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The Costs of Not Using Green Design in the USAF: Would Using Green Building Design Have Resulted in Life Cycle Cost Savings?

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THE COSTS OF NOT USING GREEN DESIGN IN THE USAF: WOULD USING GREEN BUILDING DESIGN HAVE RESULTED IN LIFE CYCLE COST SAVINGS?

THESIS

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AFIT/GCA/ENV/07-M8

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Abstract

This study's purpose is to determine if using green building design would have resulted in life cycle costs savings for the United States Air Force. Green designs are those that employ steps to mitigate the impacts facilities have on the environment by using resources more efficiently than conventional design. The prevailing ranking system for green design in the United States is the Leadership in Energy and Environmental Design (LEED) rating system which evaluates facilities on certain characteristics, assigning point values that translate to non-certified, certified, silver, gold, or platinum ratings. The author attempts here to show how previous studies indicated the presence of construction cost premiums, savings in operating costs and environmental benefits from green design. The literature review also shows the extent the Air Force and Department of Defense have incorporated green building standards into current policy. After performing an analysis of Air Force building data, this study suggests that deciding to build green would not pay for itself based off of energy and environmental benefits alone.

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THE COSTS OF NOT USING GREEN DESIGN IN THE USAF: WOULD USING GREEN BUILDING DESIGN HAVE RESULTED IN LIFE CYCLE COST SAVINGS?

I. Introduction

Background

Green designs are those that employ steps to mitigate the impacts facilities have on the environment by using resources more efficiently than conventional design. (Gregory Kats, 2003) These designs also try to better use land and surveying to streamline the construction process by using natural terrain more effectively (i.e., minimize grading), alternative construction materials, and recycling construction waste materials. This paper will first address what most research suggests is the main deterrent to building green: that green design adds some percentage to the construction price, usually referred to as a cost premium. Next, we attempt to quantify benefits of green building.

Motivation

The purpose of this research is to compare the construction and operating costs of currently constructed Air Force MILCON facilities with estimated construction and operating costs for the same facilities if the Air Force had used green design. This comparison highlights whether initially using green design would have resulted in any life cycle cost savings.

This study will show the life cycle cost had the Air Force used green design and construction. It also provides information to aid new policies so that new construction may choose to follow these initiatives. In addition, the study will highlight some of the other benefits that could have been reaped by initially going green. Planners for the Air

Force will have more information on the added cost of green design and construction by showing the life cycle costs.

Standards

Looking at current Air Force and Department of Defense (DoD) policy, we will discuss why it so hard to quantify green design benefits. Also we will attempt to show the difficulty in conclusively answering some of the questions that need to be addressed about the benefits of green design. We will find if the Air Force and the Department of Defense are actively pursuing green design and if not, why not? We will also look at the rating systems that are in use to measure green design, whether the Air Force and DoD are following them, and how do they stack up to the standards.

Cost Premiums for Green Construction

A summary of current literature shows green construction cost premiums ranging from negative premiums (cost reductions), up to 15 percent compared to the cost to build conventionally. This research quantifies the cost premium in Air Force construction for sustainable design and investigates current literature which suggests a green design learning curve as companies gain experience in green design. As more experience is gained companies learn to construct green buildings for the same price as conventional construction. Some research also reports it is possible to eliminate any cost premium in green design by having a team working together early in the design and construction process.

Operating Cost Savings

We reviewed the relevant literature regarding the effects of sustainable design on operating costs, which primarily consists of utility usage. Experience has shown that by complying with sustainable design requirements buildings actually reduce operating costs. We perform a present value calculation to see if the operating cost savings actually offset any perceived cost premiums.

Environmental Benefits

Next we add in green design environmental benefits. If green design produces energy use savings, there are studies and factors that can estimate the amount of pollution prevented by these reductions. We use current literature and non-market evaluation to test and see how much society values these savings and what they are willing to pay in order to accomplish this. Some of the environmental benefits include reducing pollution, global warming and waste. These are some of the more difficult benefits to quantify, but by putting a dollar value to these benefits, decision makers will be able to make more informed decisions.

The next chapter looks at the current literature. Chapter 3 establishes a methodology for investigating the effects of green design, Chapter 4 discusses the findings from the analysis of Air Force green design implementation, and Chapter 5 discusses future research.

II. Literature Review

Standards

The United States Green Building Council developed the Leadership in Energy and Environmental Design (LEED) certification system to help provide guidelines on how to rank the extent to which a construction project used green building design (Kats, 2003:2). The LEED system evaluates facilities on the following characteristics: site selection, water and energy efficiency, materials use, indoor environment and health, and design innovation. Each area is assigned certain point values. All the points are added together to give the facility the final green rating, which can be non-certified, certified, silver, gold, or platinum (LEED-NC, 2005). The values from LEED-New Construction (NC V2.2) (2005) to achieve each certification level are in Table 1.

Certification	Minimum	Maximum
Certified	26	32
Silver	33	38
Gold	39	51
Platinum	52	69

Table 1: LEED Criteria

As seen in Table 1, in order to achieve the lowest level of certification, a building must achieve at least 26 points.

AF Sustainable Policy Letter 2001

Current Air Force policy, issued by the Air Force Civil Engineer, Major General Robbins (2001), requires organizations to apply green design in all phases of construction and operation of facilities. It also states that 20 percent of each of the Air Force's Major Commands (MAJCOMs) FY04 military construction program (MILCON) projects should be capable of achieving a LEED certification (Robbins, 2001). This Sustainable Development Policy (2001) also sets a goal of having all FY09 MILCON projects capable of achieving LEED certification. According to Doddington's (2006) Air Force Facility Energy Program briefing (personal communication with Nadja Turek, December 2006), MAJCOMs achieved or at least reported 27% of FY04 total MILCON achievable LEED design. The Air Force has a new Sustainable Policy being developed that was scheduled for release around mid-February 2007 (personal communication with Paula Shaw, December 2006). Upon release, we can determine if there are any changes in the current policy, such as more closely mirroring the EPACT 2005 standards.

Looking past 2004, the latest figures (personal communication with Dale Olson, January 2007) show the Air Force did not meet their FY05 goal of 36%. Table 2, provided by Dale Olson (personal communication, January 2007) from HQ USAF/A7CCM, shows that MAJCOMs estimated 53% of their total FY05 MILCON projects were capable of achieving LEED (at least 26 points) when reported in January 2006. After probing into the projects during the design phase the number dropped to 27%. Then finally post award estimated LEED certified projects dropped to 19% (AETC data not included yet). Although it originally looked like a high percentage of the buildings would make it to be LEED certifiable, further investigation and reporting showed it not to be the case.

FY05 MILCON Sustainable Design Results (projects capable of achieving LEED Certification)			
MAJCOM	as of Jan 06 -- **MAJCOM Projection LEED Certified** (capable of achieving 26 points)	as of Dec 06 -- **LEED Certified** (capable of achieving 26 points) **During Design**	as of Dec 06 -- **LEED Certified** (capable of achieving 26 points) **Post Award**
11th WG	NA	NA	NA
ACC	6/15 = 40%	3/15 = 20%	2/15 = 13%
AETC	13/15 = 87%	8/15 = 53%	TBD by AETC
AFMC	2/5 = 40%	2/5 = 40%	2/5 = 40%
AFSOC	1/1 = 100%	0/1 = 0%	0/1 = 0%
AFSPC	5/5 = 100%	3/5 = 60%	2/5 = 40%
AMC	2/5 = 40%	0/5 = 0%	0/5 = 0%
PACAF	0/9 = 0%	0/9 = 0%	0/9 = 0%
USAFA	NA	NA	NA
USAFE	4/7 = 57%	1/7 = 14%	3/7 = 43%
TOTAL	33/62 = 53%	17/62 = 27%	9/47 = 19%*
			* = Not including AETC
	FY05 GOAL 36%		

Table 2: FY05 MILCON Sustainable Design Results

Energy Policy Act (EPACT) of 2005

Passed by Congress in 2005, EPACT 2005 set up additional guidelines for energy performance in federal buildings. The EPACT (2005) requires a reduction in energy consumption which, when implemented, will earn LEED points. Executive Order 13123 had a goal of 30% energy savings (BTU/SF), which the Air Force accomplished (Annual Energy Report to Congress 2005). For 2006, all facilities must initially reduce energy consumption by 2%, then 2% each year until 2013 (per gross square feet, using 2003 as the base year) (EPACT, 2005). This act also mandates that all buildings be metered by 2012. Also building performance standards must be better than 30% over ASHRAE building standards (**EPACT, 2005**). The EPACT (2005) also mandates that 3% of all electrical energy consumed must come from renewable energy sources during the period

FY07 to FY09; in FY10 to FY12 5% must be from renewable energy and 7.5% renewable energy must be used from FY13 on. The credited amount of renewable energy compliance can be doubled if produced on-site at a federal facility, on federal lands, or on Native American land (EPACT, 2005).

<u>Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU)</u>

This document is signed by 21 federal agencies leadership representatives to include the DoD. The purpose is to commit the signatories to employing leadership in sustainable design to include construction, design, and operation of high performance and sustainable buildings (MOU, 2006). While it is not legally enforceable, it is a step in the right direction (MOU, 2006). The four goals of this document are:

-Reduce facility total ownership cost;
-Energy efficiency and water conservation improvement;
-Provide a safe, a healthy, and a productive environment; and,
-Sustainable environmental stewardship (MOU, 2006).

Agencies are to strive to incorporate the principles into their own agencies policy within 180 days of the signature date (MOU, 2006).

The main areas discussed in the MOU (2006) are:

1- Employment of Integrated Design Principles to include: integrated design (performance goals from design through the buildings lifecycle); Commissioning (total building);

2- Optimize Energy Performance to include: Energy efficiency (earn Energy Star 7 targets, reduce costs by 30% over ASHRAE standards, reduce energy by 20% from 2003 baseline in major renovations); Measurement and Verification (meters on all major renovations and new construction, measure and record performance using Energy Star 7 benchmarking tool, record lessons learned);

3- Protect and Conserve Water to include: 20% less indoor potable water consumption (above EPACT 2005); efficient landscaping usage and reduction in outdoor potable water usage by 50%;

4- Indoor Environmental Quality Enhancement to include: ASHRAE standards compliance in Ventilation and Indoor Environmental Quality (both for environmental controls and acceptable indoor air quality); develop a moisture control strategy; minimum of 2% daylight factor in 75% of occupied space for critical visual tasks, and have either automatic dimming controls or accessible manual lighting controls as well as glare control; use of low pollution emitting materials (such as adhesives, sealants, paints, carpet systems, and furnishing); minimum of a 72-hour flush-out for new construction, with maximum outdoor air usage (while not exceeding 60% humidity);

5- Reduce Environmental Impacts of Materials to include: Use of recycled and bio-based content; 50% recycling or salvaging of construction, demolition, and land clearing waste; elimination of Ozone Depleting Compound use.

April 27, 2006 DOD Facility Metering Installation Initiative

This initiative requires meters for all buildings meeting these conditions:

1- Cost effective

a) Cost of meter, installation, and ongoing maintenance, data collection, and management do not exceed 20% of yearly utility cost

2- Existing facilities 35,000 square feet and larger metered for electricity

3- 50,000 square feet and larger must be metered for natural gas

4- Steam metered at plants

5- New or renovation projects exceeding $200K metered for gas, electricity, and water. Also must have remote reading capability (Metering Initiative, 2006)

The goal is to reap the benefits of energy and cost savings through the collection of data (Metering Initiative, 2006).

<u>Executive Order 13423</u>

Since most of the research for this thesis was completed Executive Order (EO) 13423 (2007) which revoked Executive Order 13123 in January 2007 was released. This EO signed by the President of the United States, sets goals for all federal buildings. The following are the goals of EO 13423:

1- Reduce energy by 3% annually

2- One half of required renewable energy consumed in a fiscal year should come from new renewable sources

3- Reduce water consumption by 2% annually

4- Paper should consist of at least 30% post-consumer fiber content

5- New construction and major renovations should comply with the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding

While a lot of the policy in this section is redundant in requirements, it shows that Air Force Leadership sees the value in energy efficiency and green design. Whether the goals of the policies are met remains to be seen, but we will turn our attention to some of the literature about the barriers and benefits of building green.

Cost Premiums for Green Construction

Studies looking at green design cost premiums vary in their results. Some researchers have found added costs for green construction while other researchers have been neutral regarding the added costs associated with green design and building construction. A few examples of the different estimates follow.

Berman (2001), in interviewing six California developers, found they all estimated building green has a cost premium of 10 to 15 percent. Kats (2003) looked at 33 USGBC certified LEED projects and found an average 1.8% cost premium for green buildings (Kats, 2003). Warnke (2004) also found a similar 2% premium for green building in the Department of Defense. Morris *et al.* (2005) concluded there was no significant difference in the cost of constructing a green facility as compared to a conventional facility. Kats reported that the cost premiums for green design decline as project management teams gain experience with green building (Kats, 2003). A GSA LEED cost study found that a building (depending on the type) can be constructed anywhere in the range of negative cost premium to an 8.1% cost premium, depending on the certification level and the building type (GSA, 2004). The Army commissioned a study to determine the cost of meeting the new EPACT 2005 goals and the resulting LEED certification that would be achieved (Schneider *et al.*, 2006). They found a premium range of 2 to 8 percent. Other sources believe that with the correct design and planning LEED can be achieved with little or no extra cost (personal communication with Lance Davis LEED Accredited Professional, November 2006, U.S. DOE 2003). Now we will look at the cost premium literature and evaluate the methods used to reach their conclusions and their applicability to the Air Force.

The Costs and Financial Benefits of Green Buildings – Kats

The most often cited source in literature for cost premiums is a study done by Gregory Kats for California's Sustainable Building Task Force entitled "The Costs and Financial Benefits of Green Buildings" (Kats, 2003). This study looked at the cost premium associated with green design and then took a present value of all benefits associated with green design. In this section we focus on the cost premiums this study found.

This study looked at 33 LEED registered projects (25 office and 8 school buildings) (Kats, 2003). These 33 projects were chosen because they had both green and conventional design cost data (Kats, 2003). All projects had actual or projected completion dates between 1995 and 2004 (Kats, 2003). Table 3 shows the cost premium results for this study.

Kats (2003) Green Cost Premiums by Certification Level	
Level	Average Cost Premium
Certified	0.66%
Silver	2.11%
Gold	1.82%
Platinum	6.50%
Average of 33 Buildings	**1.84%**

Table 3: Green Cost Premium (Kats, 2003)

Kats found that on average to build to a Silver or Gold LEED certification requires approximately a 2% premium (Kats, 2003). Kats (2003) found that the majority of the costs are "soft costs," such as A&E (architecture and engineering). Also, the earlier green design is incorporated into the design, the lower the cost (Kats, 2003).

Kats (2003) found some of the problems with measuring the costs of green design are: USGBC doesn't require cost info be included with LEED documentation; most construction doesn't separate out green options in design; often the cost information is proprietary; comparing between green and other buildings doesn't give you an entirely accurate comparison because each building is different; some green buildings are showcase projects (more expensive); there is a learning curve associated with green design construction so the first couple projects for a firm or organization may be more expensive; and green design is somewhat new to industry.

Some potential problems of relying on this study include a relatively small sample size spread over 9 years. The study was also confined to California, and while we can use the data, we must be careful not to draw far reaching conclusions without considering other factors that may affect the cost of a building, such as climate, location, building materials, etc.

While Kats (2003) did find a cost premium for this sample he also explains that Pennsylvania, Portland, and Seattle all have shown declining cost premiums for LEED as teams gain experience. He explains this in greater detail in his report.

However, because of the sample size, it is questionable if the results would be statistically significant (some of the comparisons are only between two buildings). In addition, we followed up by calling Seattle's Sustainable Design office and found that while it is true they do have declining costs, the first group of buildings didn't have green requirements until late in the design, which make it hard to make an accurate comparison (personal communication with Peter Dobrovolny, January 16, 2007). Mr. Dobrovolny still believes that the experience gained by the design teams will make costs associated with green design negligible (personal communication, January 16, 2007).

Costing Green: A Comprehensive Cost Database and Budgeting Methodology- Morris and Matthiessen

Probably the second most cited work on green design cost premium would be "Costing Green: A comprehensive cost database and budgeting methodology." The goal of this research was to compare projects that were LEED seeking with non-LEED seeking projects (Morris *et al.*, 2004). Davis Langdon Adamson, the company that performed this study, had a database that contains 600 distinct projects located in 19 states (Morris *et al.*, 2004). They tracked construction costs and design parameters of all buildings in their database (Morris *et al.*, 2004). The database also stored what LEED credits were achieved and the costs to obtain them if available (Morris *et al.*, 2004).

For this project, Morris *et al.* (2004) evaluated 61 projects seeking LEED certification. The most common building types, making up 45 of the buildings in their database, were libraries, academic buildings and laboratories (Morris *et al.*, 2004). After normalizing the cost for time and location Morris *et al.* (2004) took these 45 buildings and compared them to 93 projects not seeking LEED accreditation. They found no statistically significant difference between LEED and non-LEED buildings (Morris *et al.*, 2004). All costs would have been within the range of any randomly drawn sample of buildings (Morris *et al.*, 2004). The main contributor to this finding is a high standard deviation, which is one of this study's weaknesses (Morris *et al.*, 2004).

Morris *et al.* (2004) also found that by building types, libraries, academic buildings, and laboratories all had no statistically significant difference in cost per square foot. When they looked only at branch libraries (less than 40,000 square feet), those libraries seeking accreditation were actually less expensive (Morris *et al.*, 2004). Another noteworthy point they identified is that most of these branch libraries were constructed by the same owner. It is possible that there is selection bias in the data and it is also possible there is a cost savings because of a learning curve (Morris *et al.*, 2004).

Morris *et al.* (2004) also identified the factors that influence the feasibility and the cost of green design as:

1-"Demographic Location
2- Bidding Climate and Culture
3- Local and Regional Design Standards, including codes and initiatives
4- Intent and Values of the project
5- Climate
6- Timing of Implementation
7- Size of building
8- Point Synergies" (Morris *et al.*, 2004:13-14).

Morris *et al.* (2004) found that any building will achieve around 12 credits based on local codes. Their analysis shows that with little or no additional cost, projects can achieve up to 18 credits (Morris *et al.*, 2004). The non-LEED buildings from this study qualified for an average of between 15 and 25 points within their design. One project did actually have enough points (29) to earn a LEED rating (Morris *et al.*, 2004).

The study reached four main conclusions:

- "There is a very large variation in costs of buildings, even within the same building program category.
- Cost differences between buildings are due primarily to program type.
- There are low cost and high cost green buildings.
- There are low cost and high cost non-green buildings."(Morris *et al.*, 2004: 23)

From their analysis Morris *et al.* (2004) concluded that many projects can achieve sustainable design with little or no increase in their initial budget, and the cost for sustainable design falls within the normal range for similar type buildings (Morris *et al.* 2004).

Morris *et al.* (2004) find it difficult to control for factors that may more effectively illuminate when and where cost savings exist. They suggest, for instance, that researchers find difficulty differentiating between building usage and program type as they make these comparisons (Morris *et al.* 2004). Despite these neutral findings, Morris *et al.* (2004) state that most research concludes that early incorporation of green principles in the design and planning stages eliminate any significant cost premium because the cost of green is budgeted to completion with the green principles integrated as a required part of the project. Typically added costs from green design usually result from changes made to already complete systems or designs (Morris *et al.* 2004).

Some of the areas that need to be considered when applying this study to Air Force construction are that they only looked at whether or not the project had the intent to seek LEED (Morris *et al.* 2004). Also realize that some projects that weren't seeking LEED accreditation would have earned some LEED credits as well (Morris *et al.*, 2004). Also it is important to find the extent government buildings can compare to others in these types of studies. It is important to investigate whether different requirements and codes will add cost or complexity. The next two studies were conducted by government agencies, the GSA and the Army, and therefore take into account requirements and codes that are specific to the federal government.

<u>GSA LEED Cost Study Final Report – Steven Winter Associates, Inc</u>.

The General Services Administration (GSA) (2004) study looked at two different scenarios, a new mid-rise Federal Courthouse and a mid-rise federal office building modernization, for their LEED cost study. They estimated the cost for both types of buildings, both conventionally and with green design incorporated (GSA, 2004).

In order to evaluate the GSA study, we will first look at their key assumptions.

1- Building types were Courthouse and Office Building

2- Construction was New (Courthouse) and renovation (Office Building)

3- Buildings were based in the Washington D.C. area

4- GSA's criteria satisfy some LEED requirements so they did not include these in the study premium.

a) Commissioning (already required for GSA projects)

b) Energy Efficiency from ASHRAE standard

c) GSA encourages under floor air delivery systems

d) Recycled-content, GSA requires projects to recycle to maximum extent possible.

5- GSA did not evaluate any variability in size of the buildings. They mention that the soft costs could be considerably higher especially in smaller buildings.

6- Costs based on LEED Version 2.1

7- The assumed start dates for the courthouse and office building were Nov 2003 and Oct 2003 respectively (GSA, 2004)

They estimated that the Courthouse would originally cost approximately \$220/gross square feet (GSF) and the Office Building renovation would cost around \$130/GSF (GSA, 2004). They took a low and a high cost for the Courthouse scenario for each LEED certification level (certified, silver, and gold) (GSA, 2004). While they took a minimum renovation and a full renovation for the Office Building to calculate the LEED rating, the authors used the LEED rating scale plus two points for the minimum score for each of the certified levels in order to ensure they achieved the desired level (GSA, 2004). The construction cost impacts are outlined in Table 4.

GSA Study (2004)						
	New Courthouse					
	Certified		Silver		Gold	
	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
LEED Construction Cost Impacts						
$/GSF	$ (0.76)	$ 2.18	$ (0.07)	$ 9.57	$ 2.97	$ 17.79
%Change	-0.40%	1%	-0.03%	4.40%	1.40%	8.10%
LEED Soft Cost Impacts						
Expert Consultants ($/GSF)	$ 0.41	$ 0.46	$ 0.41	$ 0.55	$ 0.61	$ 0.80
Experienced Design Team ($/GSF)	$ 0.43	$ 0.45	$ 0.44	$ 0.54	$ 0.56	$ 0.73
	Office Building Modernization					
	Certified		Silver		Gold	
	Min Facade	Full Facade	Min Facade	Full Facade	Min Facade	Full Facade
LEED Construction Cost Impacts						
$/GSF	$ 1.76	$ 2.73	$ 3.94	$ 5.55	$ 10.56	$ 10.22
%Change	1.40%	2.10%	3.10%	4.20%	8.20%	7.80%
LEED Soft Cost Impacts						
Expert Consultants ($/GSF)	$ 0.41	$ 0.41	$ 0.44	$ 0.49	$ 0.70	$ 0.69
Experienced Design Team ($/GSF)	$ 0.35	$ 0.35	$ 0.38	$ 0.44	$ 0.59	$ 0.58

Table 4: GSA Study Premium Results

This study also looked at added costs due to “soft costs” which encompass non-construction costs such as design, overhead, meetings and documentation. They looked at two scenarios to investigate the price differences between a team experienced in LEED design (prior experience) and an expert consultant approach (GSA, 2004). The fees were hourly for expert consultation and a combination of a fee increase and hourly rate for the experienced team (GSA, 2004). See the results in Table 4.

With GSA’s 2.5% budget allocation for LEED design (GSA, 2004) Table 4 shows that at least some of the range for all courthouse scenarios can be built for less than the budgeted amount. Also the office building modernization falls within the budgeted range for certified buildings.

This study did not perform a cost benefit analysis on the LEED measures. It was purely a first cost evaluation (GSA, 2004). GSA chose the low or no cost LEED options first and then considered higher cost options with the most benefits (GSA, 2004). They also looked at synergistic credits, where integrating one or more sustainable design technologies are able to achieve multiple “synergistic” LEED points (GSA, 2004). When building to green standards, should first cost be most important or should the lowest life cycle cost trump any higher cost premiums? This will be discussed later. Lance Davis, a GSA LEED Accredited Professional and architect, strongly believes that it is possible to build to LEED certified or silver level without adding any cost by deciding early to incorporate green design considerations and to have a knowledgeable team (personal communication, November 2006).

Though interesting, the study only looks at two types of buildings. Because it only has two types of buildings in one location and has made some assumptions that may not hold true for all industries, it is important to critically analyze the study to see what relationship it can have with other building types, locations, and requirements. While one of the assumptions of not including the costs of under floor air delivery systems might not be significant because that requirement is not necessarily needed to be LEED certified, commissioning costs should be evaluated and possibly added to any other estimate. Also no allowance was made for different-sized buildings, so this also may have an affect on future project estimates.

Implementation of the U.S. Green Building Council's LEED as the Army's Green Building Rating System-Schneider and Stumpf

The Army LEED study attempted to look at how SPiRiT, the Army's unique sustainable design ranking system, would translate into LEED scores (Schneider *et al.*, 2006). In order to accomplish this they enlisted the help of LEED Accredited Professionals at Georgia Tech Research Institute (GTRI) (Schneider *et al.*, 2006). A detailed analysis of SPiRiT will not be attempted here as it is beyond the scope of this study. More pertinent to this study is the LEED ranking the projects would have attained and any additional costs or savings that would have been incurred or achieved. GTRI did not carry out a detailed investigation into each project, but rather compared the SPiRiT criteria to LEED credit requirements to estimate similarities and achievable LEED credits (Schneider *et al.*, 2006). Schneider *et al.* (2006) based their assessment of LEED projects in the Army on this GTRI evaluation (Schneider *et al.*, 2006).

Schneider *et al.* (2006) compares different building types, different locations, and their ability to reach certifiable levels. This study also includes high and low cost credits and likely and unlikely credits based on history (Schneider *et al.*, 2006).

The ratings Schneider *et al.* (2006) established fit into four categories: LEED Rating Estimated, LEED Rating Potential, LEED Rating Probable, and LEED Rating Adjusted. The main differences between these ratings are described in Table 5.

Army Study Estimation Definitions and Credits

ESTIMATED RATINGS	KEY	ADDITIONAL CREDITS	AREA
Estimated	1:1 Translation	2	Innovation and Design Process
		1	Innovation in Design
		1	LEED Accredited Professional
Probable	All "Estimated" plus GTRI identified probable credits on sample projects	1	Enhanced Refrigeration Management
Potential	All "Estimated" plus "Probable" plus credits typically earned by Army projects		
Adjusted	All "Probable" plus required DOD, Federal, or Army regulations that translate into earned LEED credits	Up to 6	EPACT 2005 Energy Conservation targets

Table 5: Army Study Ratings Definitions (Schneider *et al.*, 2006)

Within the sampled MILCON projects (40) Table 6 shows what LEED rating was most likely to apply to each project. Thirty five percent of projects were, according to the GTRI estimate "probable," for achieving a silver or gold rating within their programmed amount (Schneider *et al.*, 2006). This used their rating scale of "estimated," which is a one to one translation of SPiRiT credits to LEED credits, plus the credits GTRI identified as probable of achieving. Also according to the Table 6, if all projects were built to required DOD, Federal, or Army regulations (adjusted rating from Table 5), 57.5% of projects would be able to reach at least a LEED Silver rating (Schneider *et al.*, 2006). This doesn't specify if there is a premium to achieve this rating, so we have to assume that if there are requirements, funds should be sufficiently allotted to meet the standards. Thus, a good area of research would be in what it would take to get the other 32.5% capable of achieving LEED certification.

Schneider *et al.* (2006) also sought the added cost to meet the new EPACT 2005 and Army Energy standards. They discuss that with limited data on the 40 projects they selected, they had to reference expert opinion, LEED cost studies, current literature, building studies, the Whole Building Design Guide, along with other similar useful resources (Schneider *et al.*, 2006). They estimate the first cost increase (due to the costs of building to higher energy efficiency) will be between 2 and 8% in order to enable them to reach the 30% energy goals (Schneider *et al.*, 2006). Their conservative payback for such an initiative would be less than 10 years (8.6 years is the exact figure with HVAC first cost increase of 10% and energy decrease of 30%) (Schneider *et al.*, 2006).

Army Study LEED Conversions

	SPiRiT Ratings		LEED Ratings							
			Estimated		Potential		Probable		Adjusted	
Platinum	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Gold	22	55.00%	3	7.50%	9	22.50%	7	17.50%	12	30.00%
Silver	15	37.50%	4	10.00%	15	37.50%	7	17.50%	11	27.50%
Bronze/Certified	3	7.50%	11	27.50%	15	37.50%	9	22.50%	15	37.50%
No Rating	0	0.00%	22	55.00%	1	2.50%	17	42.50%	2	5.00%

Table 6: Army Study LEED Conversions (Schneider *et al.*, 2006)

The study based the energy savings on HVAC first costs (Schneider *et al.*, 2006). They admit that basing this study on just HVAC has its shortcomings (Schneider *et al.*, 2006). A regression analysis of energy cost drivers and including all energy costs would probably add more reliability to this estimate. Also, often when integrated design practices are utilized for sustainable design projects, the size of the HVAC is reduced, thus reducing first costs and decreasing payback time.

This study also analyzed which credits could be attained with the least cost, given designers followed the DOD, Federal, and Army requirements (Schneider *et al.*, 2006). The total credits for these requirements equal 39, including an additional Water Efficiency Landscaping Credit in order to achieve Gold certification (Schneider *et al.*, 2006). This analysis is careful to point out that achieving gold certification does not necessarily fall within the current Army budget (Schneider *et al.*, 2006). A good follow-on study would be to find the cost of Gold certification.

This study shows that it is possible to achieve LEED certified ratings within the program amount (Schneider *et al.*, 2006). There is still room for analysis to find out what exactly drives the cost and to find if a cost premium truly exists. Some of the research presented in this thesis suggested a premium while some of the results show they are reaching LEED for no premium.

Making the Business Case for Sustainable Design in the Department of Defense – Warnke

Warnke (2004) investigated the cost premium for Department of Defense projects. He did show a cost premium of 2% for LEED certification but also showed a 9.2% standard deviation (Warnke, 2004).

The difference in cost was obtained by subtracting the initial planning cost from the final contract cost and dividing this by initial planning cost (Warnke, 2004). This method permits too many variables to enter the equation. The supporting argument for this approach was that because planning estimates were based on conventional construction, any increase would be attributable to sustainable design (Warnke, 2004). The author did not take into account the normal difference between planned and final costs. Also if green design was planned from the beginning, without any additional funding, this could suggest that these projects were built within conventional design budgets.

With the wide variance and the method to estimate the premium, another study is needed to show what if any cost premium is attributable to sustainable design in the Department of Defense.

Operating Cost Savings

While construction cost is important to consider, Nornes (2005) found that the initial construction cost of a building is usually only 2-10% of the life cycle costs. The other 90-98% are operation, maintenance, financing and staffing (Nornes, 2005). U.S. Department of Energy (2003) showed that first costs, or construction costs, account for only 5-10% of total life cycle costs and that from 60 – 80% of the costs are Operation and Maintenance (O&M) costs.

An analysis of 116 office buildings in Australia showed life-cycle costs to be 24% energy, 19% cleaning, 10% general fees, lifts and escalators 9%, and 8.5% for air-conditioning and ventilation (Macsporran and Tucker, 1996). Sterner (2002) analyzed this study and three others to find and rank the most significant annual costs as energy, cleaning, general fees, air conditioning and ventilation, lifts, and escalators respectively.

California's sustainable building task force study concluded that an investment of 2% in green technology over 20 years would net 20% life cycle savings, 30% from energy savings and 70% from increased productivity and health values (Kats, 2003). Kats (2003) took 60 LEED rated buildings (5 in CA) and compared them to conventional buildings and found that on average they are 25-30% more energy efficient. Table 7 shows the ranges of savings.

Reduced Energy Use in Green Buildings

	Certified	Silver	Gold	Average
Energy Efficiency above standard codes	18%	30%	37%	28%
On-Site Renewable Energy	-	-	4.00	2%
Green Power	10%	-	7%	6%
Total	28%	30%	48%	36%

Table 7: Reduced Energy Use in Green Buildings (Kats, 2003)

According to Cofaigh *et al.* (1999) one can reduce energy consumption 30-40 percent with no additional cost, just by having the correct building orientation and the right shape. Literature seems to assert that any additional up-front cost of implementing green design would returned by energy savings. Therefore reducing energy consumption is a prime method for added cost savings.

U.S. DOE (2003) lays out different sustainable techniques and their paybacks in years and dollars. They look at water, landscape, maintenance, churn, energy, O&M, liability and risk, productivity and health, as well as societal and environmental benefits. This study developed energy models for two federal buildings, one that simply met American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standards and the other a sustainable model (U.S. DOE, 2003). The results showed that first cost increase was around 2% and annual energy cost savings of around 37% (U.S. DOE, 2003). The payback was around 8.7 years, with a net savings over the lifetime of $23,000 assuming a 25-year lifetime for the buildings (U.S. DOE, 2003). This study only looked at two hypothetical models, so caution must be used when applying these numbers.

Other than just energy savings there are potential savings due to green design in churn rate and commissioning. Churn rate is how often people move internally (U.S. DOE, 2003). Commissioning is the process of testing the performance of the building to insure it is operating at its potential (U.S. DOE, 2003). This study will not specifically include these in our present value figures, but will note them as contributors to savings as a result of green design.

The U.S. DOE (2003) said that the churn rate in government buildings is 27%, as compared to 44% in the commercial sector. This is figured for a 20,000 square foot building with 100 occupants and assumes that by using moveable wall partitions and raised flooring, cost savings from reducing annual churn could range between $35,000 and $81,000 (U.S. DOE, 2003).

Kats (2003) assumed a 30% churn rate for state of California employees. The study also estimates a savings of $90 per year per employee for raised floors and moveable partitions (Kats, 2003). It is important to remember that there are more than just office buildings in the Air Force. Schools, maintenance facilities, and training facilities for example may not have the churn rates shown here.

Commissioning is a required prerequisite for LEED certification (LEED-NC, 2005). Kats (2003) estimates the cost of commissioning to be 2-4% for buildings costing less than $5 million and 0.5 to 1% for buildings costing more than $50 Million. Kats (2003) also shows that for six recent LEED office buildings, the commissioning costs were from 0.3 to 0.6% of construction costs. GSA (2004) estimated commissioning to be $ 0.6-0.8/GSF. U.S. DOE (2003) estimates commissioning costs to be anywhere from 0.5 to 1.5 percent of total construction costs.

U.S. DOE (2003) completed a hypothetical scenario and estimated a savings of 10% on energy with a payback of an average of 1.4 years for commissioning alone. Kats (2003) uses a more conservative 5% per year estimate for O&M cost reductions, which equals a savings of $0.68 per square foot per year and a 20-year present value savings of $8.47 per square foot. Some of Kats (2003) assumptions for this study were a 5% real discount rate, an inflation rate of 2% and he also assumed that costs of energy and labor as well as benefits would rise at the rate of inflation (Kats, 2003).

Environmental Benefits

California's sustainable building task force study concluded that an investment of 2% in green technology over 20 years would net 20% life cycle savings, 30% from energy savings and 70% from increased productivity and health values (Kats, 2003). This is expressed in Figure 1. For this section we are going to explore specifically the health and environmental issues that affect the non-market value of green design.

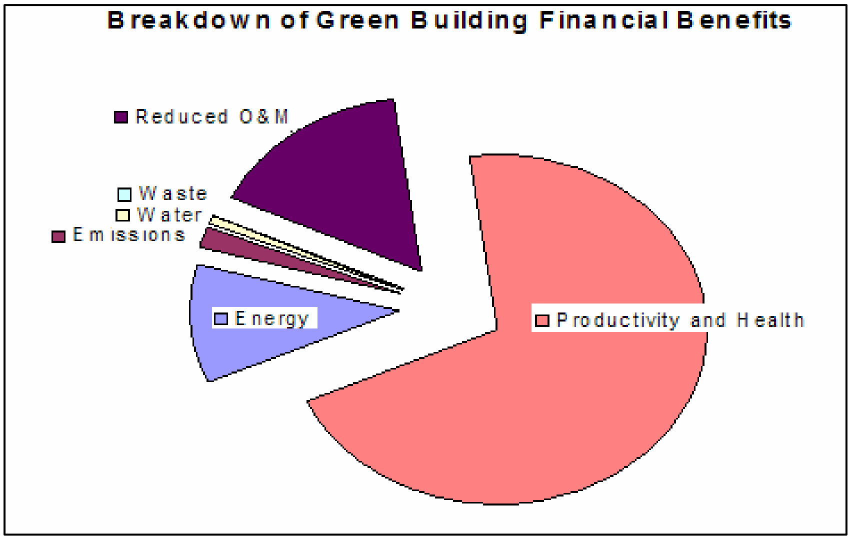

Figure 1: Breakdown of Green Building Financial Benefits (Kats, 2003)

One of the hardest benefits to quantify is the environmental benefit. In order to do so, it is necessary to first investigate environmental impacts. This paper attempts to use the current literature to quantify environmental costs of pollution. First we will see where negative impacts originate.

<u>Negative Impact Origination</u>

Junilla (2004) finds that life cycle emissions for U.S. buildings are 13% for materials, 5% for construction, 70% for use, 9% for maintenance, and 3% for end-of-life. Breslow (2004) finds that electricity accounts for approximately 33% of greenhouse gas emissions. Kats (2003) finds that buildings consume approximately 70% of the electricity generated in the United States, along with much of the materials, water, and waste in our economy. Junilla (2004) found the major environmental impacts come from electricity in outlets, Heating Ventilation Air Conditioning (HVAC), and lighting. These three contribute 10 to 30% to total environmental impacts (Junilla, 2004). This researcher looked at climate change, acidification, summer smog, eutrophication, and heavy metals as indicators for environmental impact (Junilla, 2004). For each of these respectively, she used the compounds carbon dioxide (CO_2), sulfur dioxide (SO_2), ethylene gas (C_2H_4), phosphate (PO_4) and lead (Pb) (or their equivalents) emissions as a guide to measure the environmental impacts (Junilla, 2004).

Kats (2003) assumes that because they are burning fossil fuels to generate electricity, lowering electricity usage will lower electricity emissions of pollutants. The three areas of damage that Kats (2003) investigates are health, environment and property. Kats (2003) measures the impacts of 4 pollutants (nitrogen oxides [NOx], particulates [PM10], sulfur dioxide [SO2] or sulfur oxides [SOx], and carbon dioxide [CO2]).

There are two types of energy: source energy (raw material), and site energy (what we consume). Source energy drives pollution because no matter what you consume you still produce the energy (Romaine, 2007). Only 33% of our energy is consumed as useful energy. The remaining 67% is lost to the environment as heat. Of that 33%, more is lost in transmission. So on average it takes three units of electricity to create one unit of usable electricity (Romaine, 2007).

Romaine (2007) finds that 50% of U.S. source energy is made by coal, while another 20% is made by natural gas. Usually these are the two fuels that are burned to make steam that drives the turbine in an electricity plant (Romaine, 2007). Regardless of fuel used for electricity production the conversion process is about 33% efficient (Romaine, 2007).

Under our current regulatory system if there are pollution regulations, the cost is added to the production cost of the polluter (Synapse, 2006). These regulations help reduce health and environmental damage, but some of the costs will definitely be passed on to the consumer. If there are no regulations, the cost is solely born by society and not the polluter (Synapse, 2006). This section explores the possible costs of pollution, whether they are born by the original energy production or born by society at large. The costs of pollution will be paid for by either dealing with its negative health consequences or reducing its harmful effects before it leads to negative consequences. Since we are all in some way a polluter, the Air Force should decide whether it will pay part of the cost of reducing this pollution. The government has an inherent responsibility to lead the way in reducing energy pollution by building more energy efficiently.

Effects

Now that we have seen where the effects originate, we will now see what damage they do to both health and the environment. Table 8 outlines the main pollutants and their human health and environmental effects.

Health and Environmental Effects of Pollution		
Pollutant	**Human Health Effects**	**Environmental Effects**
SO2	premature death, respiratory illness, aggravate heart disease and asthma, can form PM	acid rain component, damages forests and crops, changes soil makeup, makes streams and lakes unsuitable for fish, changes natural variety of plants and animals in ecosystem, accelerates the decay of building material and paints, precursor to PM, regional haze component (reduces visibility)
NOx	cause or worsen respiratory disease (e.g. bronchitis), aggravate heart disease, premature death, form PM	acid rain contributor, regional haze component, forms ozone (O3), fine particulates precursor, affects water quality leading to oxygen depletion and aquatic life decline
O3	O3 or ozone irritates lung airways, aggravates asthma, can cause permanent damage with repeated exposure, reduced lung capacity, increased respiratory illness susceptability (e.g. pneumonia and bronchitis)	hinders plants ability to produce and store food, makes plants more susceptible to disease, insects, other pollutants and weather, damages leaves of trees and plants, reduces crop yield, component of regional haze
PM	bronchitis, asthma, decreased lung function, heart disease, premature death	major cause of regional haze, acidic lakes and streams, changes nutrient balance in coastal waters and river basins, depletes soil nutrients, damages forests and crops, can damage stone and other materials
CO2	any effects from climate change	green house gas, climate change

Table 8: Health and Environmental Effects of Pollution (Synapse, 2006)

Knowing the effects is important, but we need to investigate who will pay for them, how much should we pay and how can we lessen the impact to society as a whole for limited costs. The next section attempts to put a price on four of these major pollutants.

How Do We Quantify the Effects?

As discussed earlier, burning fossil fuels produces pollution. Kats (2003) identifies three ways of valuing the costs of this pollution:

> 1) "The direct costs of pollution effects on property, health and environment can be calculated and then allocated on a weighted or a site-specific basis.
>
> 2) The cost of avoiding or reducing these pollutants can be used as a way to determine market value of pollutants.
>
> 3) The market value of pollutants can be used if there is an established trading market" (Kats, 2003: 30).

The direct costs of pollution effects on property, health, and environment would be the best method of quantifying the costs of pollution if it were possible to truly understand all the residual effects, but it would be almost impossible to calculate. We will look at the last two options to evaluate the market value for four pollutants found to be among the most harmful (Kats, 2003; Junilla, 2004).

Some emissions are regulated through a "cap and trade" system which uses a market based approach to pollution control. Because some pollutants are regulated, businesses producing these pollutants must stay below a certain threshold. If they are below this level they can sell any unused allowances on a market to other companies that don't want to spend the money to prevent their pollution. Two that we will look at are NOx and SO_2

(Synapse, 2006). We will also outline approaches for quantifying the market costs of PM particulates and CO2.

Sulfur Dioxide (SO2)

Even though SO2 and NOx have established markets it is still difficult to obtain a definite price because of the volatility of any exchange market. We will look at avoidance costs (also referred to as abatement which is the cost incurred to avoid emitting the pollutants), allowances (firms estimate what they will need to put aside to purchase allowances or to buy equipment to reduce pollution for planning purposes based on market history, current trends, and changing factors that affect prices (e.g. changing costs of gasoline)), and current market prices.

One example of the range of costs comes from Cantor Environmental Brokerage (2004) who estimated the environmental cost of one ton of sulfur dioxide is about $4000 while it only costs between $150 and $200 a ton to eliminate the sulfur dioxide emissions. Synapse (2006) did a study of environmental costs. They consulted many studies and compiled them in a single report. Table 9 shows most of these studies results and the extremes in pricing as well.

Synapse Studies - Different Costs of SO2 ($/ton)				
Study Name	Low	High	Avg	Base Year
ABATEMENT				
EPA	$ 579	$ 706		1995
Burtraw (abatement costs)			$ 560.00	2005
EPA (cost of wet scrubbers)	$ 200	$ 5,000	$ 600.00	2001
EPA (cost of dry spray)	$ 150	$ 4,000	$ 600.00	2001
ALLOWANCE				
Burtraw			$ 700.00	2004
EPA (weighted avg)			$ 702.51	2005
Brokerage reported trades	$ 705	$ 730		2005
Evolution Markets (2005)			$ 885.00	2005
Argus Air Daily (2005)			$ 885.00	2005
Platts (2005)			$ 882.50	2005
Cantor-Fitgerald (2005)			$ 880.00	2005

Table 9: Different Costs of SO2 (Synapse, 2006)

Predictions are that for the next couple of years the SO2 price will rise then drop in 2009 (Synapse, 2006). Synapse (2006) assumes the costs of SO2 to be $880/ton in 2006 and a levelized price of $1,239/ton for 2010 to 2020 (Synapse, 2006).

Nitrogen Oxide (NOx)

Table 10 is the compilation of the studies investigated by Synapse (2006) for NOx costs.

Synapse Studies - Different Costs of NOx ($/ton)				
Study Name	Low	High	Avg	Base Year
ABATEMENT				
SCR - Coal (Industrial)	2000	5000		1999
SCR - Oil, Gas, Wood (Indust	1000	3000		1999
SCR - Gas Turbine (large)	3000	6000		1999
SCR - Gas Turbine (small)	2000	10000		1999
SNCR	400	2500		1999
ALLOWANCE (For 2005)				
Evolution Markets			2625	2005
Argus Air Daily			2540	2005
Platts			2413	2005
Cantor-Fitgerald			2625	2005

Table 10: Different Costs of SO2 (Synapse, 2006)

Synapse (2006) assumes the levelized price of NOx will be $1,617 per ton ($2006) from 2010 to 2025. This assumption is based on the relationship NOx has with carbon and the possible cost of complying with carbon regulations they suspect will be established which will also reduce the amount of NOx pollutants. The price they estimate for 2006 is $2,650 (Synapse, 2006).

Particulates (PM10)

The cost of filters and wet scrubbers which are used to abate PM10 particles is between $37 and $337/ton (for filters) and $35 to $236/short ton (for scrubbers) (Synapse, 2006). With a less active (and non-existent in some states) trading market, PM10 estimation becomes more difficult (Synapse, 2006). Using NOx as a proxy the state of California estimated the prices for PM10. Their price from 2006 going forward is $6.47/lb (Synapse, 2006). This is just estimation, so it should be treated as such.

Carbon Dioxide (CO2)

Buildings are responsible for 36% of the carbon dioxide produced each year (Buildings, 2001). Carbon has not yet established a firm market presence in the United States so estimating carbon is inexact at best. We will look at how some have tried to calculate a cost for carbon. Carbon has been trading in the European Union for the last three years. In 2004 the trades ranged from approximately $8-17 USD (Synapse, 2006). In the U.S. ICF Consulting conducted a study in which they estimated carbon would trade at between $2.5 to 6.80 ($2003) on the east coast (Synapse, 2006). California Public Utilities Commission estimated CO2 to be $5/ton (2004) with a levelized or average value of $8/ton (2004 dollars) (Synapse, 2006). Electric Utilities long-term planning allowance assumptions are in Table 11.

Utiltiy Companies Trading Assumptions			
Company	CO2 Emissions Trading Assumptions ($/ton)	Year	Carbon Cost/metric ton
PG&E	$8	2008	$29
Avista	$1-11	2004-2023	$5-40
Portland's General Electric	$10	2010	$37
Xcel	$6-12	2009	$22-44
Idaho Power	$12.30 - 49.21	2008	$45-180
PacifiCorp	$2 - $40	2003	$29-147

Table 11: Utility Companies Trading Assumptions (Synapse, 2006)

Synapse (2006) after evaluating all this data estimates mid-case of $5/ton-CO2 increasing to $26/ton-CO2 in 2025 and a levelized value of $13/ton-CO2 (all values in $2006).

Kats (2003) also compared many different studies in an effort to quantify the costs of CO2; this is summarized in the Table 12.

Study	Low	High	Avg	Base Year
IPCC	5	125		
CO2 Programs in US avgs	1	16	under 5	
World Bank	3	4		
BP (International)			10	
ADL (range)	0.1	70		
ADL (Avgs)	2	35	13	
CEC (reforestation)			11	2002
TIAX, LLC			15	
Kats	5	10		

Table 12: CO2 Comparison (Kats, 2003)

Conclusion

Table 13 shows all Synapse's pollutant cost estimates.

Synapse Levelized Allowance Estimates	
	Levelized Allowance Price (2006$/ton)
CO2	$ 1,239
NOX	$ 1,617
CO2	$ 13

Table 13: Synapse Levelized Allowance Estimates

We must be wary of some of the information presented in this last section because of the volatility of the trading markets and all the factors that regularly affect the markets. Prices will vary widely with assumptions, fuel price fluctuations, capital costs for technologies, electricity demand, and regulations (Synapse, 2006). Also when evaluating data obtained from California, it is important to remember that California is a relatively clean energy production state (Kats, 2003). We must be careful comparing their data as their energy usage will most likely be low and their cost higher than other areas (Kats, 2003). Kats (2003) evaluation did include all energy whether produced in or out of state but the majority is energy produced in a clean energy state.

This study will use the levelized values estimated by Synapse as a conservative estimate for the cost of these four pollutants. The real historical values could be used, but because this study is meant for policy considerations, the author believes it to be a more realistic calculation and more useful. The emission rates per energy consumption that will be used will be from individual state actual reported data.

We have looked at the current standards for the Air Force and Department of Defense. We have investigated the literature regarding cost premiums, operating cost savings, and health and environmental costs. Next we will use the literature and illustrate our methodology to estimate the Air Force's cost of not using green design.

III. Methodology

The first step in this study was to find the costs, square footage, and usage (to include office, warehouse, maintenance, academic) of Military Construction (MILCON) building projects so initial construction cost comparisons can be made to estimated similar green construction projects. This will help establish that the added costs of comparable green designs can be estimated for each construction project and, furthermore, could be used as a tool for Air Force leadership to estimate life cycle costs from green design plans.

Data was pulled from the Automated Civil Engineering System (ACES), which is a database that tracks all real property assets Air Force-wide[1]. The data was pulled in August 2005. The projects from ACES were sorted to find MILCON-funded, new and renovation projects that had cost and measurement data available.

The next step was to convert all square meters into square feet. All cost data was normalized to FY 2006 dollars, so an appropriate comparison could be made. Data was normalized using the BY 2006 USAF Raw Inflation Indices for MILCON available on Air Force Financial Management website. This left us with a data set of 670 buildings fitting our criteria. The dates range from 1990 to 2005.

Dummy Variable

Building Category for establishing dummies	
Bldg	
1	Operations, Communications, Training
2	Maintenance, Storage
3	Development, Fitness, Support
4	Fire, Security
5	Lodging
6	Dining

Table 14: Building Categories

[1] ACES definition obtained from http://gis.esri.com/library/userconf/proc03/p1123.pdf

Dummy variables were created in order to see any prediction values that certain categories or conditions might have on the cost of the building. Table 14 shows the groupings.

In order to get an average building size for MILCON construction all the square footage was totaled and divided by the total number of buildings. To double check this estimate we ran another query of the ACES data and pulled all data that has a SF or SM measurement and had a value in the “totalcweam” (final cost) column. We also analyzed this data by taking total square feet divided by the total number of projects.

For the next two sections (energy and environmental) we chose all the Non-LEED buildings in our database that were of building types three, five and six (see Table 14). We sorted them and had to eliminate any that that didn’t have a base associated with the project number, any that we didn’t have energy data for, and any that were outside the United States.

<u>Energy</u>

Our energy data comes from the DUERS database, which collects all energy consumption data for the Air Force by year and by base. This data was normalized using the BY 2006 USAF Raw Inflation Indices for O&M. We analyzed this data to see the consumption averages by square foot and cost averages per MBTU for each base that has one of these building types.

Once we had this energy data we applied it to each Non-LEED building and found the average consumption and cost for each individual building. Because the LEED-certifiable buildings in the Air Force were all constructed after 2001, we averaged energy consumption on each base up until the time that any LEED building was constructed and used that average for future energy consumption in order to ensure any savings resulting from LEED were not averaged into the cost. We took the average consumption per square foot and multiplied it by the square footage of each building then took a reduction of 30% from this figure to use as our savings if the building had been constructed to LEED standards. We used this number along with the Air Force's useful life calculations for each building type to calculate present value.

Environmental

Using energy data obtained from DUERS, we followed the same procedure as with electricity. We took the consumption savings (difference by reducing the consumption by 30%) and added this to our other benefits input. We use the emission factors from each state that the Air Force base was located in to estimate reduced pollution emissions (U.S. DOE, 2006). In order to value the emissions savings we used the Synapse study's levelized values for each pollutant, and non-market evaluation to obtain our estimate. We multiplied the savings in consumption by these costs to reach our estimated cost savings from environmental impacts.

Present Value

Both the energy and the environmental savings were normalized to 2006 dollars. These were combined for the payment input into the present value calculations. The 5% rate used was consistent with Kats (2003) estimate rate. The facilities service life period for each of the buildings was obtained from HQ USAF/A7CPA estimates for the Air Force. The calculated cost premium was subtracted from the present value to give us the net present value (NPV) calculations. These NPV values were totaled by all buildings and also by each of the three types of buildings we decided to investigate.

This study will make an assumption that the same green design available today would have been available for all data obtained. It would be an arduous task to find what was available in each year and make a model that could account for all the variables. The scope of this study is to give the decision makers information relevant for future decisions.

IV. Findings

First we sorted all buildings by building type and found the difference in average cost by building type (all dollars where normalized). We calculated a cost per square foot for both LEED and Non-LEED buildings. These calculations were then compared to find the LEED premium in percentage (see Table 15). These results seem inconsistent with the literature. Some possible reasons for this could be the small sample size of LEED projects (20 of 670). Another reason is that the LEED category in ACES is not controlled. In our research we found that some LEED certified or estimated LEED certified projects were not given credit. Because buildings designated as LEED constitute such a small percentage of the total buildings in each area, the type of buildings that are applying for LEED may be more expensive than the average, thus making it appear to have a cost premium. New requirements in building may have contributed to cost increases as well. Even though the results were unexpectedly high we decided that building types three, five, and six were most consistent with the literature, so we chose these three building types to do our analysis.

Bldg Number	Type	LEED Cost/SF	Non-LEED Cost/SF	Percent LEED Premium
1	Ops, Comm, Trng	$ 30.10	$ 197.36	-85%
2	Mx, Storage	$ 245.70	$ 101.87	141%
3	Development, Fitness, Support	$ 227.27	$ 206.06	10%
4	Fire, Security	$ 230.24	$ 279.41	-18%
5	Lodging	$ 235.31	$ 188.38	25%
6	Dining	$ 330.62	$ 274.77	20%

Table 15: Building Type Cost Premiums

Without more accurate data, it is hard to prove that there is or isn't a LEED premium. For this study, we will use this data with the caveat that it is the best representation possible although better data would improve our analysis significantly, so it is a place to start our investigation into possible cost effects.

Energy

Taking the normalized DUERS data by base, and each actual building's data, we figured the yearly consumption (based on square foot data) and the yearly cost per MBTU. These figures were then reduced by 30% (assumed energy savings from green design based on Kats (2003) estimate) and the differences were calculated. The differences are the cost and consumption savings that would have been attributable to green design.

Emissions

To perform the emission calculations, the consumption savings data was converted from MBTU to MWh by multiplying MBTU by 0.29307[2]. This number was multiplied by each state factor for the particular building for each of the pollutants (NOx, CO2, SO2). The PM10 factor was obtained from the Kats (2003) study PM10 factor. These numbers tell us how many pounds of pollution per MWh are emitted for each pollutant. We then converted this number back to metric tons by dividing the pounds by 2204.62. This gave us an estimate of the savings in tons of emissions for each pollutant.

In order to value the benefits we multiplied the pollution estimate by the costs for each ton (pound for PM10) of pollutant obtained from the Synapse (2006) study. These numbers are all extremely volatile, so we chose the levelized values, even though they are lower than current and historical values to provide a more conservative estimate. Once again we wanted the results to show information more relative to present day decisions than past performance, so even though our savings will be substantially reduced, it will

[2] all conversion factors obtained from http://www.iea.org/Textbase/stats/unit.asp

provide us a better glimpse at the effect employing green design will have on future decisions. The values we decided to use for the environmental costs of the four pollutants are $13, $1,239, and $1,617 per ton for CO_2, SO_2, and NO_x respectively, and $6.47 per pound for PM-10.

Present Value

We took the calculated cost premiums, the discount rate (5%), the service life of each building (obtained from HQ USAF/A7CPA), and the savings in energy and emissions and calculated a present value for each building. Then in order to see if certain building types had any different effect on net present value, we calculated a total NPV as well as a NPV for each of our three building types. As you can see (Table 16), in every case there is a negative net present value. Our sample of 80 non-LEED buildings shows, that given our data set, there would not have been any benefit to the Air Force in building green design. The savings that we included did not outweigh any additional costs. See following page for the complete list of buildings and their NPV.

Total NPV	($58,795,066.38)
Bld 3 NPV	($16,877,888.33)
Bld 5 NPV	($27,523,178.74)
Bldg 6 NPV	($14,393,999.31)

Table 16: Net Present Value by Building Type

As seen in the full list of buildings (Table 17) there are five buildings that actually have a positive net present value. After further examination three of these five buildings are a renovation, addition, or conversion which could explain the positive NPV. Usually a renovation, conversion or addition are less costly than new building construction; so if they are reaping all the savings from green design at a fraction of the cost, it would explain the positive net present value. The cost of green design investigated in this thesis

Bldg Type	Fiscal Year	Base	ProjectTitle	SqFtg	Total Savings Per Year (Emissions)	Total Savings Per Year (Electricity)	Prem Diff	PV Benefits	NPV	Svc Life
3	2000	Dyess	CHILD DEVELOPMENT CENTER	24574	$2,899.25	$10,350.38	$636,343.69	$241,884.27	($394,459.42)	50
3	2001	Dyess	FITNESS CENTER	73668.2	$8,691.41	$31,028.47	$1,231,928.18	$559,809.71	($672,118.48)	25
3	1997	Lackland	BC-ADAL PHYSICAL FITNESS CNTR	2400	$201.90	$593.11	$54,458.84	$11,204.90	($43,253.94)	25
3	2002	Sheppard	Fitness Center/Health and Wellness Center	42409.8	$3,567.79	$10,480.72	$810,368.75	$197,999.05	($612,369.70)	25
3	2005	Hill	FITNESS CENTER	64583.5	$19,732.69	$21,061.78	$1,092,280.69	$574,955.04	($517,325.66)	25
3	2001	Langley	ADAL FITNESS CENTER	48652.9	$7,807.33	$20,877.72	$1,332,825.83	$404,285.58	($928,540.25)	25
3	1998	Langley	LIBRARY	21527.8	$3,454.57	$9,237.93	$371,733.90	$178,887.42	($192,846.48)	25
3	1997	FE Warren	CHILD DEVELOPMENT CENTER	19375	$5,374.93	$7,110.59	$412,017.74	$227,934.76	($184,082.98)	50
3	2002	FE Warren	FITNESS CENTER	54368.5	$15,082.66	$19,953.10	$1,041,510.77	$493,792.10	($547,718.67)	25
5	1992	Eielson	TRANSIENT PERSONNEL QTRS, PHI	61500	$46,264.04	$29,148.49	$4,427,565.54	$1,062,860.00	($3,364,705.54)	25
5	1994	Travis	BC - DORMITORY	43100	$32,422.44	$20,427.64	$2,450,002.41	$744,866.11	($1,705,136.30)	25
5	1997	Buckley	BC-ENLISTED DORMITORY	53500	$17,112.31	$68,623.07	$2,206,643.49	$1,208,349.60	($998,293.89)	25
5	2002	Buckley	DORMITORY (144 RM)	54250.1	$17,352.23	$69,585.21	$3,377,904.24	$1,225,291.53	($2,152,612.70)	25
5	1998	Peterson	BC-DORMITORY	8300	$1,783.56	$3,290.96	$297,441.54	$71,520.08	($225,921.46)	25
5	1997	Dover	VISITING OFFICERS QUARTERS	40902.9	$11,286.79	$18,937.63	$3,194,466.22	$551,774.70	($2,642,691.52)	50
5	1999	Mountain Home	DORMITORY	49514	$13,662.95	$22,924.50	$2,530,380.52	$515,661.52	($2,014,719.00)	25
5	2001	Grissom (AFRE	SERVICES COMPLEX PHASE 2	47361.2	$21,443.36	$21,067.86	$2,976,513.36	$599,150.79	($2,377,362.57)	25
5	2001	Westover	REPAIR/ALTER AIRMAN QUARTERS	48243.8	$7,770.07	$22,225.69	$2,024,356.68	$422,758.61	($1,601,598.07)	25
5	2000	Mc Guire	VISITING QUARTERS	41441.1	$6,674.42	$19,091.68	$3,371,664.64	$470,384.10	($2,901,280.54)	50
5	2003	Kirtland	VISITING QUARTERS	50633.4	$6,776.30	$18,636.52	$2,150,149.42	$463,934.62	($1,686,214.81)	50
5	2003	Nellis	DORMITORY	51150.1	$6,526.75	$22,033.04	$2,865,750.52	$402,520.08	($2,463,230.45)	25
5	2000	Niagara Falls	LODGING FACILITY	34035.5	$4,327.39	$17,378.29	$1,871,377.28	$305,918.70	($1,565,458.58)	25
5	1997	Lackland	BC-IAAFA ENLISTED DORM (150PN)	61750	$7,851.11	$31,529.14	$2,378,976.42	$555,023.09	($1,823,953.33)	25
6	1990	Eielson	DINING HALL	16600	$6,473.11	$7,867.72	$1,685,652.65	$202,118.91	($1,483,533.74)	25
6	1999	Maxwell	OTS DINING FACILITY	24757	$4,693.78	$11,464.74	$1,057,347.19	$227,737.36	($829,609.83)	25
6	2003	Beale	GLOBAL HAWK DINING FACILITY	7459.39	$456.98	$2,228.21	$878,574.91	$37,844.93	($840,729.98)	25
6	1991	Travis	AIRMEN DINING HALL	18400	$1,009.76	$5,062.73	$1,613,509.89	$85,585.36	($1,527,924.53)	25
6	1993	USAFA	RENOVATE CADET DINING HALL PH2	44000	$2,414.65	$12,106.53	$115.68	$204,660.64	$204,544.97	25
6	2000	Eglin	DINING FACILITY	20505.2	$3,349.24	$10,048.79	$1,090,665.86	$188,831.08	($901,834.77)	25
6	1995	Eglin Aux Nr	RENOVATE AIRMEN DINING FAC	15000	$2,450.03	$7,350.89	$632,997.73	$138,133.71	($494,864.02)	25
6	2002	Hurlburt	DINING FACILITY/FITNESS CENTER	27986.2	$3,229.58	$9,609.59	$1,333,889.11	$180,954.60	($1,152,934.51)	25
6	2001	Robins	AIRMAN DINING FACILITY	14014.6	$3,084.38	$4,918.82	$1,087,368.66	$112,796.65	($974,572.01)	25
6	1998	Malstrom	ADD/ALTER AIRMEN DINING FAC	21527.8	$4,614.07	$9,807.82	$1,142,490.94	$203,261.37	($939,229.57)	25
6	1997	Grand Forks	DINING FACILITY	27663.2	$5,929.08	$12,603.05	$1,525,153.77	$261,190.86	($1,263,962.91)	25
6	1999	Mc Guire	DINING FACILITY	20989.6	$2,956.21	$13,097.75	$1,351,180.28	$226,263.54	($1,124,916.74)	25
6	1997	Dyess	CONSOLIDATED DINING FACILITY	28524.4	$2,304.92	$12,014.24	$1,589,195.34	$201,813.45	($1,387,381.89)	25
6	1997	Sheppard	BC-CENTRAL PREP KITCHEN	7750.02	$604.63	$2,471.81	$394,396.65	$56,163.24	($338,233.41)	50
6	2001	Sheppard	DINING FACILITY	25004.6	$1,950.77	$7,975.02	$1,478,709.87	$139,893.50	($1,338,816.37)	25

Table 17: Individual Buildings NPV

is a percentage of the cost of new construction and not for renovations so this type of data does not necessarily give us much useful information.

This data would suggest that deciding to build green would not pay for itself based on energy and environmental benefits alone. We must however realize some of the limitations of this data.

1. We were not able to normalize construction cost data for different locations across the U.S. We did what the data would allow but with the limited set of LEED buildings (11) for 7 bases, this is crude at best.
2. The LEED premium is a rudimentary measure given the quality of the data. Without diving into the specific building plans of each building to see if the premiums were actually due solely to LEED or other extenuating circumstances, we have no way of knowing if these cost premiums are attributable solely to LEED.
    a. Air Force policy does not mandate buildings to be certified, only certifiable. It is not known the level or even the certainty of LEED certification for most of these buildings. It would be useful to put some sort of control on entering data, so in the future this data will be useable and accurate.
    b. Also, LEED buildings should be compared to the same building or a very similar type to do a proper comparison. A more thorough analysis of buildings (LEED and Conventional) and usage for a study would provide a more useful data.

3. Utility data is by base and not by individual buildings. As more buildings start complying with the metering initiative and EPACT 2005, it will be possible to do a more thorough and useful study. We would then be able to compare similar buildings (LEED and Conventional) and find an actual energy usage differences. The Navy is undergoing a study currently to do just that.
4. Better and more data are needed. Possible suggestions include obtaining GSA, Army, and Navy data on green design or doing a research project much like the GSA study based on particular building plans to see the cost and benefits of green design for the Air Force.

Literature and research discussed in this thesis show usual cost premiums for green design are 0-10%. This study did not show the same results and may have inaccuracies based on the above mentioned reasons. If this study accounted for the fact that energy consumption is only 33% efficient due to energy conversion losses, the benefits discussed here could be multiplied by three and the present values would be greater.

V. Discussion

Green Design in the Air Force is relatively new. The Air Force is taking steps to incorporate certain aspects of sustainable design, but because it is not yet fully required, there is not much data that can be used to get an actual cost of green design. As more buildings become LEED certified and as more program managers get experience with green design it will be easier to estimate the costs and those estimates will be more accurate.

This study did not conclusively prove any premium based on the data that was available. It did however show some of the savings that could be reaped by going green. These estimates are conservative and only begin to shed light on all the savings and benefits of green design. As Kats (2003) showed, 70% of the benefits from green design are from productivity and health. This study only accounted for 13% of the total benefits that could be realized, it would be in the best interest of the Air Force to study the benefits not considered here. Health, O&M, and productivity enhancements could show substantial cost benefits.

Another area that could be studied is the current budget process. MILCON funds are separate from O&M funds. Because O&M and capital expenditure budgets are separated the program managers often find it difficult to apply life cycle cost analysis and consider both O&M and capital costs together in the analysis (US DOE, 2003). A study that finds a way to account for these differences or make up one area by savings in another would be beneficial to the Air Force. If it is life-cycle effective to pay a premium up front for significant savings, a process should be investigated to make it feasible.

Another question that could be asked is if it is appropriate for the Air Force to have an increase in budget for LEED construction?

The Air Force is attempting to make a difference in energy efficiency through the MOU, EPACT, Metering Initiative and other areas. A study could look at the cost of complying with the MOU and EPACT as well as all the benefits that would be realized. LEED certification is a measurement tool; these other areas are sometimes going above and beyond LEED criteria. Looking at the differences in cost and benefits would be beneficial.

As Morris *et al.* (2004) showed there are many different types of green buildings, both low and high cost. This research seemed to show that early planning is the key.

Positive impacts on the environment, resources, energy consumption, people, health, and financial resources all can be obtained by green design.

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Vita

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14. ABSTRACT

This study's purpose is to determine if using green building design would have resulted in life cycle costs savings for the United States Air Force. Green designs are those that employ steps to mitigate the impacts facilities have on the environment by using resources more efficiently than conventional design. The prevailing ranking system for green design in the United States is the Leadership in Energy and Environmental Design (LEED) which evaluates facilities on certain characteristics, assigning certain point values that translate to non-certified, certified, silver, gold, or platinum ratings. The author attempts here to show how previous studies indicated the presence of construction cost premiums, savings in operating costs and environmental benefits from green design. The literature review also shows the extent the Air Force and Department of Defense have incorporated green building standards into current policy. After performing an analysis of Air Force building data, this study suggests that deciding to build green would not pay for itself based off of energy and environmental benefits alone.

15. SUBJECT TERMS
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