervention explained as benefiting foreign policy (i.e. framing to gain).

Similarly, loss aversion affects engineering decision making about infrastructure. Simply re-framing points in rating systems for sustainability as a loss in achievement rather than a gain in achievement improved engineers' consideration for sustainability. Engineers endowed points in the Envision Rating System set a 15% higher goal for energy and water reduction than when no points were endowed (Shealy et al., 2016). Such an increase could drastically affect possible outcomes. If applied to all U.S. infrastructure, a 15% reduction in greenhouse gas emissions would result in a reduction of over 2 billion tons of CO_2 (Shealy and Klotz 2015).

Of course, infrastructure decisions are subject to varying constraints, goals, and resources with different stakeholder schedules, agendas, mandates, and budget cycles. And decisions about infrastructure are made in groups. A similar study investigated the effect of choice architecture on group decision making and found parallel results as individuals (Shealy et al. 2016). Thus, experts are similarly influenced by cognitive biases as consumers, which aligns with additional behavioral science research that suggest experts are influenced just as novices (Englich et al. 2006; Northcraft and Neale 1987).

Restructuring the decision environment can reduce the effects of cognitive biases during contract structuring for infrastructure development. For example, status quo bias led to underestimating project costs and overestimating financial returns on investment for a capital project between the Dutch Highway and Waterways Agency and a Dutch contractor. Redirecting biases towards improved performance instead of the price of managerial intervention helped remove status quo bias leading to more realistic expectations and more opportunities for financial gains (van Buiten and Hartmann 2013).

The premise is that facility managers are like other decision makers, bounded by rationality and prone to systemic cognitive errors, or biases, during decision making, and that these biases lead to less than optimal (at times irrational) outcomes. Although, much of the literature devoted to facility management focuses on sustainable needs, reducing risk, and uncertainty that contributes to ineffective project management, the solutions do not frequently include behavioral decision science (Delgado and Shealy 2017, Under Review). Rather, the solutions seem to focus on increased public participation, training, and new policies for environmental protection.

Similar to how behavioral decision science research is leading to advances in medicine (Johnson and Goldstein 2003), finance (Fox and Langer 2005), and insurance (Johnson 1993), behavioral decision science research can help explain how cognitive biases influence facility management decision making. For example, how EO mandates increase risk of decision making by stipulating a LEED score that may act as an anchoring bias. And facility managers, for instance, cannot make energy reduction decisions appropriately if they do not consider long term costs – inadvertent loss aversion in facility management which prevents energy savings (Hodges 2005). Another example, facility managers have the potential to reduce energy consumption but are often cut out of the conversation resulting in decisions that do not maximize utility due to imperfect information (bounded rationality) during design and construction. Figure 3.1 illustrates the link between not meeting energy reduction targets, approaches thus far to reduce energy, and potential cognitive biases which prevent decision makers from energy efficient decisions in facilities. By no means is this a full review of the potential cognitive biases represented in behavioral science literature or the only biases applicable to facility management. Rather this is meant to introduce the concept of cognitive biases as they relate to facility management. For more detail about cognitive biases about energy see (Houde and Todd 2010; Johnson et al. 2012). For more detail about how these biases relate to infrastructure management see (Shealy & Klotz, 2016) and energy reduction in facility management see (Delgado and Shealy 2017, Under Reivew).

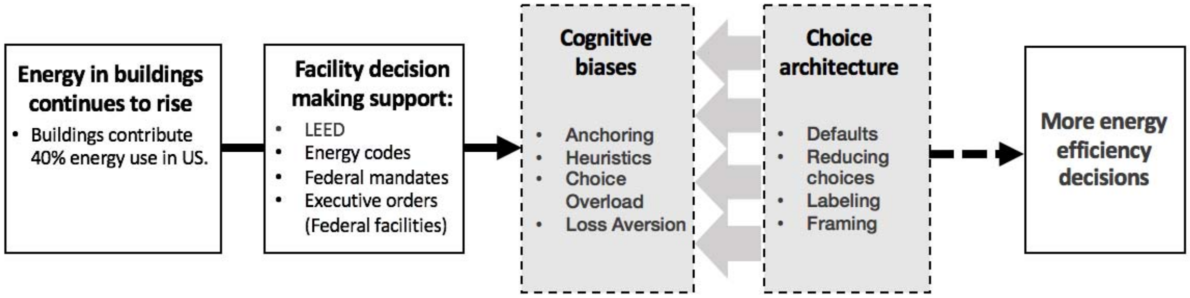

Fig.3.1. Choice architecture can help overcome cognitive bias during facility management to reach more energy efficient goals

3.2.3 Choice Architecture

Choice architecture is a method to orient the decision environment to account for known cognitive biases and to improve decision maker choice and autonomy. A principle of choice architecture is to construct choice information that helps decision makers better process the information. For example, when presented with miles per gallon (mpg) metric, consumers wrongly assume that increases in mpg have a linear effect in fuel use and CO_2 emissions, suggesting that an increase from 10 to 20 mpg has the same benefit as going from 40 to 50 mpg. However, this is not true. The shift from 10 to 20 mpg reduces fuel use by 50%, whereas from 40 to 50 mpg, fuel use is reduced by only 20%. Restructuring the information as a linear metric, such as gallons per mile, improves decision makers ability to pick the most efficient option (Larrick and Soll 2008). As the mpg example highlights, choice architecture is a powerful tool to help restructure decisions about energy. Choice architecture is inherently embedded in every choice, whether the decision maker is aware or not. Several approaches, or "tools" for choice architecture, are discussed to illustrate their benefit. Included are defaults, reducing choices, labeling, and framing. This is not a complete list. For more see (Leonard 2008; Shealy and Klotz 2016; Thaler et al. 2010).

Defaults helped increase organ donation rates when the Department of Motor Vehicle's license form is preset to automatic enrollment but decreased when the default was set to nonenrollment (Johnson and Goldstein 2003). The choice is preserved; citizens can check either box but the starting point matters. Similarly, reducing the number choices can help preserve choice. When decision makers encounter too many options they often decide not to choose, called choice overload. A study of Medicare patients found that reducing options from 100 to under 10, improved patient satisfaction and medical outcome (Kling et al. 2008).

Another choice architecture tool is labeling. Labeling can provide a visual aid when the information is difficult to understand, and can reduce processing time for new information. Energy star uses labeling to increase consumer purchases of energy efficient appliances (Newell and Siikamäki 2013). Related to labeling is framing choices, which means modifying the presentation of information in a positive, negative, or neutral tone. There are two types of framing: attribute and goal framing (Heath et al. 1999; Krishnamurthy et al. 2001; Levin et al. 1998) . The difference between attribute and goal framing is the object being highlighted. In attribute framing, the frame is focusing on the characteristic of an option or choice. For example, describing the success rate of surgery as 90% survival rate (positive) or 10% mortality rate (negative) is an example of attribute framing. Attribute framing is usually more effective when the characteristic is positively framed (Levin and Gaeth 1988). Goal framing relates behavior to obtaining the goal (Heath et al. 1999). For example, a positive frame, “If you get a mammogram, you take advantage of the best method for early detection of breast cancer” compared to a negative frame, “If you don’t get a mammogram, you fail to take advantage of the best method for early detection of breast cancer.” Surprisingly, goal framing is most effective when goals are negatively framed (Krishnamurthy et al. 2001). This occurs because framing choices as losses or gains in value is often more influential in decision making than the resulting end point (Kahneman and Tversky 1979) because even when two presentation formats are formally equivalent each may give rise to different psychological processes.

These examples of choice architecture "tools" are intended to outline the growing field of behavioral decision science and the many applications of choice architecture to account for cognitive biases. In this paper, specific focus is on framing effects because the same type of preference construction is likely true for energy decision makers. Framing effects that over emphasize immediate rather than long-term savings may lead to sub-optimal decisions. The next sections list the research question and hypothesis based on this literature review of cognitive biases and choice architecture and provides an overview of the research methods to measure how framing energy savings as a gain instead of a loss (compared to initial cost) can influences product purchasing choices during procurement.

3.3 Research Question and Hypothesis

The cheapest products for facilities are not always the most energy efficient; more frequently energy efficient products cost more upfront to pay for their efficiency over time. With recent technological advances and automation, the pay back period continues to shrink. For example, two comparable HVAC systems, an efficient system initially costs $197,500 and 114,941 kwh/yr. of energy consumption and a less efficient model has an initial cost of $157,000 and 206,440 kwh/yr energy consumption. A quick pay back period (full process explained in more detail in the methods section) yields approximately a four year pay pack period leaving 16 years for saved energy expenses (given a 20-year lifespan).

Directly related to this HVAC example, the research question is "can framing procurement options with higher upfront monetary costs as long term gains shift decision makers' consideration in product choice for facilities?" The hypothesis is that product choices framed as long term savings significantly improves decision makers choosing the most energy efficient option. Significance is defined as a 95% confidence interval. The hypothesis, framing energy efficient options as long term gains influences engineers' choice, was tested with decisions about HVAC systems, galley freezers, and lighting.

To support the main hypothesis, an additional question about framing was asked to participants and is described in more detail in the methods section. The additional framing question applied the seminal work of (Kahneman and Tversky 1979) about Asian disease to energy efficiency. The hypothesis is that decision makers' follow previous Kahneman and Tversky's findings about risk and uncertainty, meaning product choices framed as either probability of gains or certainty of loss effects the way decision makers choose. Finally, five questions about beliefs and preferences in relation to energy efficiency were included to understand the participants point of view and, if needed, control for varying beliefs about energy and greenhouse gas emissions.

3.4 Methods

3.4.1 Decision Scenarios

Decision scenarios about actual procurement choices were developed from form 4200.1.2 CG (Rev. 2-84), used in the Department of Homeland Security, and distributed to students in engineering and building science from Virginia Tech and Colorado State, combined for analysis (n=56). These students are not facility managers but within the next six months could become facility managers or energy decision makers making the types of decisions posed through the scenarios in actual buildings. Additionally, the students were all currently studying risk in engineering or building science; therefore, were well qualified to act as engineers. Previous research that uses both engineering students and experts finds no significant difference between groups in their engineering design decision making (Shealy et al. 2016b) and between experts and novices (Northcraft and Neale 1987).

There were four product options (for each HVAC, galley freezer, and lighting) that started as the lowest cost but highest energy usage (conventional), and the options gradually increased in cost and decreased in energy usage (most efficient). The least efficient but cheapest upfront option and most efficient but expensive upfront option were real product choices. The two additional choices in between these were fabricated by interpolating between the conventional and most efficient options. For a detailed description of how the costs of the equipment were calculated, see Appendix A. The scenario options were listed as Option A, B, C, & D, however they were randomized within the scenario to prevent participants from detecting a pattern. Except for Option A, which was always the conventional least efficient option to keep pay back period calculations simple for the second group.

The objective was to test how prompting consideration for pay back period influenced procurement choices: either choosing the low-cost option (but high energy use) or the higher upfront cost option (with more long term savings because of less energy use) or one of the two options in between. The 'rational' option was defined as the choice that maximizes energy savings. This option had the lowest energy usage with a pay back period under five years compared to the cheapest option.

The decision scenarios were developed and validated with engineering students. A small group (n=9) checked for face validity following a think aloud protocol. The scenarios were intended to imitate typical real world decisions about facility upgrades that often lack complete information about future energy savings. Participants (n=56) were given specification sheets about products (i.e. HVAC, galley freezer) and asked to choose which was most appropriate for a mock facility. Participants were given the survey in paper form, half of the participants received the control version and the other half received the intervention. Both groups of students from

Virginia Tech and Colorado State were split in half, meaning, half of the students from Virginia Tech received the control and the other half the intervention option, the same goes for Colorado State. All participants were given 4 HVAC options, 4 freezer options, and 4 lighting system options. For example, freezer option A was the conventional option. If participants were given the intervention version, they were required to first record the annual energy use on the specification sheets then calculate the pay back period by taking the difference between the cost of the conventional option A vs another option (B, C or D), and dividing that by the difference of annual energy use cost between the same two options. For instance, option A cost $6840 and used 14,400 kwh/yr, and option B cost $7,700 and used 7637 kwh/yr, using $0.111 as the annual energy cost per kwh then the following calculations would occur:

$$\frac{\$7700-\$6840}{\$0.111\times(14{,}400-7637)} = 1.15\ yrs.$$

All the option specification sheets were identical except for the energy consumption and initial cost. Table 3.1 shows the difference in energy consumption for the HVAC, freezer, and lighting options used for this research.

Table 3.1: The Only Difference on the Specification Sheets was the Energy Consumption kwh/yr

Lighting Cost	Lighting Energy Consumption (kwh/yr)	HVAC Cost	HVAC Energy Consumption (kwh/yr)	Freezer Cost	Freezer Energy Consumption (kwh/yr)
$2099	102,000	$157,000	206,440	$6840	14,400
$5000	42,237	$176,084	168,626	$7700	7637
$5300	25,217	$188,306	142,384	$7950	5270
$5500	17,500	$197,500	114,941	$8043	4050

3.4.2 Attribute Framing

This section included a question developed by Kahneman and Tversky (Tversky and Kahneman 1981) on disease control, which illustrates how people act risk averse and risk seeking under uncertainty. The disease question was adapted to energy efficiency. Participants were randomly given the question framed as either a gain or loss in value. Version A is framed with certain gains while version B is framed with certain loss. The two versions are written as follows:

> <u>Version A – Framed as Gain</u>
> You work as a Facility Manager/Engineer at Virginia Tech. A major AC unit has failed in one of the dorms on campus. Your immediate solution is to rent a portable AC unit, which is currently costing you approximately $1500/month. Understanding that this is a temporary solution, you browse your files and quickly find information on the AC that failed, the part number and vendor (Option A). However, you are interested in efficient solutions so you do a quick search on efficient AC units compatible with the loading demands necessary for the dorms (Option B). Please select 1 option.
>
> - If Option A is chosen, you will save $400/month in cost difference between the temporary unit and selecting this unit.
> - If Option B is chosen, there is 1/3 probability that you will save $1200/month with this new unit, and a 2/3 probability that you won't save any money.
>
> <u>Version B – Framed as Loss</u>
> You work as a Facility Manager/Engineer at Virginia Tech. A major AC unit has broken in one of the dorms on campus. Your immediate solution is to rent a portable AC unit, which is currently costing you approximately $1500/month. Understanding that this is a temporary solution, you browse your files and quickly find information on the AC that failed, the part number and vendor (Option A). However, you are interested in efficient solutions so you do a quick search on efficient AC units compatible with the loading demands necessary for the dorms (Option B). Please select 1 option.
>
> - If Option A is chosen, it will certainly cost you $1100/month.
> - If Option B is chosen, there is 1/3 probability that you will only pay $300/month, and a 2/3 probability that you will end up paying $1500/month.

3.4.3 Beliefs & Preferences

The last section asked participants about their beliefs and preferences towards energy and greenhouse gas emissions using a Likert scale (strongly agree, agree, neither agree or disagree, disagree, and strongly disagree) format. The statements used are the following:

1. I believe that climate change affecting the planet adversely.
2. I personally value short term cost savings over environmental performance.
3. Others value short term cost savings over environmental performance.
4. I always consider pay back period prior to purchasing an item that consumes energy.
5. I always calculate potential CO_2 emissions prior to purchasing an item that consumes energy.

3.4.5 Statistical Analysis

The decision scenario questions (HVAC, freezer, lighting) were multiple choice and the results were categorical. A scale was assigned to the categorical data, based on the pay back period and energy consumption of each choice, giving the quickest pay back period option a value of "1" and the longest pay back period a value of "4." The response options were equally distributed, meaning that the difference between option 3 and 4 is equal to the difference between 1 and 2. Thus, the data was ordinal and responses evaluated based on percent frequency. A Wilcoxon Ranks Sum test was used to calculate a significant difference between the control and intervention group based on the framing intervention. The R language and environment for statistical computing was used (R Core Team 2012).

3.5 Results

The purpose of the decision scenarios and additional questions were to test whether framing procurement decisions as long term energy savings by requiring pay back period calculations before deciding influenced the outcome.

3.5.1 Decision Scenarios

All participants from both schools were split into two groups, the control group made procurement decisions without being required to calculate pay back period, and the intervention group was required to calculate pay back period before making a product choice. The first scenario asked participants to choose a replacement HVAC system for their facility. The results indicate a significant difference in selections (p=0.0002) between the control group and intervention group. Participants who received the framing intervention selected the most efficient option (25/27), as indicated in Figure 3.2, while the control group was less decisive.

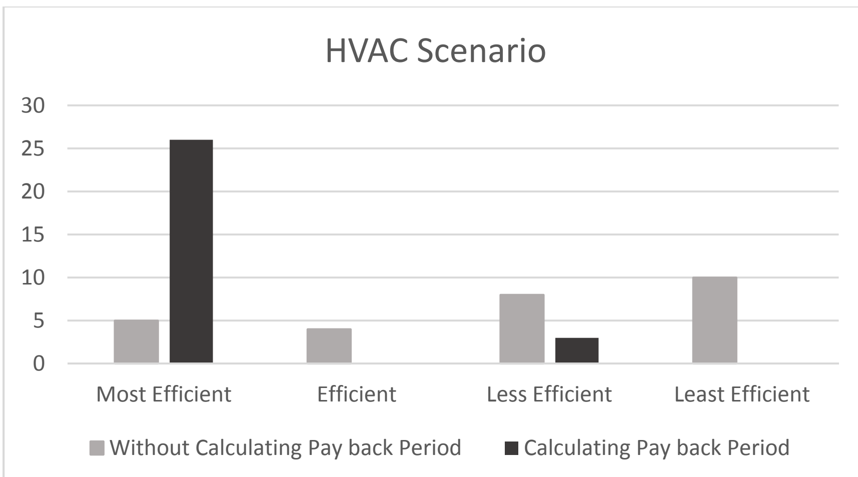

Fig. 3.2. Respondents chose the most efficient HVAC after calculating pay back period.

The next decision scenario asked students to replenish a stock of lights. Results indicated a statistically significant difference (p=0.0002) between the control and the intervention group. The control group was split between lighting options but two of the participants that received the framing intervention (23/25) chose the most efficient option, as shown in Table 3.2. The third decision scenario asked participants to install a new large freezer unit for a federal facility. The results indicate a statistically significant change in responses between the control and intervention group in this scenario as well (p=0.0005), as shown in Table 3.2. The control group mostly selected the least efficient option (11/26), and the group that received the framing intervention selected the most efficient option (20/21). A summary of results from these decision scenarios are provided in Table 3.2. Note that not all of the participants answered all of the scenarios.

Table 3.2: Requiring Pay Back Period Calculations Before Making a Procurement Decision Significantly Improved Consideration for the Most Energy Efficient Product Option

Statistics			Control	Intervention	Control	Intervention	Control	Intervention	Control	Intervention
Test	**P value**	**N**	**Most Efficient**		**Efficient**		**Less Efficient**		**Conventional**	
HVAC	0.0002	52	5	25	4	0	8	2	10	0
Lights	0.0002	46	7	23	5	0	2	0	9	0
Freezer	0.0005	42	5	20	6	1	0	0	10	0

3.5.2 Results of Attribute Framing

The questions used to determine how participants respond to risk were consistent with Kahneman and Tverksy's (1981) study. When participants encountered gains with certainty, 82% of participants chose Option A, to save $400, despite the fact that Option B is equivalent in potential savings. Similarly, when participants are faced with certain loss, 85% of participants chose Option B, which was the riskier option for possible gains.

3.5.3 Results of Behavior and Preferences

The results of the behavior and preference construction questions found 86% (42/49) of participants believe that climate change is adversely effecting the planet. Only, 40% (20/50) of participants indicated they normally calculate pay back period prior to making product purchasing decisions that are related to energy. Similarly, 78% (39/50) of participants responded they do not consider potential CO_2 emissions prior to purchasing a product that consumes energy. Table 3.3 shows the results of the behavior and preferences of the participants.

Table 3.3: Most Participants Neglect to Consider Long Term Energy Costs

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**n**

I believe the climate change is effecting the planet adversely	18 (37%)	24 (49%)	3 (6%)	2 (4%)	2 (4%)	49
I personally value short term cost savings over environmental performance	4 (8%)	14 (28%)	9 (18%)	20 (40%)	3 (6%)	50
Other value short term cost savings over environmental performance	8 (16%)	24 (48%)	14 (28%)	4 (8%)	0 (0%)	50
I always consider pay back period prior to purchasing an item that consumes energy	6 (12%)	14 (28%)	12 (24%)	16 (32%)	2 (4%)	50
I always calculate potential CO2 emissions prior to purchasing an item that consumes energy	2 (4%)	3 (6%)	6 (12%)	24 (48%)	15 (30%)	50

3.6 Discussion

The results from the decision scenarios and additional sections demonstrate that restructuring the decision environment using known choice architecture tools can improve decision making about energy efficiency in facility management. The implications of this research are that small “tweaks” to the procurement form may help alleviate cognitive biases. Decision makers do not always understand the outcome of each choice due to lack of time, information or processing capability to evaluate each option (Simon 1957). As a result, decision makers often choose options with less than optimal outcomes (Friedman 2002). The results of this study indicate that simply adding a prompt to the procurement form asking users to calculate pay back period before making a procurement decision lead to choosing more energy efficient products.

Calculating the pay back period appears to help decision makers realize the annual energy costs of ‘cheaper’ upfront option, and the potential savings of an ‘expensive’ option. The rational choice that maximizes utility over the life span of the product, in these scenarios, was the most efficient option, which happened to have the highest price tag. Once annual energy costs and pay back periods were calculated, decision makers appear to be better able to understand the shorter payback periods and the long-term savings associated with each option and help the decision maker choose the more efficient option, which quickly outweighed the potential short term savings.

Thus, the results denote to reject the null hypothesis. Prompting decision makers who are considering facility upgrades to first calculate pay back period enables decision makers to better account for potential loss aversion (in the form of upfront cost) in energy products by framing the long-term gains (energy savings) as a gain of much greater value. These results have implications for widespread application, especially as organizations try to find low cost options to achieve their goals of energy efficiency. Each situation is different and an all-encompassing conclusion about the effectiveness of framing pay back period over initial cost in every scenario cannot be simply stated, but the results at least for three scenarios show potential.

Furthermore, the results of the attribute framing questions are consistent with Kahneman's and Tversky's results (1981). The findings suggest that when decision makers encounter certain losses, they are more willing to take a risk to recoup their loss. When decision makers encounter certain gains, they are less likely to risk losing these gains for the potential of even more gains. While these results are not new, they are noteworthy because they help suggest that engineers (at least engineering students) are influenced by framing effects similar to previous studies about consumers cited in literature from behavioral science. Simply changing the wording from "you will save" to "it will certainly cost you," provoked different behavioral reactions that influenced decision makers' choice. Thus, choice architecture, more specifically framing, should be a consideration when designing and considering methods to help facilities reduce energy and emissions.

Despite 86% of participants who believe climate change is negatively effecting the planet, many do not think to consider the long-term energy consumption of the product they buy. Specifically, 60% of participants either were neutral or indicated they do not calculate long term energy costs before making purchases that include energy use and 78% indicated they do not consider CO_2 emissions. Here is an opportunity to help meet national energy goals. When the decision environments require participants to consider long term savings they are more likely to choose the product option that saves more over time compared to the option that is cheaper upfront. With this knowledge, decision environments can be re-framed where long term energy savings are more prominent, which may help narrow the gap between intent and actual savings.

3.6.1 Limitations

This experiment was done with two student groups and not professional facility managers, although these engineering students could likely be making these types of decisions after graduation. This experiment was conducted under controlled settings more closely related to a laboratory than the real world, which would include more than four product choices, real money at stake, and additional institutional barriers. Therefore, future experiments should include multiple iterations with actual facility managers managing real facilities. One potential down side, not tested, is normalization, where the intervention is no longer useful because decision makers become accustomed to the intervention. Determining if there is a “useful” life on choice interventions would also be helpful.

3.7 Conclusion

Despite government's conventional efforts to reduce energy consumption, and decision makers' commitment to energy reduction, energy consumption has not decreased to levels set by mandates and legislation. A potential reason for the gap between energy efficiency mandates and actual energy consumption reduction are cognitive biases that prevent facilities managers from recognizing the energy efficient options.

Facility management decisions about energy efficiency compete for time against other managerial duties, potential cognitive biases (Wilson 2008; Wilson and Dowlatabadi 2007), and institutional barriers (Beamish and Biggart 2012). As in other fields, like finance (Thaler and Benartzi 2004), medicine (Johnson and Goldstein 2003), and infrastructure (Shealy et al. 2016b), choice architecture can help overcome biases and barriers to improve decision making outcomes. This study provides evidence that facility management procurement decision environments influence product selection and that more conscious effort to design these processes may enable decision makers to more easily see the utility beyond initial cost.

In this study, framing effects were used to redesign the decision environment of a government procurement form to show the utility choices that may not have been apparent to the decision maker at first glance. In this case, the utility maximizing choice was defined as the option that had the highest price tag, but saved the facility money in the near term through energy savings. The results indicate that restructuring the decision by requiring first pay back period be calculated before making a product decision significantly influences the product choice for purchase. Decision makers who received the framing intervention appear to be more aware of the overwhelming difference between the cheapest option and the option that maximized energy savings.

Although tested in a lab experiment, these results have direct and application in the real world. Simply changing the procurement form to require considering payback period and energy savings of each product before making a procurement decision could lead to significant energy savings. If the three decision scenarios tested about HVAC systems, lighting, and galley freezer were applied to one government facility the savings of the product life time would be 88%. Applied to all government facilities the savings would be approximately $1.2 trillion (U.S. Department of Energy 2013). Obviously, not all government facilities are equivalent nor are they being upgraded at all once. The benefit though of this approach is that restructuring a procurement form requires no new mandates, congressional acts, or executive orders. Furthermore, the applications of additional choice architecture to help reduce energy consumption in buildings are immense. Future research could test how reducing choices helps account for choice overload when choosing energy related products, defaults to account for status quo bias and heuristics where decision makers rely on past decisions about product choices. Ultimately, better understanding of how decisions are made can help to quickly reach energy efficiency goals. More focus on the decision process can help redesign the decision environment to make energy efficient decisions easier for facility managers. The intended outcome of this research is to spur more research, bridging behavioral decision science to effect lasting reductions of energy consumption in facilities and more broadly, the built environment.

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LESSONS LEARNED

In the course of developing this thesis, I have learned much about the research process. Specifically, I have learned that survey development is challenging and even more challenging is getting people to complete your survey. I have learned that the best way to distribute and get responses back for my survey is to distribute paper copies and have a separate control group instead a control question within the surveyed group. I have also learned not to combine framing attributes within one research group. Instead, each separate group should only be exposed to one intervention. Lastly, surveys that include equations are discouraging to the person surveyed, they would rather not go through the effort. This is important to consider when developing the survey and building the question order.

An important take away from a master's thesis is scope control. I often found myself distracted by the multitude of methods this topic could be applied, and had to narrow my scope appropriately. However, when I extended my survey to encompass students I extended my scope, and if I were to do it again I would recommend taking a realistic view of the response rate into account when determining a population to study.

The theory behind cognitive bias is growing every year and it is difficult to write a literature review which encompasses the growth pace of this field. Also, when selecting the literature, I found that google scholar was extremely helpful in finding articles from around the world without individually searching through dozens of journals manually. Finally, I learned that cognitive barriers exist throughout the government, especially in the procurement process. The Coast Guard procurement process is especially difficult for those outside of the organization to comprehend, and it is likely that Coast Guard members are used to the tools and do not think about how cognitively overwhelming the form is.

CONCLUSION

In this manuscript, chapter one examined the theory behind cognitive bias and choice architecture, and explored government command control measures. Chapter two identified cognitive bias found in Coast Guard energy decisions using qualitative analysis. Chapter three empirically tested specific attributes of cognitive bias (loss aversion) and choice architecture (attribute framing) on students' energy decisions. The empirical test with students found that options framed as potential gains in energy savings significantly influenced decision outcomes. Students given scenarios which framed energy savings as potential gains chose the most efficient option over students not given any frame.

This manuscript identified that decisions have helped other fields account for cognitive bias using choice architecture, whether those goals are increased retirement planning (Thaler and Benartzi 2004), medical treatments (Li and Adams 1995), healthier food choices (Sunstein 2013), or energy efficiency infrastructure (Shealy et al. 2016a). We attempted to show potential use of cognitive bias, and applications of choice architecture to facility management and energy efficiency procurement decisions, to demonstrate the opportunity for significant energy reductions.

Many government organizations are recognizing the need for increased energy efficiency, as well as the potential cost savings that energy efficient offers. However, despite the desire by organizations and companies to reduce energy consumption, behavior was not corresponding, and thus energy savings have fallen below goals. The way that choices are structured and presented can have an impact on decision making, which can in turn impact behavior. If the connection between choice structure, decision making, and behavior is ignored, organizations will lose this opportunity to reach goals without overhauling systems, installing new infrastructure, or passing new legislation. Future work on decision making in fields which are risk averse, such as the government, includes designing better purchasing tools, identifying cognitive bias of all stakeholders, and testing these tools and choice structures on actual monitored behavior in the field.

To close, the research has shown that decisions and behavior are inexplicably linked with achieving energy efficiency goals. Students in this study were able to reframe decisions about energy and chose the utility maximizing decision by careful design of the choice environment. Organizations who wish to reduce energy consumption must understand decisions and how to apply interventions when appropriate, in order to achieve their goals.

Appendix A: Survey Design

To conduct this study, we used electricity consumption and pounds of Carbon Dioxide (CO2) emissions as a measure of a facility manager's likelihood of energy decisions. The Coast Guard's 2015 Operational Sustainability Performance Plan examines several large contributors to green house gas emissions, which included refrigeration, air conditioning systems, and electrical systems (Alford 2015). We determined three electrical sources to evaluate facility manager's decisions: large walk-in freezer units, Heating, Ventilation, and Air Conditioning (HVAC) systems, and lighting. Each of these systems can normalize electricity in kilo-watt hours per year. Kwh/yr can be converted into pounds (lbs) of CO2 using averages from EIA.gov. This system allows us to determine how much energy is being used by these systems, evaluate in a survey, and relate the electricity consumption to the big picture via CO2 consumption.

The survey was developed by using various sources of information on energy usage and initial cost data. RS Means was utilized to find the initial costs of the equipment in the scenarios. Several assumptions were made in order to establish hypothetical costs; they are below in Table 1.

Table 1: Assumptions

Assumptions			Source
Capacity of AC	10000	btu/hr	Energy Star Calculator
EER Conventional	10.8		Energy Star Calculator
EER midgrade	10.271		Interpolated
EER efficient	9.8		Energy Star Calculator
Location Demand (Cooling)	224	San Francisco	Energy Star Calculator
Heat Pump Capacity	36000	btu/hr	Energy Star Calculator
SEER Conventional	10		Assumed inefficient value
SEER Midgrade	12.0342		Interpolated

SEER Efficient	14		Assumed efficient value
HSPF Conventional	8.2		Energy Star Calculator
HSPF Midgrade	7.93385		Interpolated
HSPF Efficient	7.7		Energy Star Calculator
Location Demand (heating)	2948	San Francisco	Energy Star Calculator
Conventional Freezer demand	1600	kwh per 24 CF	Energy Star Calculator
Midgrade Freezer demand	913.93		Interpolated
Efficient Freezer demand	450	kwh per 24 CF	Energy Star Calculator
Freezer size	216	6x6x6 CF Freezer	Energy Star Calculator
Bulbs amount	500	Bulbs	Energy Star Calculator
Conventional 60W incandescent demand	204.00	kwh/yr	Energy Star Calculator
Midgrade lighting demand	119.5		Interpolated
Efficient 10W LED demand	35	kwh/yr	Energy Star Calculator
National Electricity Rate	$0.11		Energy Star Calculator
Building SF	10000	SF	Assumed
CO2 Emissions (natural gas)	1.21	lbs/kwh	EIA.gov
CO2 Emissions (Bituminous coal)	2.07	lbs/kwh	EIA.gov
CO2 Emissions (Distillate oil No. 2)	1.67	lbs/kwh	EIA.gov
CO2 Emissions (Residual oil No. 6)	1.8	lbs/kwh	EIA.gov

Initial Cost:

Once assumptions were established, the initial costs could be determined. For initial costs we used (Waier et al. 2010), and (*RS Means Square Foot Costs* 2009). The conventional lighting price was determined by assuming 1000 bulbs purchased, and they would be incandescent 60W bulbs (*RS Means Square Foot Costs* 2009). The midgrade and efficient pricing data was found examining (Waier et al. 2010), using efficient options equivalent to incandescent 60W and 100W.

The conventional cost for the galley freezer was determined using (*RS Means Square Foot Costs* 2009), finding a walk-in freezer, normalizing the size to 216 CF, and determining a final cost. The efficient freezer initial cost was found by using (Waier et al. 2010). We interpolated between conventional and efficient options to calculate the midgrade option.

The conventional initial cost for HVAC units (assumed outdoor, rooftop multi-unit) was calculated similarly and found in (*RS Means Square Foot Costs* 2009), assuming 79.16 ton loading demand for a 10,000 SF building. The efficient cost was found in (Waier et al. 2010), and the corresponding unit had a Seasonal Energy Efficiency Rating (SEER) of 14. We assumed the conventional HVAC option had a SEER of 10. In addition to SEER efficiency ratings, we assumed that there were 15 conventional units necessary, 10 midgrade units, and 8 efficient units. We determined the initial cost from these parameters. We then interpolated between conventional and efficient options and assumed that calculation as the midgrade option initial cost.

Energy Usage:

The energy usage was calculated differently than the initial cost. We attempted to use online calculators to determine the utility fees. There are many calculators available on the Energy Star website, as well as different companies' calculators. We quickly found that using the calculators from different sources would yield results that were incompatible with our loading requirements and assumptions. For example, a calculator would only give us utility fee data for AC units that were of a maximum size of 5 tons and with a different SEER rating, when the HVAC initial cost data was found assuming a 79.16-ton unit and a SEER rating of 14.5. This is excluding the fact that many of the HVAC calculators would calculate cost for only AC or only heating, and not both.

Instead we decided to calculate energy demand for each of the scenarios, and calculate the price using a national average electricity price (EIA 2014). We adapted the energy star formula for energy consumption, and imputed our parameters. Lighting was straightforward, we assumed 1000 bulbs, and found the demand for the different wattage required (EIA 2014).

The Galley Freezer utility fees were straightforward as well, the energy star website freezer electricity calculator was used to find the conventional and efficient electricity demand in kilo-watt hour (kwh). We interpolated the two numbers to find the midgrade option's demand in kwh.

The HVAC utility fees were more involved. The following formula was adapted from the Energy Star calculator for use in our calculations:

$$AC\ demand = Elec.\ Rate\ x\ \left(\frac{AC\ Capacity}{EER}\right) x\ No.\ of\ Units$$

$$Heating\ demand = \left(\frac{Pump\ capacity}{1000}\right) x \left(\left(\frac{Cooling\ Demand}{SEER}\right) + \left(\frac{Heating\ Demand}{HSPF}\right)\right) * No.\ of\ Units$$

Using the formulas above, we determined the electricity demand in kwh for the HVAC units of varying efficiency. The independent variables (variables that could adjust demand because of changing efficiency) are Energy Efficiency Rating (EER), SEER, Cooling Demand (city specific), Heating Demand (city specific), and Heating Seasonal Performance Factor (HSPF). The conventional and efficient numbers for the aforementioned variables were found with the energy star assumptions (EIA 2014). We interpolated to determine the midgrade variables. Following the interpolation, we were able to determine the total cost of utility fees based on typical and assumed electricity usage and the electricity rate. The electricity rate is found at EIA.gov in their average electricity price tables, and we used the national average for commercial buildings at the end of 2015, which was approximately $0.11/kwh (EIA 2014).

Assumptions:

Annual Usage vs Maintenance

Early in the process we had used maintenance cost information as a method to evaluate which choice to select. The maintenance data proved difficult to estimate for hypothetical units from RS Means, and the various calculator found online were also set to the vendor’s specific parameters and could not be altered. In addition, maintenance for HVAC varies greatly from freezer or lighting maintenance. Utility fees are a universally accepted operational cost and can be found with equations and location specific information to determine energy use and electricity rate. Additionally, it is important to differentiate between testing participants to determine if influenced by initial losses vs long term savings, revealing a participant’s susceptibility to behavior architecture and risk aversion.

Life Cycle Costs:

Pay back period examines a participant’s ability to think ahead for economic purposes, and consider the future in a way that is more attainable than a life cycle cost. Additionally, pay back periods are a component of life cycle cost, and considering the entire life cycle cost would add a layer of complexity to an otherwise straightforward scope. Within our hypothesis we are testing for the ability to influence facility managers to consider the long term savings as opposed to short term losses, and the life cycle cost would not only consider long term savings but also capital and salvage costs, maintenance fees during the life of the asset, and inflation, to name a few.

Informal v. Analytical Pay Back Period:

Energy costs can be found using professional analytical methods, or via informal methods. We are using informal methods in our survey, because people are more likely to use an informal method to determine energy use over an analytical method even if they are educated in the analytical method (Kempton and Montgomery 1982). Kempton's research examines this observation, and concludes that people are susceptible to bounded rationality, and are more likely to choose the easier calculation over the more robust for residential energy calculations.

Kempton did note differences between informal and analytical methods of calculating pay back period for energy costs. The informal method estimated pay back period higher than it actually would be using the analytical method, and the differences increased as the pay back period increased (Kempton and Montgomery 1982).

This is a known limitation on our research. We are asking facility managers to do an informal calculation that will not yield the most accurate pay back period. However, the informal calculation will cause facility managers to consider the long term benefits vs the short term loss, and this study is not intended to test a facility manager's ability to complete sophisticated equations, but to introduce facility managers to bounded rationality and framing issues differently.

Measuring the difference in responses:

We will examine the difference in responses between the conventional questions (initial price and annual electricity use), and the intervention. The intervention will include questions that ask the participant to calculate annual electricity costs, and pay back period. This is an intervention that will cause the participant to examine the question with long-term implications, instead of simply considering it as an initial loss of revenue.

CO2 Emissions:

We are testing reactions to cost, assuming cost is the primary catalyst for decisions by facility managers. By including CO2 emissions, we are able to reach those facility managers that may be influenced by potential CO_2 emissions as well as cost.

Appendix B: Research Study Detailed Charts

Cognitive Barriers to Energy Efficiency Decision Making in US Coast Guard Facility Management
Laura Delgado
Thesis Defense

CG Survey Results (n=8)

The barriers that exist in my organization, which prevent energy savings are:	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Lack of available funds	3	3	2	0	0
Lack of time	0	6	2	0	0
Command emphasis on initial cost savings	0	0	3	5	0
Procurement process	1	4	1	2	0
Conflict with Mission requirements	1	1	1	5	0
Existing procedures/standards	0	1	4	3	0
Unclear measure of success	1	2	2	3	0
Lack of incentives to save energy	1	1	1	5	0
Lack of resources	1	4	2	1	0
Lack of management buy-in	0	1	3	3	1
Risk of failure	0	1	2	5	0
Lack of necessary knowledge	2	3	1	2	0
Resistance to change	1	3	2	2	0
Perceived economic impacts	0	2	2	4	0
Other (please indicate in the box below)	2	0	6	0	0

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I believe that climate change is affecting the planet adversely.	2	4	2	0	0
My organization values short term cost savings over reducing energy consumption.	0	2	2	3	1
I personally value short term cost savings over environmental performance.	0	0	0	7	1
I always calculate pay back period prior to completing a procurement request.	1	2	3	2	0
I always calculate potential CO2 emissions prior to completing a procurement.	1	1	2	2	2

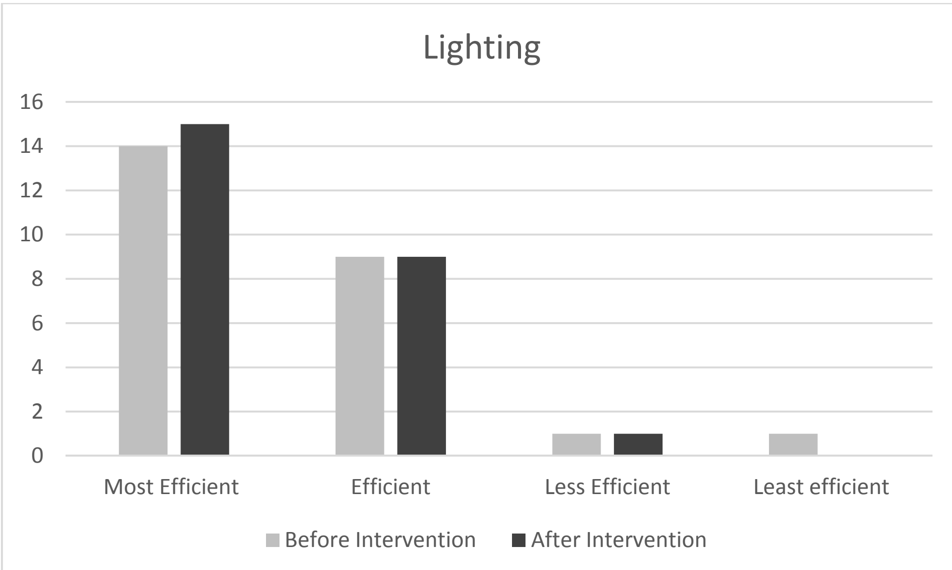
CG Facility Managers Interviews

		Participant 1			Participant 2			Participant 3		
Question		Risk Aversion	Loss Aversion	Status Quo Bias	Risk Aversion	Loss Aversion	Status Quo Bias	Risk Aversion	Loss Aversion	Status Quo Bias
1	What are the CG's energy reduction goals?		x		x				x	
2	What are your responsibilities as a Facility manager?				x					
3	What do you consider energy efficiency?	x				x				
4	How are facility systems monitored and benchmarked?	x			x			x		x
5	Do you think other Facility Managers make similar decisions to you?	x			x					
6	Do you see the utility bill for your facility?	x	x			x		x	x	
7	What efforts are made to educate base personnel on energy use?	x		x	x					
8	Can you describe the organizational structure of the facility management office?				x					
9	Can you describe your interactions with the regional energy manager in the last 6 months?	x	x		x			x	x	
10	Can you describe the maintenance process for equipment or energy efficient upgrades to your buildings?	x	x	x	x		x	x		
11	Can you describe the procurement process?	x	x		x	x				
12	When do you consider energy use when making purchases for equipment?	x			x	x				
13	How would you recommend making energy efficient decisions easier for facility managers?	x		x	x	x		x		

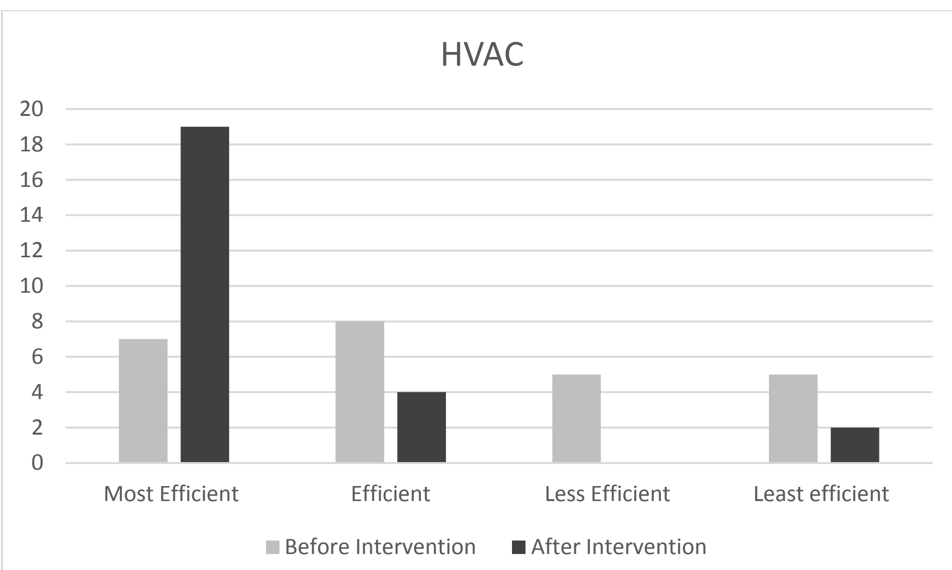
Three facility managers were interviewed, and the above chart shows how their answers to each question were coded (risk aversion, loss aversion, status quo bias).

Student Decision Scenarios (n=24)

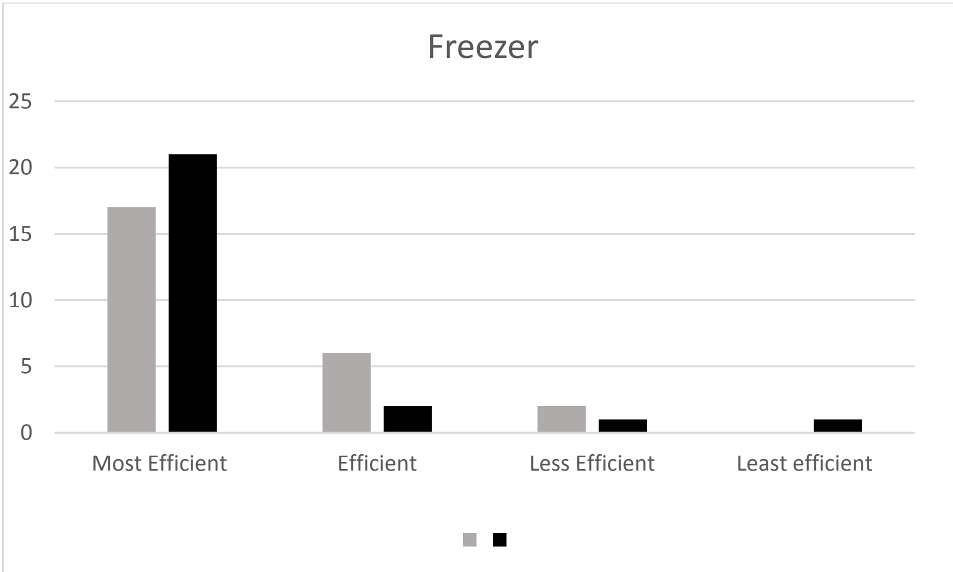
The first scenario concerned lighting, the students selected a lighting choice without an intervention. The next scenario asked the students to calculate pay back period (intervention) before selecting an option. In this scenario there wasn't a significant difference between the pre and post intervention questions (p=0.3).



The second scenario concerned HVAC, the students selected an HVAC choice without an intervention. The next scenario asked the students to calculate CO2 emissions (intervention) before selecting an option. In this scenario there was a significant difference between the pre and post intervention questions (p=0.001).



The third scenario asked the students to calculate pay back period from the beginning, with the next 'intervention' being CO2 emission calculations. Data was not significant, with a p=0.307.


Freezer
25
20
15
10
5
0
Most Efficient
Efficient
Less Efficient
Least efficient

Appendix C: Coast Guard Survey

VirginiaTech
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Certainty and the effect on Risk

Informed Consent Form

Introduction

This study attempts to collect information about building facility engineering within the Coast Guard.

Procedures

The questionnaire will take approximately 30 minutes or less. You will likely need a simple calculator, pen and paper. This questionnaire will be conducted with an online Qualtrics-created survey.

Risks/Discomforts

Risks are minimal for involvement in this study.

Benefits

There are no direct benefits for participants. However, it is hoped that through your participation, researchers will learn more about decisions in facility management.

Confidentiality

All data obtained from participants will be kept confidential. All questionnaires will be concealed, and no one other than then primary investigator and assistant researches listed below will have access to them. The data collected will be stored in the HIPPA-compliant, Qualtrics-secure database until it has been deleted by the primary investigator.

Compensation

There is no direct compensation for participating in this study.

Participation

Participation in this research study is completely voluntary. You have the right to withdraw at anytime or refuse to participate entirely without jeopardy to your academic status. If you desire to withdraw, please close your Internet browser.

Questions about the Research

If you have questions regarding this study, you may contact Laura Delgado, laurad89@vt.edu, (956) 342-2305, or Dr. Tripp Shealy (principal investigator), at tshealy@vt.edu.

By continuing onto the survey, I have given implied consent that I have read, and understood the above

Demographics

Please answer the following:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I believe that climate change is affecting the planet adversely.	O	O	O	O	O
My organization values short term cost savings over reducing energy consumption.	O	O	O	O	O
I personally value short term cost savings over environmental performance.					
I always calculate pay back period prior to completing a procurement request.	O	O	O	O	O
I always calculate potential CO2 emissions prior to completing a procurement request.	O	O	O	O	O

The barriers that exist in my organization, which prevent energy savings are:

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Lack of available funds	O	O	O	O	O
Lack of time	O	O	O	O	O
Command emphasis on initial cost savings	O	O	O	O	O
Procurement process	O	O	O	O	O
Conflict with Mission requirements	O	O	O	O	O
Existing procedures/standards	O	O	O	O	O
Unclear measure of success	O	O	O	O	O
Lack of incentives to save energy	O	O	O	O	O
Lack of resources	O	O	O	O	O
Lack of management buy-in					

	O	O	O	O	O
Risk of failure	O	O	O	O	O
Lack of necessary knowledge	O	O	O	O	O
Resistance to change	O	O	O	O	O
Perceived economic impacts	O	O	O	O	O
Other (please indicate in the box below)	O	O	O	O	O

Interested in contributing more to this study? Such as a half hour phone interview with researchers at Virginia Tech on Sustainable Decision Making? Please provide your email.

The interview will be about a half hour that will focus on how you made decisions in this survey. If you provide your email, you will be sent supporting documentation with the interview questions and logistic details, and you will have the opportunity to agree to participate in the interview or not. The purpose of the interview is to validate survey responses.

- O Yes
- O No

Before you are recruited to participate in the interview, the researchers will add supporting documentation to the Internal Review Board application via an amendment.

If you selected YES to the interview question above, you will be contacted separately via email after this study is completed. The interview will be recorded. It will begin with a few short questions about your work title and position, what type of decisions you make daily, and what things you consider before making decisions. In addition, we will refer to this survey and ask why you made each of these decisions. It should take approximately 30 minutes.

Please indicate your rate/rank:

What is your approximate level of experience in the Civil Engineering community?

- O 0-2 yrs
- O 3-5 yrs
- O 5-10 yrs
- O 10 yrs or more

Please indicate your age:

- O 18-24
- O 25-34
- O 35-44
- O 45-54

○ 55-64
○ 65+

Please enter the zipcode where you claim residency in the space provided.

Appendix D: Student Decision Scenarios

The following 6 six questions will lead you through a fictional scenario. In this scenario you are a US Coast Guard Facility Engineer assigned to Base Blacksburg, in Blacksburg, VA. There are two smaller bases inside of Base Blacksburg: Base Blacksburg East, and Base Blacksburg West. Each base is comprised of approximately 250 personnel. You are mainly concerned with the primary administrative building of each Base, which is about 10,000 SF. Your budget is tight with an annual operating expense of approximately $500,000 for maintenance.

You can assume that all other factors not discussed in the question are comparable, for example, all options will be considered for the same annual use, and installation cost, time, and labor.

The next 3 scenarios will involve Base Blacksburg East.

You must replace your supply of light bulbs for Base Blacksburg. You have a variety of different types of replacement lights to choose from:

Option A
Option B
Option C
Option D

Please select one of the above options and complete the Description of Items on the Procurement Request Form for 500 bulbs:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)
Item No. 1	Light bulbs			

Base Blacksburg East

The HVAC at your Base has failed due to end of service life. This system provides cool air to communication equipment critical to the mission, in addition to providing temperature controlled air to the 80-100 personnel who work in this building during normal work hours.

Option A
Option B
Option C
Option D

Please select one of the above options and complete the Description of Items on the Procurement Request Process for 1 HVAC system:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)
Item No. 2	HVAC			

Please describe why you chose the above answers:

Base Blacksburg East

The Galley freezer has been giving your technicians trouble for over a week now. The temperature is

struggling to stay low enough to keep the food at the correct temperature. Your technicians have found several rotted pipes and further indication that the freezer is near end of service life. You are informed it will probably last another week or so with heavy maintenance. You know that if that freezer fails the galley will lose approximately $6000 worth of food. You want to mitigate food and money loss and create as seamless a transition as possible.

Option A
Option B
Option C
Option D

Please complete the following steps:

. Calculate the expected annual electrical cost ($0.111/kwh x energy use given in kwh) for Options A, B, C, and D and enter in the table below.

. Determine the expected pay back period for Option B:

[(Initial B - Initial A)/(Electrical Cost A - Electrical Cost B)]

3. Determine the expected pay back period for Option C:

[(Initial C - Initial A)/(Electrical Cost A - Electrical Cost C)]

4. Determine the expected pay back period for Option D:

[(Initial D - Initial A)/(Electrical Cost A - Electrical Cost D)]

	Expect Electrical Cost (Energy Use x Electricity Rate)	Expected Pay Back Period
A		N/A
B		
C		
D		

After calculating the expected Electrical Cost and Pay Back Period, select an option and complete the description of Items on the Procurement Request Form for 1 freezer system:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)	Pay Back Period (years)
Item No. 3	Freezer				

Please describe why you chose the above answer:

Now consider you are the Facility Engineer for Base Blacksburg West. You're going to be presented with similar scenarios and decisions in the following questions.

Base Blacksburg West

You must replace your supply of light bulbs for Base Blacksburg. You have a variety of different types of replacement lights that you must order. Consider the following options.

Option A
Option B
Option C
Option D

Please complete the following steps:

1. Calculate the expected annual electrical cost ($0.111/kwh x energy use given in kwh) for Options A, B, C, and D and enter in the table below.

2. Determine the expected pay back period for Option B:

[(Initial B - Initial A)/(Electrical Cost A - Electrical Cost B)]

3. Determine the expected pay back period for Option C:

[(Initial C - Initial A)/(Electrical Cost A - Electrical Cost C)]

4. Determine the expected pay back period for Option D:

[(Initial D - Initial A)/(Electrical Cost A - Electrical Cost D)]

	Expected Electrical Cost (Energy Use x Electricity Rate)	Expected Pay Back Period
A		N/A
B		
C		
D		

After calculating the expected Electrical Cost and Pay Back Period, select an option, and complete the Description of Items on the Procurement Request Form for 500 light bulbs:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)	Pay Back Period (years)
Item No. 1	Light bulbs				

Please describe why you chose the above answer:

Energy use and Equivalent CO_2 Emissions: Base Blacksburg West

In 2014, the Coast Guard set a goal of reducing CO_2 emissions by 294,655 million tons. The actual reduction seen in 2014 was 49,000 million tons short, about 17%.

Operational Sustainability Performance Plan, USCG 2015.

The HVAC at your Base has failed due to end of service life. This system provides cool air to communication equipment critical to the mission, in addition to providing controlled air to the 80-100 personnel who work in this building during normal work hours.

Option A
Option B
Option C
Option D

Please calculate the expected CO_2 emissions (lbs) for each choice, enter the value, and select an option.

	Expected CO_2 Emissions in lbs (1.21 lbs x Energy Use)
A	
B	
C	
D	

After calculating expected CO_2 emissions for each option, select one option and complete the Description of Items on the Procurement Request Form:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)	CO2 emissions (lbs)
Item No. 2	HVAC				

Please describe why you chose the above answer:

Energy Use and Equivalent CO_2 Emissions: Base Blacksburg West

In 2014, the Coast Guard set a goal of reducing CO_2 emissions by 294,655 million tons. The actual reduction seen in 2014 was 49,000 million tons short, about 17%.

Operational Sustainability Performance Plan, USCG 2015.

The Galley freezer has been giving your technicians trouble for over a week now. The temperature is struggling to stay low enough to keep the food at the correct temperature. Your technicians have found several rotted pipes and further indication that the freezer is near end of service life. You are informed it will probably last another week or so with heavy maintenance. You know that if that freezer fails the galley will lose approximately $6000 worth of food. You want to mitigate food and money loss and create as seamless a transition as possible.

Option A
Option B
Option C
Option D

Please calculate the expected CO_2 emissions (lbs) for each choice.

	Expected CO2 Emissions in lbs (1.21 lbs x Energy Use)
A	
B	
C	

D

After calculating expected CO_2 Emissions for each option, select one option and complete the Description of Items on the Procurement Request Form:

PROCUREMENT PROCESS REQUEST RAPIDLY

	Description	Product Option (A, B, C, D)	QTY	Amount ($)	CO_2 emissions (lbs)
Item No. 3	Freezer				

Please describe why you chose the above answer