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An Analysis of Insulated Concrete Forms for Use in Sustainable Military Construction

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AN ANALYSIS OF INSULATED CONCRETE FORMS FOR USE IN SUSTAINABLE MILITARY CONSTRUCTION

THESIS

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AN ANALYSIS OF INSULTED CONCRETE FORMS FOR USE IN SUSTAINABLE MILITARY CONSTRUCTION

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Abstract

The Department of Defense has undergone multiple efforts in recent years tos integrate new technologies and practices in the areas of construction, restoration, and operations in an effort to construct high performance buildings and develop sustainable military installations. One way to improve building performance and improve sustainability is to find ways to reduce energy consumption. This can be accomplished by utilizing newer, energy efficient materials such as Insulated Concrete Forms in lieu of more traditional construction materials.

Insulated Concrete Forms are a block style construction material more typically comprised of expanded polystyrene which fit together and are filled with reinforced concrete to construct the exterior wall systems of a building. By design, this material provides a higher level of insulation and greater structural integrity that stands up to damaging winds, fire, and explosive blasts. This study shows that utilizing this material is not the most cost effective material choice when constructing new facilities, however, it does reduce energy consumption and contributes towards total energy reduction goals established by the Department of Defense. This study also showed there are multiple barriers preventing increased use of Insulated Concrete Forms to include a lack of knowledge of the advantages of this material, a resistance to change from more traditional materials, and to some degree the increased initial cost of utilizing this material. This study concludes there is merit in considering Insulated Concrete Forms for use in sustainable military construction.

Acknowledgments

I would like to extend my sincere appreciation to my thesis committee for supporting my initial idea of researching this topic. For all of their patience, critical insight, and technical knowledge which proved invaluable; without which I would not have been able to succeed in accomplishing my goals with this thesis.

I would also like to acknowledge the continued support I have received from my family. My parents who have shown me the importance of always being true to myself. Who taught me when I was growing up to dare to be my own self, to never be afraid to question things and to discover for myself who I am and to be proud of all I have accomplished in life. To my sister who was always there for me when we were kids, who has supported me in all of my endeavors, and still supports today.

I would also like to thank the many members of my family who have previously served and are currently serving our country in all branches of the military; who have instilled in me a strong sense of patriotism and dedication to service. Thank you to everyone for helping me make this life goal a reality.

Captain Rebecca L. Ponder

Table of Contents

List of Figures

List of Tables

Page

AN ANALYSIS OF INSULATED CONCRETE FORMS FOR USE IN SUSTAINABLE MILITARY CONSTRUCTION

I. Introduction

The United States is experiencing a time when energy costs are increasing each year. Therefore, many Americans are searching for methods which will reduce their energy consumption in an effort to lower annual utility costs. Over the last several years, the "Green Movement" has gained momentum as contractors begin utilizing renewable and energy efficient materials and technology in both residential and commercial construction. The federal government has also taken steps to create more sustainable and efficient facilities. Specifically, the Department of Defense has published several policies and directives in the last few years establishing guidelines and requirements for sustainable military installations by utilizing new sustainable technologies and materials. There are many types of energy efficient and sustainable construction methods and materials to choose from when deciding to construct a new building with factors such as durability, cost, and material availability being taken into consideration. This research investigates the value of utilizing one type of sustainable construction material, Insulated Concrete Forms (ICFs), as an alternative to more traditional structural materials in material construction, specifically looking at energy efficiency, life-cycle costs, and implementation .

Sustainable Construction

The concept of sustainable construction, also known as "green building," includes the design and construction of buildings using methods and materials that are resource efficient throughout the building's life (Landman, 1999). Also referred to as High Performance Building, sustainable construction takes into consideration siting impacts, energy and water usage, building materials, and indoor environment (Landman, 1999). According to the U.S. Environmental Protection Agency (EPA), the idea of sustainable practices such as utilizing renewable materials has been around for millennia. However, the contemporary movement towards sustainable construction in the U.S. arose from the desire to utilize energy efficient and environmentally friendly materials and practices during the environmental movement of the 1960s and the oil price increases of the 1970s (U.S. Environmental Protection Agency, 2012). Formal development of sustainable building practices began in the 1990s with the American Institute of Architects forming the Committee on the Environment and publishing their Environmental Resource Guide. Additionally, the EPA and the U.S. Department of Energy (DOE) launched the *Energy Star®* program in 1992. Furthermore, the U.S. Green Building Council (USGBC) was founded in 1993 and later launched the Leadership in Energy and Environmental Design (LEED) program in 1998 (U.S. Environmental Protection Agency, 2012). Sustainable building has continued to evolve over the last 10 years with the establishment of the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007, which includes requirements for high performance federal buildings. By 2006, 19 federal agencies had signed the *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding;* that same year saw the first Federal Green Construction Guide for Specifiers available on the Whole Building Design Guide to provide multiple performance-based options for green construction (U.S. Environmental Protection Agency, 2012). Executive Order (EO) 13423 was signed by President George

W. Bush in 2007 to strengthen federal management of environmental, energy, and transportation related activities in an environmentally supportive, economically sound, and sustainable manner (EO 13423, 2007). In 2009, President Barrack Obama signed Executive Order 13514 which expanded guidelines in EO 13423 by "establishing an integrated strategy towards sustainability in the federal Government" (EO 13514, 2009, p. 1).

Sustainable Construction in the Military

Along with the development and implementation of the energy efficiency and sustainability policies previously mentioned, the U.S. military has incorporated sustainable construction practices. In 2008, while serving as the Air Force Civil Engineer, Major General Del Eulberg outlined a facility energy strategy incorporating four action "pillars" to improve current infrastructure, improve future infrastructure, expand renewables, and manage costs (Eulberg, 2008). This guidance served as the foundation for implementing energy efficiency and sustainable construction throughout the Air Force. In June 2011, after assuming the position of the Air Force Civil Engineer, Major General Timothy Byers reinforced the Air Force commitment toward incorporating sustainable concepts into all installation activities to include planning, programming design, construction, and facility and infrastructure operation (HQ USAF/A7C, 2011). This guidance incorporated elements from eleven different directives which had been released between 2004 and 2011. The Army and Navy have also produced similar strategies. The Army established the *Army Energy Strategy for Installations* in 2005, the *Army Energy Conservation* in 2007, and the *ASCIM Master Planning Policy Guidance for Sustainable Design and Development (Environmental and*

Energy Performance) in 2011 (Army, 2014). The Navy mirrored the Army and Air Force energy policies by developing and publishing their *Naval Energy: A Strategic Approach* policy in 2009. Like the Army and Air Force energy policies, this policy established goals for energy conservation, efficiency, and alternatives for both shore installations and fleet operations (Naval Energy Office, 2009).

The most recent policy regarding high performance and sustainable building criteria for U.S. military construction is the Unified Facilities Criteria (UFC) 1-200-02, *High Performance and Sustainable Building Requirements (HPSB),* which was signed into effect in 2013 by the engineering branches of each military service. This UFC supersedes two previous criteria, (UFC 4-030-01, *Sustainable Development,* and UFC 3-400-01, *Energy Conservation)* and was developed with the objective of bringing uniformity across the Department of Defense (DoD) and serving as a companion document for UFC 1-200-01, *General Building Requirements* (UFC 1-200-02, 2013). The stated goal of the HPSB UFC is to improve mission capability through reduced facility costs, improved energy efficiency and water conservation, and enhanced facility performance and sustainability, while promoting sustainable resources and enhancing energy and water security (UFC 1-200-02, 2013). These goals can be met in a number of ways, one of which is in the selection of building materials, which is the driving factor behind this research of Insulated Concrete Forms as a sustainable construction material.

General Problem

Many studies have been conducted to show the higher energy efficiency of ICF blocks over more traditional construction materials such as wood framing. In 2001, four homes in Dallas, TX, were monitored for overall energy use for an 8-month time span.

Two of the homes were constructed using wood framing with rolled insulation batting, and the other two were constructed using ICF blocks. The results of this study showed a 17-19% reduction in seasonal cooling energy use (Chasar, Moyer, Rudd, Parker, & Chandra, 2002). A similar study was conducted at the same time by researchers with the Portland Cement Association. In this study, two residential homes with identical floor plans were modeled using DOE energy software. One home used wood framing with rolled insulation batting, and the other used ICFs. Energy simulations were run for a consecutive12- month timespan using five different climate locations. Here again, the results showed a similar reduction of 8-19% in overall energy savings of using ICFs over wood framing (Gajda & VanGeem, 2000). The inherent properties of ICF blocks make them more energy efficient by design over framed construction. A detailed discussion of these properties can be found in Chapter II.

With this known energy efficiency, the use of ICF blocks as an alternative material for sustainable construction has increased in popularity among contractors in the private sector for both residential and commercial construction. Given the energy savings attributed to the use of ICF blocks and the previously mentioned policies regarding sustainable construction within the military, it is surprising that ICFs are not utilized more often in military construction. If ICF blocks meet the established criteria for high performance and sustainable construction set forth by the military, what is preventing the use of ICFs as a material for military sustainable construction? Is it a lack of knowledge among the military engineering community regarding the advantages of ICFs, a resistance to change from past practices, or a result of cost and/or current policies specifying how military projects are programmed and funded? To help answer these questions, the following research objectives were established.

Research Objectives

The objective of this research was twofold. The first objective was to discuss the ways in which ICFs meet military sustainability design requirements as outlined in UFC 1-200-02. The second objective was to identify and clarify key barriers which prevent the use of ICFs in sustainable military construction. To achieve these objectives, this study focused on the following investigative questions:

- How do ICFs meet sustainability design requirements for optimized energy performance as outlined in the HPSB UFC?
- How do ICFs meet life-cycle cost requirements as outlined in the HPSB UFC?
- What are the key barriers preventing increased use of ICFs in sustainable military construction?

Methodology

This research was a two-part study consisting of different methodologies. The first part of the study involved quantifiable analysis of ICFs related to current military guidance regarding sustainable construction. The methodology used in this part of the study utilized eQUEST energy modeling software to conduct energy analysis calculations. This energy analysis was designed around the specifications of a stereotypical two-story administrative office building. This building was modeled in accordance the Unified Facilities Criteria for military construction and design; the specific design details are discussed in Chapter III. The model was run at six Air Force installations in different geographic regions of the continental United States; it was run for a consecutive 24-month timespan to encompass seasonal changes in each region.

Baseline energy costs utilized for comparison were based on actual 2012 and 2013 data for the six locations provided by the Air Force Civil Engineer Center (AFCEC).

The second methodology in the first part of the study involved conducting life- -cycle cost analyses (LCCA) for the modeled facilities at each test location. The UFC 1-200-02 requires a Life Cycle Cost Analysis to be completed for each facility in accordance with Title 10 of the Code of Federal Regulations (10 CFR) part 433 using the Building Life-Cycle Cost (BLCC) program. For this study, the BLCC5 software was utilized to conduct an LCCA for each of the modeled facilities using energy data generated from the eQUEST analysis.

The second part of the study involved a qualitative analysis of ICF use in construction. The methodology for this part of the study included interviews with 14 ICF contractors with various experience levels using ICFs in both residential and commercial construction. The interviews consisted of structured questions utilizing a five-point Likert scale designed to identify potential barriers to the implementation of ICFs in sustainable military construction. Further details of these methodologies are discussed in Chapter III.

Assumptions

There were several technical assumptions required to conduct this analysis. One primary assumption was the type of ICF block. There are multiple manufacturers of ICF blocks and different types of material from which the blocks are manufactured. The specific sizing and type of ICF block utilized for this study are detailed in Chapter III. This study followed the Unified Facilities Guide Specifications (UFGS) 03 11 19.00 10, *Insulating Concrete Forms,* for Air Force construction when selecting ICF block materials and details. Another major assumption was that there were no added costs regarding the availability of ICF blocks and concrete. By referencing the ICF Builders Network, the EPS Industry Alliance, and a general internet search, multiple licensed ICF distributors and contractors were found in each of the six states selected for this study. The study assumed the utilization of an ICF distributor and contractor within the state instead of outside the state; therefore, additional transportation costs were not a factor for consideration.

Implications

This study should serve as a tool when considering construction methods and materials for new facilities. Each Air Force installation develops their own design guide which outlines the basic design standards regarding architectural and finishing designs unique for their base. This research is solely focused on the use of ICF blocks as a structural construction material and can be integrated into the design guides of each installation.

Preview

This document contains four additional chapters including the literature review, methodology, results and analysis, and conclusions and recommendations. The literature review contains details regarding ICF blocks and their energy efficiency to include thermal insulation and industry standards, as well as how cost and life-cycle calculations are determined. It also discusses details regarding the implementation of sustainable military construction requirements specifically related to the UFC 1-200-02. The methodology chapter explains in detail how the study was conducted, including details of the selected software programs and specifics regarding how the models were created.

The chapter also gives details regarding how the interview questions were developed and how the interviews were conducted. The results of the modeling analysis, as well as analysis of the interview results, are explained in Chapter IV. Finally, the last chapter summarizes the study and makes recommendations for future research.

II. Literature Review

This chapter details what Insulated Concrete Form (ICF) blocks are and why they are used in the construction industry to achieve higher energy efficiency. It also describes what energy efficiency is and discusses the specifics behind thermal insulation and heat transfer in a facility. The chapter then covers the details of the various guidelines specified for sustainable military construction related to energy efficiency and life-cycle calculations. Finally, the end of the chapter discusses barriers that prevent more widespread use of ICFs.

Insulated Concrete Form Block Overview

ICF blocks are a relatively new construction material compared to wood and steel framing, arriving on the market in the U.S. in the late 1960s (History of ICFs, 2011). An ICF wall is simple to construct with contractors comparing the construction of an ICF wall to constructing with Lego ® bricks in how they snap together. Once the ICF blocks are connected into the desired wall shape, the wall is completed by tying in supporting rebar and filling the interior of the ICF blocks with concrete to provide structural integrity. ICF blocks are known for their high level of energy efficiency; a detailed description of the energy efficient properties of ICF blocks will be covered later in this chapter.

The first U.S. patent for ICF blocks was applied for by a general contractor named Werner Gregori in 1967 based on an idea he had using the same material found in foam drink coolers; he subsequently called the new product "Foam Form" blocks (History of ICFs, 2011). These original construction blocks measured 16 by 48 inches with metal support ties, tongue and groove interlocking edges, and a waffle-grid core (History of ICFs, 2011). This original design remained unchanged for nearly 15 years and has since been modified to varying degrees into the ICFs available in today's construction market.

Modern ICFs are constructed using several materials including polystyrene and polyurethane foam, as well as cement-bonded wood fiber or polystyrene beads; the most common material being used is polystyrene foam. Individual blocks can be manufactured in various sizes and shapes as required by the user for the specific architectural design. Like the original "Foam Form," ICFs have tongue and groove interlocking edges to allow the blocks to 'snap' together during assembly as shown in Figure 1 (Saber et al., 2010).

Figure 1. Insulated Concrete Forms (ICF Photo Gallery, 2013)

The thickness of the polystyrene (or other material) varies depending on the user specification, with the typical range being between 1-7/8 to 3-3/4 inches and the interior cavity of ICF blocks typically being 6 or 8 inches wide. Today, the tie webs used between the material edges are more commonly made of plastic in place of the original metal bracing. The tie webs provide structural support to the ICF blocks as well as anchor points for the supportive rebar used to provide added strength to the concrete as shown in Figure 2.

Figure 2. Insulated Concrete Forms with Rebar (ICF Photo Gallery, 2013)

Shown in Figure 3, there are three basic designs for modern ICF wall systems: flat, grid, and post-and-beam. Flat wall systems form a flat vertical slab of concrete with continuous thickness on the interior of the ICF wall. This type of wall system utilizes more concrete compared to the waffle and post-and-beam type of wall. A flat ICF wall provides the greatest strength of the three types with wider range of rebar placement options allowing walls to support greater structural loading capacity (ICF Direct, 2006).

Grid wall systems have a grid or wavy pattern on the interior surface of the ICF blocks thereby producing a concrete slab with a waffle pattern. This pattern produces a concrete slab with thinner concrete between thicker horizontal and vertical ribs. This type of ICF wall system has more expanded polystyrene on the inside of the blocks which can cause higher air infiltration if not properly installed (ICF Direct, 2006).

The post-and-beam wall system is designed so the interior concrete forms vertical posts which can be spaced up to 4 feet apart depending on manufacturer specifications (BuildCentral, Inc, 2014). This type of ICF wall system, like the grid wall, reduces the thermal mass of the wall system which can cause higher air infiltration (ICF Direct, 2006). The three types of ICF walls require different amounts of concrete and affects the overall strength of the wall, total thermal resistance, and the cost. The lower amount of concrete required by grid and post-and-beam ICF walls are commonly used to replace wood framing in residential homes due to their lower cost while still providing the greater strength and insulation known to ICF (ICF Direct, 2006).

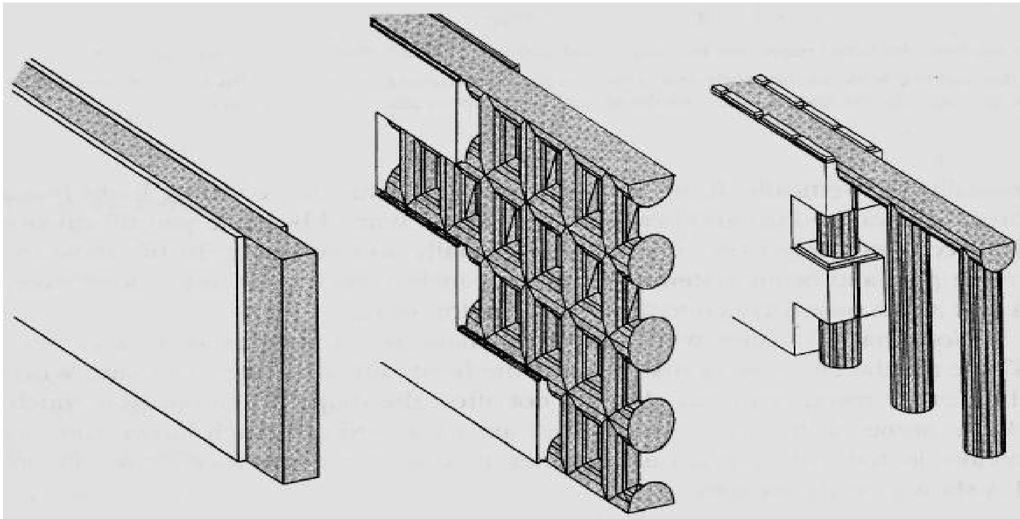


Figure 3. Cut outs of ICF wall systems (Insulated Concrete Forms, 2014)

ICF Advantages

There are many benefits to using ICF blocks when constructing a facility. ICFs provide greater energy efficiency due to a decreased demand for electrical and/or mechanical heating and cooling systems in the facility. This decrease results from the presence of a continual insulation barrier on both the exterior and interior of the wall provided by the ICF blocks and a greater thermal resistance (R-value) of the expanded polystyrene and interior concrete. The thermal resistance of polystyrene alone is around R-20 whereas wood and steel framing can range between R-9 and R-15. This higher R-value along with the thermal mass of concrete combines to give ICF walls a higher total effective R-value.

Another advantage is the increased structural integrity resulting from the use of concrete throughout the wall system. This structural strength is especially advantageous in regions subjected to natural disasters such as tornados, hurricanes, and earthquakes.

To validate this structural strength, the Wind Engineering Research Center of Texas Tech University conducted a study of impact resistance between conventional wall construction and flat style ICF walls. The study included wood frame, steel frame, and ICF wall systems, with both vinyl siding and brick veneer for each system (Concrete Homes, 1998). According to the study report, the test walls were all constructed in accordance with the International Building Code and subjected to wind velocities and debris equal to what is typically found in tornadoes (between 50-110 mph). In all cases, debris managed to penetrate completely through all wood framed and steel framed wall systems. In the case of the ICF wall systems, debris only penetrated the first layer of polystyrene and never penetrated or caused major structural damage to the concrete within the ICFs (Concrete Homes, 1998).

A third advantage is increased fire resistance due to the higher fire resistance rating from the concrete used in the ICF walls. While wood framed walls burn and steel frames soften and bend when exposed to temperatures commonly reached during fires, concrete does not burn, bend, or soften. In fire-wall tests, ICF walls were exposed to continuous gas flames for 4 hours at temperatures reaching up to 2,000 ^{o}F and the concrete did not structurally fail (Concrete Homes, 1997). Concrete ICF walls also resist the spread of fire and prevent the heat from penetrating to the cooler side for 2-4 hours. In addition, the flame-retardant additives mixed with the polystyrene foam during manufacturing of the ICF block prevent the foam from fueling fires. Instead, the polystyrene simply melts (Concrete Homes, 1997).

A final advantage of using ICF blocks as a primary structural material is the blast resistance compared to more traditional materials such as prefabricated steel framing and even concrete masonry units (CMUs). This advantage is particularly advantageous to military construction given the antiterrorism requirements found in UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings.* In 2003, the Insulated Concrete Form Association (ICFA) [now called the EPS Industry Alliance] conducted a 3-day blast test of six different ICF walls using 50 pounds of military grade TNT at distances between 6 and 40 feet. At each distance, the impact resistance properties of the expanded polystyrene absorbed and reduced the blast load. Despite small cracks of less than 2 millimeters in width and singeing of the material from the close proximity of the fireballs, there was no deflection, spalling, or structural damage to the ICF walls, whereas the other test walls suffered high levels of structural damage (Insulating Concrete Forms Come Under Fire (and Blast), 2003). This higher level of resistance to blast allows facilities to withstand higher weight explosions which could potentially reduce the minimum standoff distances listed in Tables B-1 and B-2 of UFC 4-010-01.

ICF Disadvantages

The primary disadvantage to using ICF blocks relates to cost, which varies from project to project depending on the size of the facility being constructed. If comparing residential homes of the same size, construction using ICF blocks can be $1.00-$4.00 more per square foot compared to wood framing. This results in approximately 0.5-4% additional overall costs (NAHB Research Center, 2014). The percentage increase is dependent on the size and type of facility. This cost premium has decreased in the last few years. According to the EPS Industry Alliance, the increase in the number of ICF manufacturers and contractors within the U.S. has attributed to the decrease in added costs of ICF construction.

A second disadvantage relates to design. ICFs can be manufactured in customized shapes to accommodate the architecture of each building; however, they can be difficult to work with when the design calls for cantilever walls for a second story. Figure 4 shows a basic cantilevered wall design. While it is not impossible to construct a cantilevered wall out of ICFs, it does require additional supports and bracing during the construction process which adds to the costs.

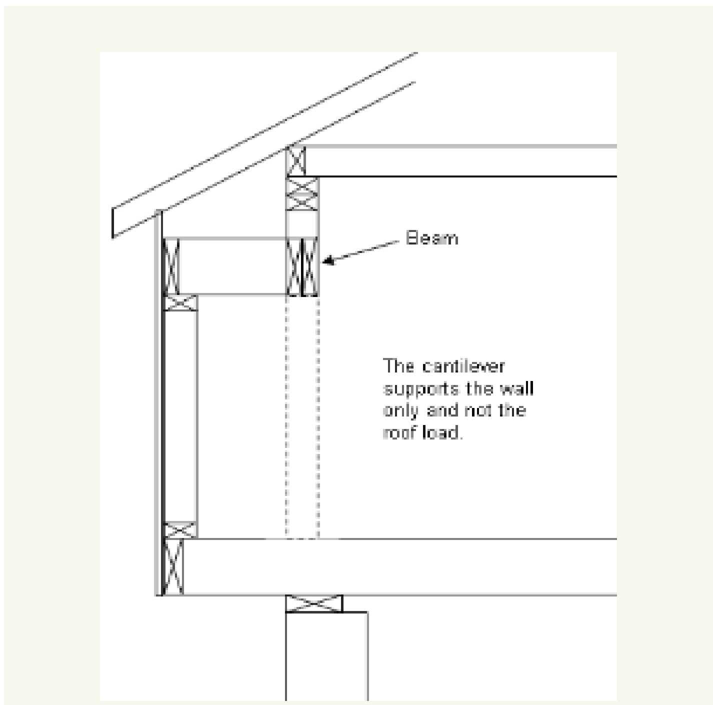


Figure 4. Cantilevered Wall System (Using Cantilevers in House Design, 2013)

Energy Efficiency

Insulated concrete forms are energy efficient by their design. To better understand the level of energy efficiency of a facility constructed with ICF blocks, it is important to understand the scientific principles and properties related to energy efficiency and how it is achieved during construction. Understanding theses principles starts with an understanding of basic engineering properties such as thermal comfort, heat transfer, and other thermal properties.

Thermal Comfort

Thermal comfort in a facility is determined through several factors, to include the material selected for construction and how the building is constructed. The human body, particularly the conscious mind, makes decisions regarding comfort or discomfort from the physical environment; this includes direct temperature, moisture sensations on the skin, and core body temperature (ASHRAE Handbook, 2009). All of these factors of thermal comfort are taken into consideration when designing a facility's building envelope. The building envelope is defined as everything separating the interior of a building from the outside environment and includes elements such as the building foundation, exterior walls, ceiling, roof, doors, windows and even the interior wall insulation (Lemieux & Totten, 2010). With a focus on the use of ICF blocks, the wall system is the most relevant part of the building envelope in this study. A wall system in a building is comprised of multiple layers to achieve an air- tight, water- tight, and energy efficient barrier between external and internal elements. Figure 5 shows the various elements comprising a typical wall system.

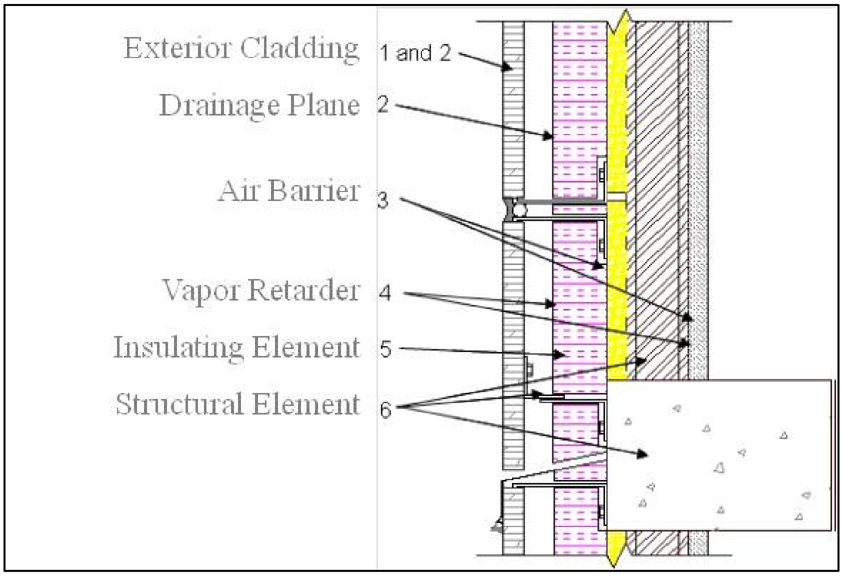


Figure 5. Wall System Components (Lemieux & Totten, 2010)

The exterior cladding is the visible part of the outside of the building, such as vinyl siding or brick veneer. The drainage plane is the space between the exterior cladding and the insulating element; it controls penetrating rainwater. An air barrier is designed to separate outside air from infiltrating into the interior of the building and, conversely, inside air from infiltrating outside (Lemieux & Totten, 2010). The vapor retarder protects the interior wall materials from moisture diffusion due to exterior and interior climatic elements. The insulating element is any material used to reduce heat transfer and is typically made of rolled fiberglass blankets, loose fill, spray or rigid foam, and even natural fibers. The structural element is the rigid framework to which all other wall elements are anchored. Structural elements are typically wood, steel framing, or concrete masonry units (Lemieux & Totten, 2010). These elements of a wall system are designed to work together to provide thermal comfort which is made possible through the scientific principle of heat transfer.

Heat Transfer

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) defines heat transfer as the transfer of energy moving from a higher-temperature region to a lower temperature region through means of conduction, radiation, or convection (ASHRAE Handbook, 2009). When considering heat transfer as it relates to a building, the mode of transfer is conduction, which is the method of heat transfer through a solid mass. For a building during summer months, heat is transferred through exterior walls from the outside, where the air is warmer, into the building. During the winter, the reverse is true where heat from inside the building transfers through the exterior wall to the outside where air is cooler. This concept of heat transfer through wall systems is illustrated in Figure 6.

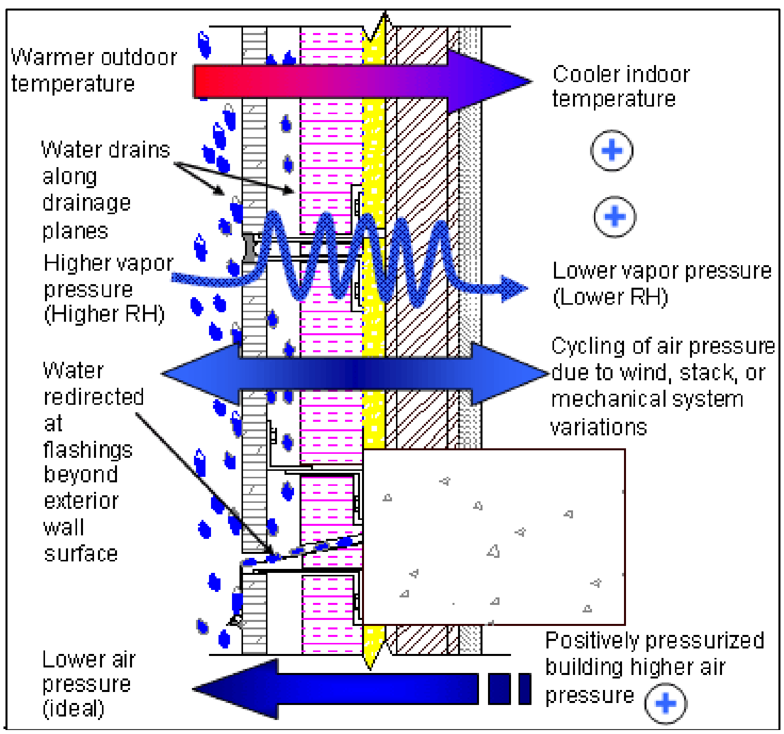


Figure 6. Heat Transfer through Wall System (Lemieux & Totten, 2010)

The process of heat transfer brings into account the principle of thermal conductivity. By definition, thermal conductivity is the time of steady state heat flow through a unit area, one meter thick, of a homogeneous material perpendicular to isothermal planes (Al-Homoud, 2005). Essentially, thermal conductivity measures the effectiveness of a type of material in conducting heat. The calculation for thermal conductivity is shown in Equation 1,

$$q = k\frac{(t_{s1} - t_{s2})A_c}{L} \quad (1)$$

where q is heat transfer rate, t_{s1} is the temperature on one wall side, t_{s2} is the temperature on second wall side, A_c is the wall area, L is the wall thickness, and k is the thermal conductivity of material property. Thermal conductivity can be further described by looking at the thermal resistance of each layered building material within a wall system.

Thermal Resistance

Thermal resistance (R-value) is defined as "the mean temperature difference between two defined surfaces of material" (ASHRAE Handbook, 2009). The overall thermal resistance of a wall consists of surface-to-surface conductance and resistance to heat transfer between interior and exterior surfaces. This means the higher the R-value, the greater the insulation performance of the insulating material (ASHRAE Handbook, 2009). Each material used to comprise the layers of a wall system contains R-values. Building materials provide a wide range of thermal properties in order to provide high R-values.

For a wall system using common construction material such as prefabricated steel framing and rolled insulation, such as shown in Figure 7, the overall thermal resistance equals the sum of each layer's R-value. In this type of wall system, the main components include the continuous layer of exterior bricks, the continuous layer of insulation board, steel framing with rolled insulation batting between the studs, and the continuous layer of interior drywall. The majority of the thermal insulation for this type of wall comes from the insulation between the studs. Calculating the total R-value of a framed wall system, similar to the one shown in Figure 7, requires (1) calculating the R-value through the studs, (2) calculating the R-value through the insulation, and then (3) factoring in the area percentage of the wall with framing and the percentage area of the wall with insulation (ICF, 2012). This is calculation is illustrated in Figure 8.

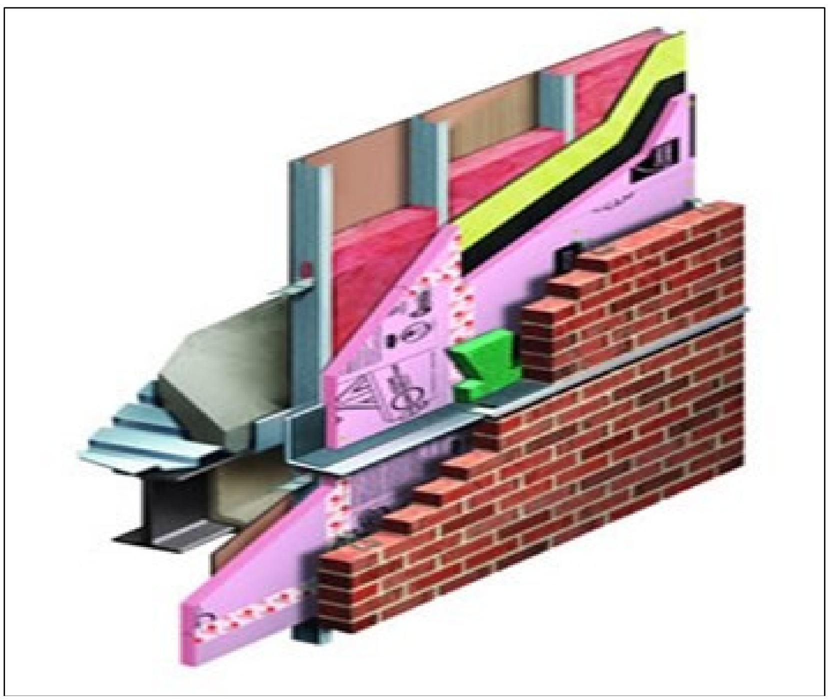
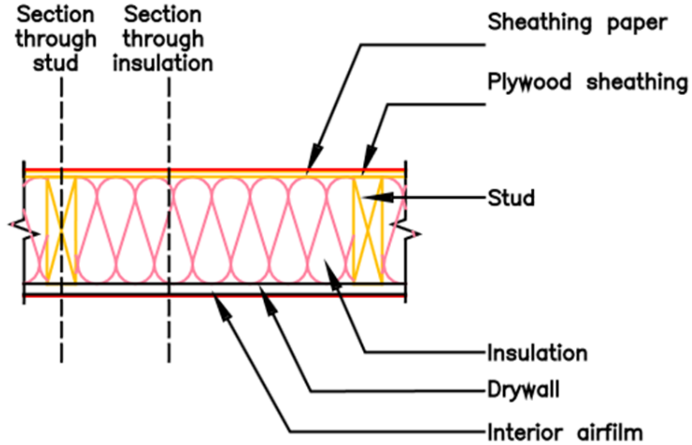


Figure 7. Elements of Steel Framed Wall System (Steel Stud Wall Framing, 2013)



Component	R-Vaule through Stud	R-Value through insulation
Sheathing paper	0.06	0.06
5/8 inch Plywood	0.79	0.79
Stud @ 16 inch o.c.	6.41	-
Insulation	-	19
1/2 inch Drywall	0.45	0.45
Interior airfilm	0.68	0.68
Total	8.39	20.98
Percent of Total Area	19	81
Overall thermal resistance	16	

$$Overall\ thermal\ resistance = \frac{100\%}{\frac{\%\ area\ with\ framing}{R-value\ framing} + \frac{\%\ area\ without\ framing}{R-value\ without\ framing}} = \frac{100\%}{\frac{19\%}{8.39} + \frac{81\%}{21}} = 16$$

Figure 8. Total R-value calculation of stud wall system (ICF, 2012)

The elements of an ICF wall system are illustrated in Figure 9 and consist of a continuous layer of exterior bricks, a continuous layer of polystyrene from one side of the ICF blocks, a continuous layer of reinforced concrete, another continuous layer of polystyrene from the other side of the ICF blocks, and a continuous layer of interior drywall.

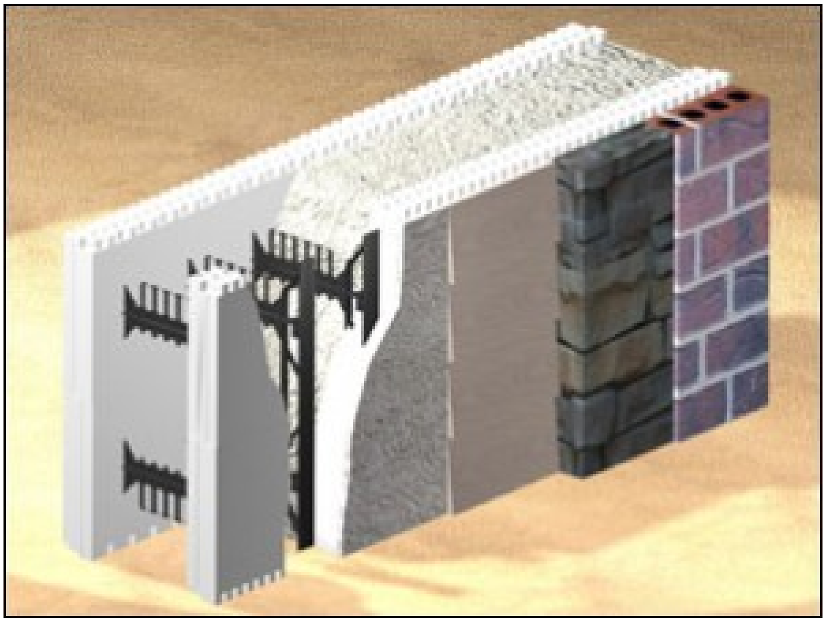
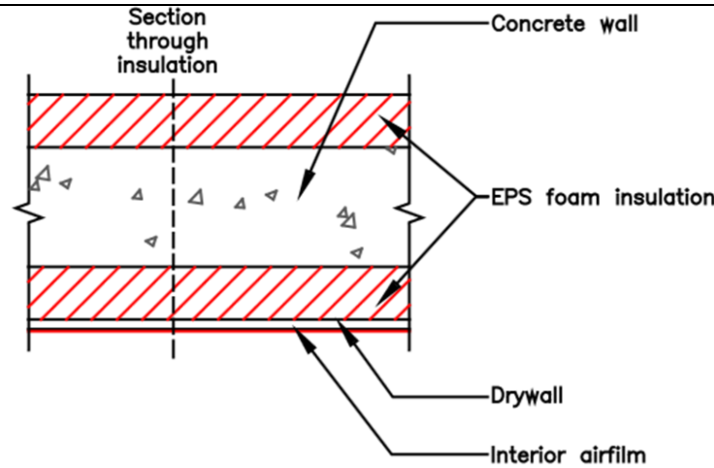


Figure 9. Elements of an ICF Wall System (ICF Construction, 2013)

Since the ICF wall system is comprised of continuous layers, as illustrated in Figure 9, the calculation of the total R-value for an ICF wall does not have to factor in the percentage area as with stud wall systems. An illustration of calculating the total R-value for an ICF wall system is shown in Figure 10. This particular example shows the ICF calculation of a 2-3/4 expanded polystyrene ICF block (ICF, 2012).



Component	R-Vaule through ICF
2.75 inch EPS insulation	11.39
Concrete wall	0.28
2.75 inch EPS insulation	11.39
1/2 inch Drywall	0.45
Interior airfilm	0.68
Total	24.15
Percent of Total Area	100
Overall thermal resistance	24

$$\boldsymbol{Overall\ thermal\ resistance} = \frac{\mathbf{100\%}}{\frac{\%\ area\ with\ framing}{R - value\ framing} + \frac{\%\ area\ without\ framing}{R - value\ without\ framing}} = \frac{\mathbf{100\%}}{\mathbf{0} + \frac{\mathbf{100\%}}{\mathbf{24.15}}} = \mathbf{24}$$

Figure 10. Total R-value calculation of ICF wall system (ICF, 2012)

The total R-values for each wall system can change dependent upon the insulation selected for the stud walls as well as the thickness of the expanded polystyrene of the ICF wall system. The multiple continual layers of material in the ICF wall system brings into discussion the concept of thermal bridging.

Thermal Bridging

Thermal bridging occurs when materials with different thermal conductivities, such as steel framing and rolled fiberglass insulation, creates a bridge for thermal conduction and heat loss spanning from one material to the next. Multiple studies have shown that exterior wall systems in which structural elements penetrate or disrupt the insulating layer, such as illustrated in the steel framed wall system, substantially reduces in the overall thermal resistance of the wall system. In one of these studies, 3D models of ICF walls were shown to have uniform temperature distribution throughout the wall while thermal conductivity through wood framing varied where it acted as a thermal bridge (Saber et al., 2010). This is as a result of thermal bridging and illustrates one of the key design advantages of ICFs over more traditional construction methods because ICF blocks create uninterrupted layers of insulation on either side of an uninterrupted concrete layer. The most common areas of a building envelope where thermal bridging occurs is around window and door installation where the differing materials join together (Saber et al., 2010). ICFs can be shaped to create a more uniform junction between windows and the walls to minimize thermal bridging as shown in Figure 11.

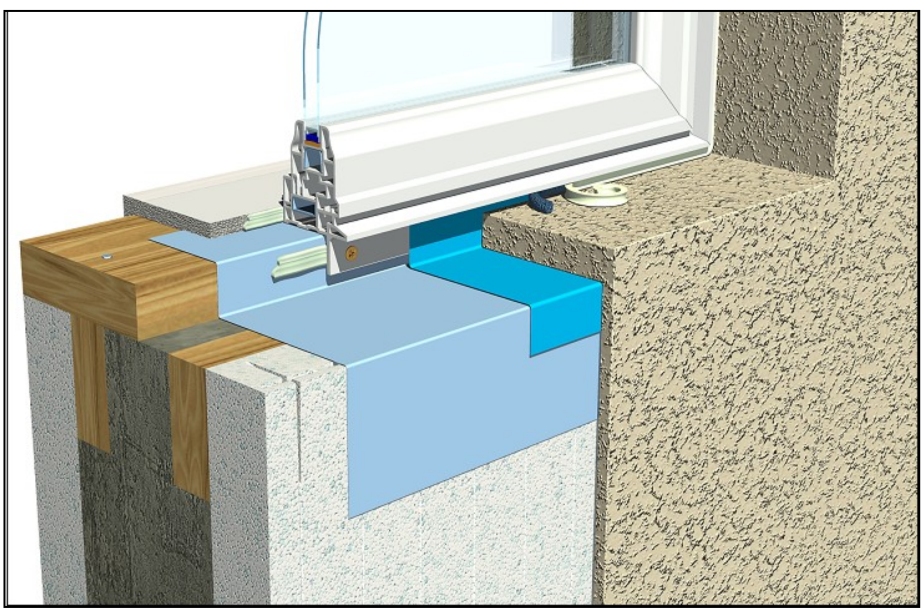


Figure 11. Cutout of Window Installation with ICF wall (Quad-Lock, 2014)

Unified Facilities Criteria 1-200-02: ***High Performance and Sustainable Building Requirements***

As discussed in Chapter I, the newest DoD guidance regarding sustainable construction for the military is UFC 1-200-02, *High Performance and Sustainable Building Requirements* (HPSB), which outlines minimum requirements and direction for achieving high performance in new construction. This UFC is written to include building additions, renovations, and Operations and Maintenance (O&M), as well as Sustainment, Restoration, and Modernization (SR&M). The methodology for this study involves building a simulated facility utilizing ICFs; therefore, the study considered only the new construction application of the HPSB UFC. The first research objective examined energy performance, which is found in section 4 of the new construction chapter of the HPSB UFC.

Energy Performance

Chapters 2-4 of the HPSB UFC reiterates the DoD objective of reducing total ownership costs of facilities by designing facilities which "must be energy efficient while balancing life-cycle costs, energy efficiency, energy security, and occupant benefits" (UFC 1-200-02, 2013, p. 7). To achieve this, the guidance calls for buildings designed after August of 2012 to meet all requirements outlined in ASHRAE 90.1-2007 and achieve whole building energy consumption levels that are, at a minimum, 30% below the levels specified in ASHRAE 90.1-2007 baseline. The revised ASHRAE guidance (90.1-2010) requires greater energy efficiency; therefore, new construction following the revised guidance will be required to achieve an energy consumption reduction of 12% compared to 30%. This reduction can come from any combination of energy sources such as electricity or natural gas. The HPSB UFC directs the Air Force and Navy to utilize ASHRAE 90.1-2007 for meeting requirements and the Army is to utilize ASHRAE 90.1-2010. In anticipation of possible future use of the revised edition, this study will utilize ASHRAE 90.1-2010; therefore, the test results presented in Chapter IV will focus on a 12% reduction.

Life-Cycle Cost Analysis

An essential aspect regarding the viability of one product over another is the comparison of life-cycle costs. By definition, a building Life-Cycle Cost Analysis (LCCA) "is a method for assessing the total cost of facility ownership" (Fuller, 2010, p. 1). An LCCA considers all costs related to constructing, owning, and disposing of a facility. Building LCCAs are useful as a comparison tool when project alternatives exist which fulfill the same requirements regarding performance but differ regarding initial and operating costs (Fuller, 2010).

There are multiple variables to consider in LCCA calculations. First is the consideration of total cost which consists of initial costs (construction costs), fuel costs, Operation and Maintenance (O&M) costs, replacement costs, salvage or disposal costs, finance charges, and even non-monetary benefits (Fuller, 2010). The formula for calculating the LCCA is detailed in Equation 2. The HPSB UFC discusses the requirements for an LCCA which must be performed for all new projects utilizing a building life-cycle cost program. These LCCAs are to be run using a 40-year building life (UFC 1-200-02, 2013).

$$LCC = I + Repl - Res + E + W + OM\&R + O \tag{2}$$

where *LCC* is the total life-cycle cost in present-value (PV) dollars of a given alternative, *I* is the present value of investment costs (if incurred at base date, they need not be discounted), *Repl* is the present value of capital replacement costs, *Res* is the present value of residual value (resale value, salvage value) less disposal costs, *E* is the present value of energy costs, *W* is the present value of water costs, *OM&R* is the present value of non-fuel operating, maintenance and repair costs, and *O* is the present value of other costs (e.g. contract costs).

ASHRAE Standard 90.1

ASHRAE Standard 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* is the current energy standard for construction. Utilized by the International Energy Conservation Code (IECC) and the U.S. Green Building Council's LEED, the 90.1 standard is one of the most widely used energy codes (Callan, 2013). This newest revision calls for more stringent energy conservation by looking beyond initial design and accounting for the full lifespan of a facility. Originally published in 1975, the ASHRAE 90.1 sets the minimum energy efficiency requirements for buildings (other than low rise residential) by considering their design, construction, and planned operation and maintenance, as well as the utilization of onsite renewable energy resources (ASHRAE Standards Commitee, 2012). The standard considers all aspects of a building to include the building envelope, HVAC systems, water heating, power, lighting and other equipment related to energy production or consumption.

Chapter 5 of ASHRAE 90.1-2010 examines the building envelope and establishes requirements for all aspects of the envelope to include walls, roofs, and fenestration (windows and doors). Specifically, the tables 5.5-1 through 5.5-8 detail minimum insulation requirements for all parts of the building envelope for all eight climate zones found in the U.S. Table 1 lists the minimum insulation R-values applicable for the types of walls and floors used in the models obtained from the ASHRAE tables for each of the six climate zones used in this study. These tables also list the maximum U-values and minimum Solar Heat-Gain Coefficient (SHGC) values for windows. The U-value is defined as a measure of thermal transmittance and includes the thermal resistances of all layers and air cavities (ASHRAE Standards Commitee, 2012); it is the reciprocal of the summation of all R-values, therefore, the lower the U-value the greater the thermal transmittance. The SHGC is the measure of solar radiation which can pass through a window (ASHRAE Handbook, 2009). Best described as a ratio, an SHGC of 1 equals the maximum, while and SHGC of 0 equals the least amount solar heat allowed to pass through a window (Gromicko & Wart, 2014). The SHGC is used to quantify the energy efficiency of the entire window assembly to include the window frame, glazing and any spacers (Gromicko & Wart, 2014). Table 2 lists the U-values and SHGC for the six climate zones used in this study. Some of the changes made to the building envelope in the newest revision of the standard include increased insulation requirements and the requirement of cool roofs for climate zones 1, 2, and 3. Another change is the requirement that no more than 40% of any façade can be fenestration unless the fenestration can be shown to perform as well as meeting the 40% requirement (Callan, 2013). The model criteria for this study, listed in Chapter III, will be chosen to incorporate these changes and meet the new minimum insulation values from Table 1.

Table 1. Minimum R-values for selected materials from ASHRAE 90.1-2010 tables

	Climate Zone 2	Climate Zone 3	Climate Zone 4
Mass Wall	R-5.7 c.i.	R-7.6 c.i.	R-9.5 c.i.
Steel Frame Wall	R-13	R-13 + R-3.8 c.i.	R-13 + R-7.5 c.i.

	Climate Zone 5	Climate Zone 6	Climate Zone 7
Mass Wall	R-11.4 c.i.	R-13.3 c.i.	R-15.2 c.i.
Steel Frame Wall	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.

Note: c.i.- continual insulation

Table 2. Maximum U-values and minimum Solar Heat-Gain Coefficient values for windows from ASHRAE 90.1-2010 tables

	Climate Zone 2	Climate Zone 3	Climate Zone 4
Window	Max U-0.75	Max U-0.65	Max U-0.55
	Min SHGC-0.25	Min SHGC-0.25	Min SHGC-0.40

	Climate Zone 5	Climate Zone 6	Climate Zone 7
Window	Max U-0.55	Max U-0.55	Max U-0.45
	Min SHGC-0.40	Min SHGC-0.40	Min SHGC-0.45

Unified Facilities Guide Specifications

The U.S. military has multiple guides to assist with the construction of facilities on installations to include detailed requirements for installation of plumbing, electrical wiring, HVAC systems, and even the types of construction materials. In 2012, the U.S. Army Corps of Engineers (USACE) took the lead in developing and acquiring approval for the Unified Facilities Guide Specifications (UFGS) for Insulating Concrete Forming (UFGS 03-11-19.00-10, 2012). This guide specification is utilized by all branches of the military in constructing facilities with ICF blocks. This guide is divided into three parts. Part one gives details on Quality Assurance (QA), which includes selection of qualified ICF manufacturers, as well as, delivery, storage, and handling of the material. ICF manufacturer qualifications include production of ICFs for no less than five years as well as listed certification ensuring ICFs are code-compliant. ICF installer qualifications include specified training as well as experience in successful completion of no less than three project of similar size, scope and complexity. Part two gives specifications detail regarding product descriptions including allowable materials, cavity size, insulation thickness, and product type. The final part of this guide specification gives details regarding execution of constructing with ICFs to include site examination, installation, and quality control. Within part one, this guide specification outlines the required ICF manufacturer and installer qualification as well as required quality documentation of the ICF material elements. Part two of this guide specification details requirements of the ICFs themselves. Sections 2.1-2.3 specify the system to be flat wall systems comprised of expanded polystyrene with interior cavities between 4-12 inches. Selected ICFs shall provide minimum R-value of R-22. Smaller R-values are allowed for certain sizes of ICFs provided the ICFs meet required ASTM tests listed in section 2.2.2 of the UFGS. The final part of this guide specification details installation requirement to include inspection of block and rebar placement prior concrete placement as well as quality control requirement through the duration of the ICF construction.

Sustainable Barriers

As evident from the directives previously discussed, sustainable construction is being integrated into current construction practices in public and private sectors. There is still, however, a noticeably slower trend of implementing some of the newer sustainable technologies. A few studies have been conducted in the last few years to identify various barriers which may be preventing widespread sustainable practices in the private sector for residential and commercial construction. For example, Landman (1999) specifically examined possible barriers as related to government initiatives. She investigated 12 barriers and found that the top four barriers were a lack of interest or demand from clients, a lack of education in sustainable practices, a failure to account for long-term savings, and higher costs (Landman, 1999). Osaily (2010) conducted a similar study and investigated the key barriers to implementing sustainable construction in the West Bank of Palestine. His study focused on seven hypothesized barriers: people, cost, time, technology, market, legal aspects, and political situation (Osaily, 2010). Additionally, Tomkiewicz (2011) explored barriers to implementation of sustainable construction practices in residential homes in the Rochester, NY, area. The four main barrier categories in her study were market perceptions, information gaps, infrastructure issues, and implementation issues (Tomkiewicz, 2011). In an online survey of residential homeowners, 36% of homeowners were found to be motivated in their home buying decisions by one of three factors: environmental stewardship, energy savings, or health benefits (Binsacca, 2008). This survey shows there is a desire in the residential market for sustainable construction. The question remains though, what is preventing more homeowners in the private sector from acting on this desire? All of these studies show there are barriers towards implementing sustainable construction in various areas of private sector construction. More details of these results and how they relate to this study will be discussed further in Chapter IV.

Summary

This chapter discussed the various physical aspects of ICFs and how their design characteristics relate to higher energy efficiency compared to wood and steel framing.

These details form the foundation of why ICFs are considered a sustainable and energy efficient construction material. This chapter also reviewed at the various design requirements for sustainable military construction as outlined in the *High Performance and Sustainable Building* criteria and ASHRAE 90.1. The details found within this guidance were utilized in this study to test ICFs. The end of the chapter looked at previous studies regarding barriers which hindered the implementation of sustainable building ideas and methods in private sector construction. This prior research served as the foundation for investigating similar barriers regarding the use of ICFs in sustainable military construction. The methodology of how this ICF study was conducted is discussed in the following chapter.

III. Methodology

This chapter discusses the methods used to compare the performance of Insulated Concrete Form (ICF) blocks regarding energy efficiency and life-cycle cost analysis as it relates to the *High Performance and Sustainable Buildings* (HPSB) criteria. It begins with descriptions of how the modeling simulations were established, followed by discussions on the software selected for the analysis, and ending with how the analysis was executed within the software programs. The final part of the chapter discusses the method used to develop the questions for the interviews and how the data was analyzed to identify barriers in implementing ICFs in sustainable military construction.

Energy Efficiency Analysis

The energy efficiency analysis of this study utilized an energy modeling software called eQUEST. This software was developed by James J. Hirsh and Associates in collaboration with Lawrence Berkeley National Laboratory as a platform to accomplish sophisticated building energy use simulation which runs off of the DOE-2 computer algorithm from the U.S. Department of Energy (The Quick Energy Simulation Tool (eQUEST), 2014). DOE-2 was developed by the Department of Energy as a whole-building energy analysis program designed to analyze the energy efficiency of designs and new building technologies. The Air Force Energy Program office has approved eQUEST for use in building energy simulation; eQUEST is recommended for use in the HPSB UFC.

Installation Selection

For this study, six Air Force active duty installations were selected from within the continental U.S. (CONUS). These installations were selected by utilizing the International Energy Conservation Code/American Society of Heating, Refrigeration and Air-Conditioning Engineers (IECC/ASHRAE) climate region designations. This guide divides the United States into eight separate zones based on climate designations. The Department of Energy developed the IECC climate zone map as a tool to facilitate a simplified and consistent approach to defining climate regions for implementation of various construction codes (IECC/ASHRAE, 2010). The eight zones are labeled as zone one being 'very hot' through zone eight being 'subarctic.' For the purpose of this study, zones one and eight were not used since they represent Hawaii and Alaska, respectively, and are outside the CONUS region. There are active duty Air Force installations in Hawaii and Alaska; however, due to their geographic locations, the potential existed for limited ICF availability and possible higher transportation costs. The selected installations and their representative climate zones are listed in Table 3, and Figure 12 shows a map of the IECC/ASHRAE climate zones with the selected installations for this study. The selected installations are located in moist or dry locations which are denoted in the IECC Climatic zone classification as A and B respectively while no bases were selected in the marine location denoted as C. In ASHRAE 90.1-2010, the insulation requirements for a particular numbered climate zone does not change in relation to the lettered designator. Based on the established methodology of utilizing insulation requirements from a particular numbered climate zone there would be no change by selecting an installation in an A region over a C region.

Table 3. Selected Installations and Climate Zones

Air Force Installation	Location	IECC Climatic Zone
Tyndall AFB	Florida	2 (Hot-Humid)
Holloman AFB	New Mexico	3 (Hot-Dry)
Joint Base Langley-Eustis	Virginia	4 (Mixed-Humid)
Offutt AFB	Nebraska	5 (Mixed-dry)
Malmstrom AFB	Montana	6 (Cold)
Minot AFB	North Dakota	7 (Very Cold)

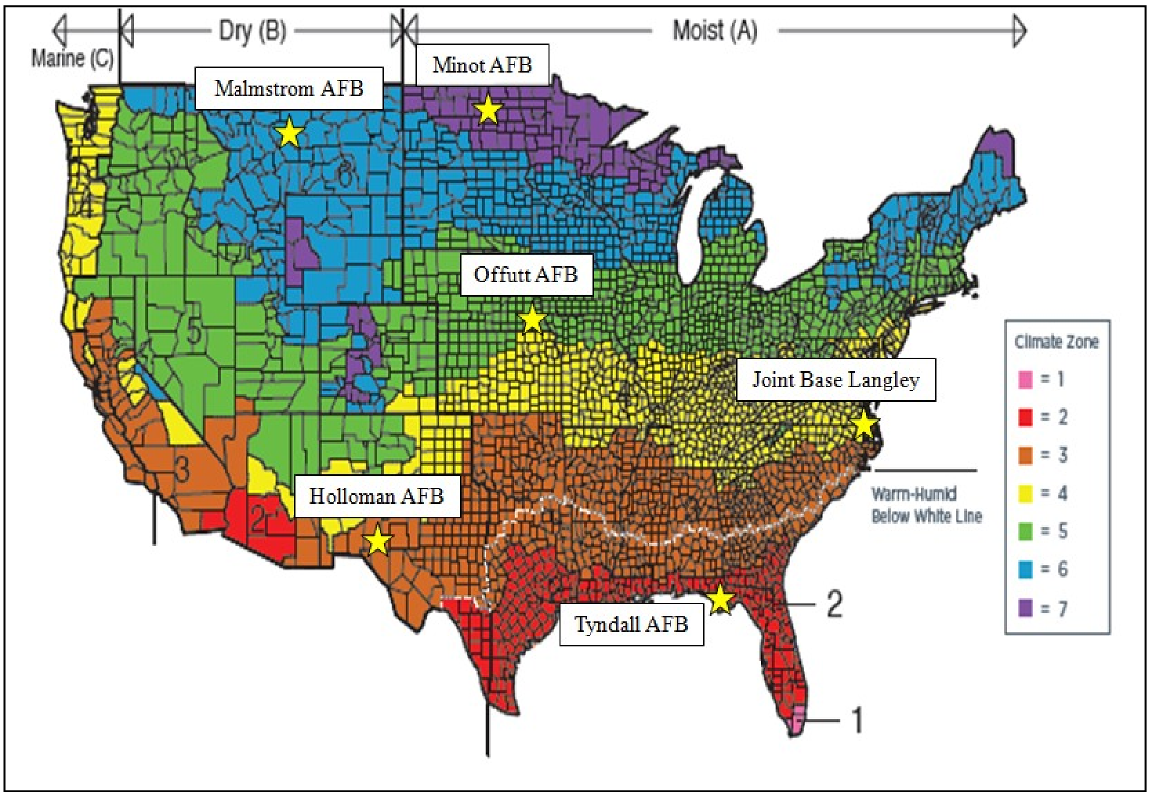


Figure 12. IECC/ASHRAE Climate Zones (IECC/ASHRAE, 2010)

Building Floor Plan and Construction

To conduct an all-encompassing general assessment, this study selected a type of facility which could be reasonably found at all CONUS military installations regardless of individual installation mission. For this reason, the research focused on a general purpose two-story administrative office facility such as a squadron operations facility. UFC 4-610-01, *Administration Facilities,* outlines the criteria for designing and siting administrative facilities. According to this UFC, the size of the facility should be determined on the number of occupants, special purpose space requirements, circulation, and net-to-gross multipliers (UFC- 4-610-01, 2013). Since this study models a hypothetical facility, the number of occupants and special purpose space requirements are unknown. According to the Air Force Civil Engineer Center (AFCEC), the historical average size of a squadron operations and aircraft maintenance unit is 36,000 square feet (sf); therefore, the simulated facility was modeled to this size. This is the same square footage utilized in a previous study which utilized eQUEST to model day-lighting strategies for the Air Force (Lee, 2009). Since one of the installations selected for the study is the Headquarters of Air Combat Command (ACC) located at Joint Base Langley-Eustis, facility information from the ACC Facility Design Guide for a Squadron Operations and Aircraft Maintenance Unit was used as the floor plan for this study. An illustration of the layout for both floors of this facility, taken from the ACC design guide, can be found in Appendix A. Based on this design, a model of the facility was created using the minimum design requirements specified by ASHRAE 90.1-2010 in each of the six selected climate zones.

eQUEST contains over 40 types of pre-loaded facilities available for constructing energy models to include offices, schools, hospitals and retail facilities to name a few. This study selected the two-story office space as the base model which was then customized to fit the specifics of the analysis. eQUEST also allows for the selected type of facility to be modeled in numerous shapes. UFC 4-610-01 recommends designers consider simplistic shapes in the design of administrative facilities (UFC- 4-610-01, 2013). This study thus selected the ‘T’ shape shown in the ACC squadron operations floor plan. The specific dimensions for the facility were not provided in the ACC squadron operations floor plan, therefore individual dimensions of each wall were approximated to equal the overall 36,000 sf previously established. Figure 13 shows the overall dimension of the model facility where each floor equaled 18,000 sf to achieve the total 36,000 sf requirement. The floor-to-floor height used was 12 ft and the floor-to-ceiling height was 9 ft. The facilities were constructed at grade with concrete footer foundations. Other options for model constructions are below grade with crawl spaces or full basement.

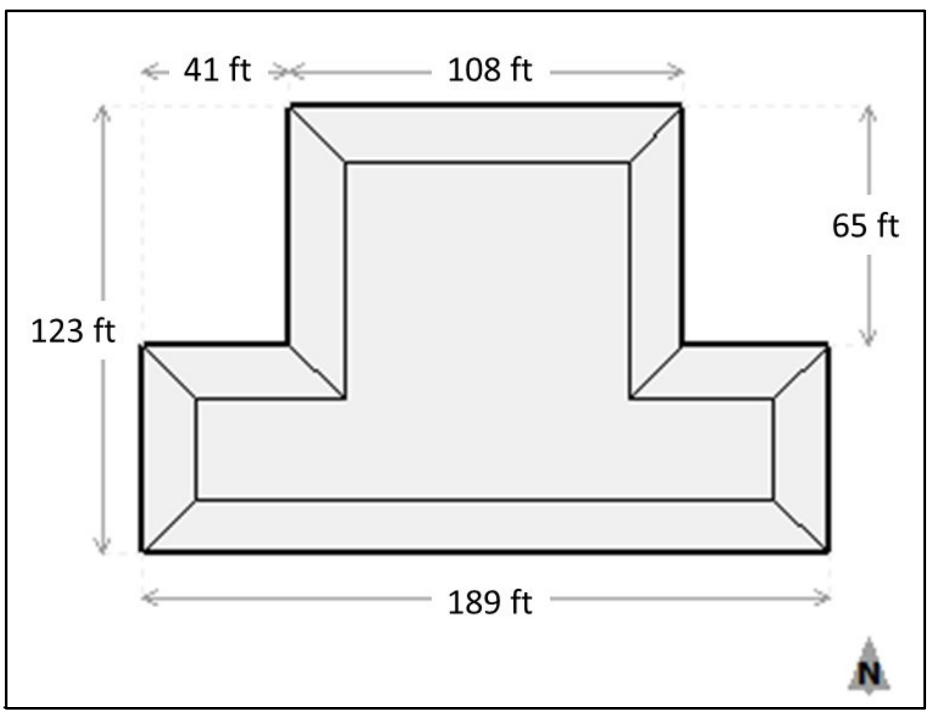


Figure 13. Floor plan of modeled facility

In accordance with ASHRAE 90.1-2010, the percentage of windows on each facade remained below 40%. In this model, windows were placed along the walls where offices would likely be located and the percentage remained at 23% or less. The walls no windows represent areas likely to contain no windows such as stairwells, restrooms, storage rooms and mechanical equipment rooms. The windows used for the model were double pane, clear tint, 1/4-inch thickness with 1/2- inch between panes. The frames were aluminum without thermal breaks. To meet the U-value and SHGC values discussed in Chapter II, the specific glass code selected was code 2005 which has a U-value of 0.45 and SHGC of 0.70. Each window was sized at either 5 x 5 ft or 7 x 5 ft. The differences in window sizes represented windows located in private offices and windows located in open space offices. The front door selected was a glass, single pane, clear tint, 1/4- inch, with aluminum frame. All other doors were steel, hollow core doors with aluminum frames. UFC 3-110-03 details roofing selection criteria and design requirements. Section 2-8.1 of this UFC suggests using built-up roof (BUR) systems "unless it can be shown that it fails to meet important design criteria" (UFC 3-110-03, 2012). Therefore, the roof style selected was a built-up system with metal framing at 24-inch on center, aggregate surface and polystyrene insulation rated at R-20. This insulation rating meets the minimum roof insulation requirement specified in ASHRAE 90.1-2010 for all model locations.

Military installations can utilize either centralized or decentralized HVAC systems. Centralized systems are those where the cooling and heating is generated at one location and distributed via underground or above ground pipes to individual air-handling or fan-coil units located at the individual building (Bhatia, 2014). Centralized systems utilized by the military are chilled water, high heat, or steams systems. Decentralized systems are those where the individual units for each building are located with the facility instead of a central location. Decentralized air conditioning systems tend to be lower in initial cost and allow the user to select the type of system which would be most efficient based on the facility use (Bhatia, 2014). There are multiple types of HVAC systems; however, eQUEST offers variations of three types of systems from which to choose. The types of systems available are direct expansion systems, chilled waters systems, or ground source heat pumps. A direct expansion system is an air cooled system, where air is pulled across cooling coils to absore the heat before being fanned back into the area at a cooling temperature (Bhatia, 2014). These systems are commonly used for residential homes or smaller commercial application. A chilled water system utilizes water to absorb the heat of a space and reject the heat through cooling towers or air coolers. These systems are more efficient for multistory facilities and complex building systems such as hospitals and airports (Bhatia, 2014). The third type of HVAC system available in eQUEST is a ground source heat pump system which utilizes the natural cooling of the ground to cool either water or refrigerant which passes through underground pipes. The HVAC system selecedt for this facility was a standard chilled water system and hot water coil heating system. The ACC squadron operations guide specified the HVAC system to have the ability to operate in multiple zones with variable air volume and hot water reheat therefore the HVAC system for the models included these options.

Figure 14 shows a 3D rendering of the model facility from eQUEST. These design specifications remained constant for each facility model completed in this study at each location. A summarized list of these design specifications is shown in Appendix B.

The only part of the facility which changed in the models was the exterior walls of the building envelope.

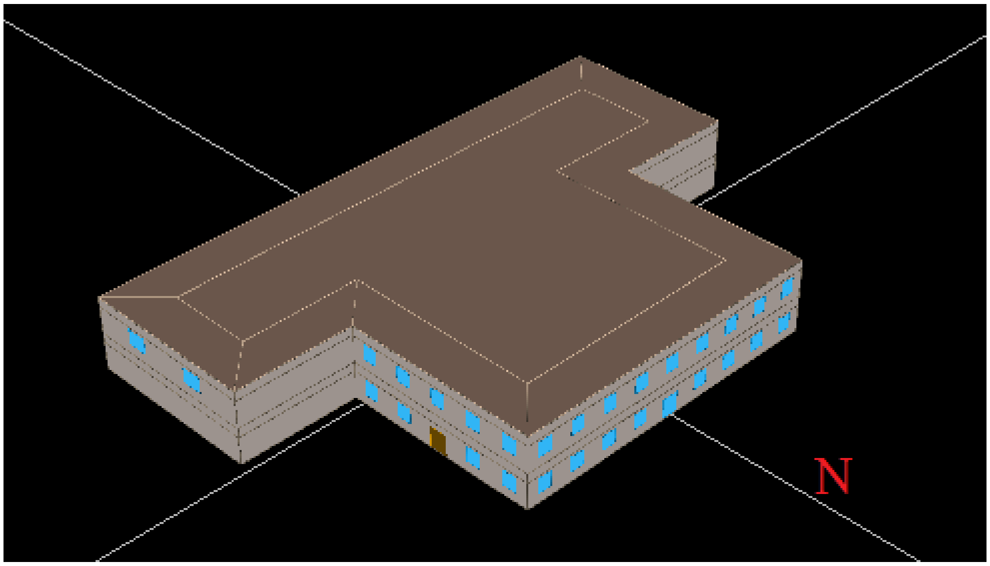


Figure 14. 3-D rendering of modeled facility in eQUEST

This model analysis utilized three types of exterior wall systems: steel framing, CMU mass wall, and an ICF wall. Framed walls and mass walls are two types of wall systems commonly used to construct facilities. Steel framing was chosen as representative of framed walls and is recommended as wall type in the ACC squadron operations design guide. Since ICFs are considered a mass wall, a CMU mass wall was also selected for the model in order to compare to like type wall systems. As mentioned in Chapter II, the steel framed wall is a type of framed system which utilizes a material such as wood, steel, or aluminum to form the structure of the wall, while CMU and ICFs are both defined in the ASHRAE standard as mass walls. The structural components of the walls remained the same for all models; however, the insulation requirement varied.

The insulation selected for each simulated location was chosen to meet the minimum insulation requirement discussed in Chapter II and shown in Table 1. The eQUEST software contains a materials library which allows the user to construct the exterior walls to various design specifications; however, the insulation selections within the eQUEST library do not exactly match the minimum R-values listed within ASHRAE 90.1-2010. Therefore, the insulation selected for the models utilized the available insulation options within eQUEST which most closely matched the minimum ASHRAE requirements. A detailed list of the structural elements and selected eQUEST insulation for each climate zone simulation are listed in Table 4.

Table 4. Structural Elements for Steel framed and CMU walls and Floor used in eQUEST models for selected climate zones

	Climate Zone 2	**Climate Zone 3**	**Climate Zone 4**
CMU Mass Wall	6 in CMU Block	6 in CMU Block	6 in CMU Block
	Grout 24 in o.c, hollow cell	Grout 24 in o.c, hollow cell	Grout 24 in o.c, hollow cell
	1.5 in polystyrene (R-6)	2 in polystyrene (R-8)	1.5 in polyisocyanurate (R-10.5)
Steel Frame Wall	Metal Frame, 2x6, 24 in o.c.	Metal Frame, 2x6, 24 in o.c.	Metal Frame, 2x6, 24 in o.c.
	4 in Brick veneer	4 in Brick veneer	4 in Brick veneer
	Batt insulation (R-13)	Batt insulation (R-13)	Batt insulation (R-13)
		Additional 1 in polystyrene (R-4)	Additional 2 in polystyrene (R-8)

	Climate Zone 5	Climate Zone 6	Climate Zone 7
CMU Mass Wall	6 in CMU Block	6 in CMU Block	6 in CMU Block
	Grout 24 in o.c, hollow cell	Grout 24 in o.c, hollow cell	Grout 24 in o.c, hollow cell
	3 in polystyrene (R-12)	2 in polyisocyanurate (R-14)	3 in polyurethane (R-18)
Steel Frame Wall	Metal Frame, 2x6, 24 in o.c.	Metal Frame, 2x6, 24 in o.c.	Metal Frame, 2x6, 24 in o.c.
	4 in Brick veneer	4 in Brick veneer	4 in Brick veneer
	Batt insulation (R-13)	Batt insulation (R-13)	Batt insulation (R-13)
	Additional 2 in polystyrene (R-8)	Additional 2 in polystyrene (R-8)	Additional 2 in polystyrene (R-8)

The third type of wall tested in this study was an ICF wall. As mentioned in Chapter II, ICF blocks can be manufactured with different thicknesses and materials. For this study, one type of ICF block was used for all six test locations. The design aspects of this type of block conformed to the requirements specified in the UFGS 03-11-19.00-10 for Insulated Concrete Forms. As noted in part 2 of the guide specification, the block selected was an expanded polystyrene flat wall block. The cavity width chosen was six inches, which is one of the allowable widths, with insulation thickness of three inches providing an R-value of 25 which is above the minimum value specified in the ICF UFGS. The concrete to fill the cavity was selected from the available choices within eQUEST to be a density of 140 lb/ft^3. Table 5 shows the elements selected from the eQUEST materials library to comprise the ICF wall. The total thermal resistance for this ICF wall equals R-28 which exceeds the minimum insulation requirements for each climate zone.

Table 5. ICF wall elements utilized for simulation

ICF Wall
Brick, Common, 4 in
Polystyrene, Expanded, 3 in
Concrete, Dried, 140 lb/ft^3, 6 in
Polystyrene, Expanded, 3 in

Energy Simulations

The models for the three types of facilities (steel frame, CMU, and ICF) were simulated through an energy consumption analysis at each of the six locations for a consecutive 24-month timespan, January 2012 through December 2013, utilizing historical weather data from those years. The climatic data for each location was downloaded from the Department of Energy eQUEST database. These energy simulations resulted in three sets of calculated annual energy usage and peak demand spanning 24 months at each of the six locations; one for the steel frame facility, one for the CMU facility and one for the ICF facility. The results and subsequent analysis of these energy simulations are detailed in Chapter IV.

Assumptions

This study serves as a proof of concept and methodology, therefore, it assumes multiple constants. Aspects of the building such as overall shape, window selection, roof selection, location of windows along the wall and HVAC selection will all effect the energy consumption of the facility. Another constant assumed was the selection of the ICF block. This model utilized the same size block for all six locations. By making this assumption the overall insulation was greater for some climate zones than the required minimums.

Building Life-Cycle Cost Analysis

While there are multiple tools available to perform an LCCA, this study utilized Building Life-Cycle Cost version 5 (BLCC5) to conduct the LCCA of the facilities at each installation. BLCC5 was developed by the National Institute of Standards and Technology for the U.S. Department of Energy's Federal Energy Management Program (FEMP) and has been continually utilized by the U.S. Air Force for LCCA of various projects (Fuller, 2010).

There are three primary costs considered for an LCCA: initial investment, annual utility costs, and life-cycle energy costs. The initial investment consists of all costs related to new construction of the facility. To calculate the initial investment cost of the facilities, specific cost data came from the 2011 RSMeans Green Building Cost Data Handbook (RSMeans, 2011). The costs for the ICF blocks came from the block average by the EPS Industry Alliance (NAHB Research Center, 2014). Since this study focused on the differences in building envelope related to the exterior wall construction, the LCCA calculations involved only the costs related to the construction of the exterior walls. Therefore, the costs related to site preparations, electrical, HVAC and plumbing systems, the roof and all interior construction were not factored into the calculation. The purpose of limiting the calculations to the exterior wall construction is to ascertain if the energy cost savings over the life time of the facilities will pay back for the initial cost. The costs found in RSMeans are based on the national average and include materials and labor. To get a representation of the cost at the individual locations tested within this study, the total cost calculated from RSMeans were multiplied by the city cost index found within RSMeans for each location (RSMeans, 2011). The estimated costs for the exterior walls of the three facility types are shown in Table 6. As mentioned in Chapter II, there is an increase in initial cost of using ICFs over steel more traditional materials. For this study, the percentage increase in cost of ICFs over steel-framed walls was approximately 34% where the difference between CMUs and ICFs was approximately 23%. A detailed table of the calculation costs for each wall type is shown in Appendix C.

Table 6. Facility Initial Construction Cost Estimation

Installation	**City Cost Index**	**Steel-Frame Estimate**	**CMU Estimate**	**ICF Estimate**
Tyndall AFB, FL	0.806	$90,873	$98,586	$121,479
Holloman AFB, NM	0.883	$99,555	$108,005	$133,084
JB Langley-Eustis, VA	0.855	$96,398	$104,580	$128,864
Offutt AFB, NE	0.912	$102,825	$111,552	$137,455
Malmstrom AFB, MT	0.921	$103,839	$112,653	$138,812
Minot AFB, ND	0.880	$99,217	$107,638	$132,632

Other than the name and location of each installation, other general input requirements for BLCC include the discounting convention of end-of-year or mid-year. The tutorial for BLCC5 suggests middle of year for the DoD which is what was used for this study. For the analysis, current dollar analysis was selected with the default nominal discount rate of 3.5%. Current dollar analysis was selected to include the general inflation rate of 0.5%. Three alternative analyses were created for each location, one for each of the three building types tested through eQUEST. The inputs for annual consumption of electricity and natural gas were obtained from the eQUEST simulation results. The analysis was run for CY 2013 and utilized the actual utility costs for each location which were obtained from AFCEC. Table 7 lists the utility rates for each location for 2013. The initial cost input came from the RSMeans total cost previously discussed and shown in Table 6. For the purposes of this study, operations and maintenance costs were not included in the LCCA. The results and analysis of the LCCAs are detailed in Chapter IV.

Table 7. 2013 Utility rates for selected installations

Air Force Installation	**Electric Rate ($/kWH)**	**Natural Gas Rate ($/MBtu)**
Tyndall AFB, FL	0.0756	4.854
Holloman AFB, NM	0.0645	4.932
JB Langley-Eustis, VA	0.0618	7.482
Offutt AFB, NE	0.0343	4.918
Malmstrom AFB, MT	0.1096	5.236
Minot AFB, ND	0.0576	3.522

Barrier Analysis

To gather data addressing the third research objective regarding barriers in ICF use, research was conducted regarding previous studies of a similar nature. A set of questions was subsequently developed based on these previous studies regarding barriers for implementing sustainable construction. These questions were submitted for approval through the Air Force Institute of Technology (AFIT) Institutional Review Board (IRB). The AFIT IRB gave guidance for the interviews to be conducted to non-military personnel. After acquiring IRB approval, these questions were then asked during interviews with 14 ICF contractors throughout the U.S. The use of interviews was not designed to achieve a random or representative sample; therefore, the data was not subjected to tests of statistical significance. The qualitative and quantitative data resulting from the interviews were meant to provide insight into the views of ICF professionals.

Participant Selection

The selection of survey respondents was done on a voluntary basis. A list of 65 ICF contractors was compiled from contractors listed through the EPS Industry Alliance and ICF Builders Network, as well as a general internet search for ICF contractors in each of the continental states. Requests for participation in the study were sent to the 65 contractors of which 14 agreed to participate. The contractors who participated in the study were then individually interviewed over the phone.

Question Formulation

The phone interviews of each ICF contractor started by asking a few demographic questions to gather their experience level regarding their use of ICFs; this was followed by the structured questions used to help identify potential barriers. The demographic breakdown of the participants is shown in Table 8. The demographic data shows that there is a breadth of experience with ICFs among the participants with nearly 50% having worked with ICFs for more than 10 years. This data also shows that while all participants worked with residential home construction over 78% have also had some experience in the commercial application of ICFs. None of the contractors interviewed had worked on ICF projects for the military however a few of them had bid on military contracts and several which were located near military installation expressed an interest in securing contracts to construct ICF project for the military.

Table 8. Demographic Breakdown of Survey Participants

Year experience with ICFs		**Types of Commercial Projects**	
Less than 5	1	Retail Stores	6
5-10	7	Shopping Centers	5
More than 10	6	Restaurants	0
		Other	6
Types of ICF projects		**Average number of Commercial Projects per year**	
Residential	14	Less than 10	8
Commercial	11	10-25	3
Institutional	1	25-50	0

The questions asked to the participants were formulated from previous research. Landman (1999) and Osaily (2010), previously mentioned in Chapter II, both utilized questionnaires completed by construction professionals to gather data regarding barriers. The current study followed the same methodology by creating questions specifically related to barriers for ICF construction. Comparing the identified barriers from both of these previous studies, similarities were focused in four areas; therefore, the questions for this study were developed around these barriers (people, cost, time, and market). A full list of the questions asked to the ICF contractors are shown in Figure 15 and can be found in Appendix D. Like the previous studies by Landman (1999) and Osaily (2010), the questions for this study used a 5-point Likert scale, which is a psychometric response scale used to obtain preference or degree of agreement with a given statement (Uebersax, 2006). The anchors for the scale used in this study were 1 to represent “No impact” and 5 to represent “Strong impact” regarding decisions to utilize ICFs for new facility construction.

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding what is sustainable construction					
Lack of awareness & understanding of types of sustainable construction materials					
Lack of information about what practices qualify as sustainability					
Resistance to change					
Lack of cooperation b/w owner and contractor					
Lack of training regarding sustainable construction methods/techniques					
Preconception towards traditional construction methods & materials					
Lack of interest & demand from client					
Lack of incentives for utilizing sustainable construction					
Cost Impact					
Relationship between construction cost and implementing sustainable construction					
Limited projects released in the market					
Fierce competition; enhance sustainable construction implementation					
Reduced profit margin					
Emphasizing on lowest price for subcontractors will facilitate sustainable construction					
Expenses for transportation of materials and equipment					
Limited project budgets prevent use of sustainable construction materials					
Time Impact					
Tight schedules					
Delays in material submittals					
Delays in material approvals					
Higher emphasis on speed of construction					
Availability of ICFs in construction area					
Market Impact					
Unique characteristics of each project					
Inefficiency of available equipment					

Figure 15. Interview Questions for ICF contractors

During the interviews, the contractors were asked to provide a numerical response to the questions utilizing the established Likert scale and then to provide any additional comments or explanations for their answer choice. As mention before, none of the interviewed contractor had worked on ICF projects for the military but had expressed a desire to acquire military contracts. The contractors were therefore asked to consider these barriers in relation to military use of ICF when giving their answers. An analysis of contractor responses to the questions is detailed in Chapter IV.

Summary

This chapter described the methods utilized in this study to analyze ICFs as a viable construction material in sustainable military construction related to the HPSB UFC requirements. It outlined how the prototypical facility was modeled utilizing eQUEST energy modeling software to determine the energy efficiency and savings of an ICF administrative facility compared to an identical facility utilizing either steel framing or CMU blocks. The chapter also discussed how life-cycle costs were used to analyze the three types of facilities. The chapter concluded with a description of how the ICF contractor interviews were conducted and how the interview questions were developed to gather information regarding possible barriers hindering ICF use in military construction. The results and analysis of this research are discussed in the following chapter.

IV. Analysis and Results

This chapter presents the research results which include the energy performance from the eQUEST simulations, the life-cycle cost analysis results, and the survey results. Along with the quantitative results of the model simulations, the chapter also provides an analysis of the data along with comparative insight.

eQUEST Results

This study investigated the energy performance of a facility constructed using ICFs as the structural element for exterior walls compared to those of a facility utilizing the minimum insulation requirements for a steel framed or CMU facility. This analysis was conducted using eQUEST energy modeling software under the modeling parameters discussed in Chapter III. Full results of all eQUEST simulations are shown in Appendix E; however, the summarized results are analyzed in this chapter.

Data Analysis

The energy simulations confirm a higher energy efficiency of ICF walls over steel framed walls. Table 9 shows the summarized energy usage for electricity and natural gas over the 24-month time span for the steel framed and ICF models at each of the simulated locations. The energy savings ranged from approximately 3,000 to 6,000 kWhs and approximately 7 to 108 MBtus dependent on the climate zone. The greatest reduction in MBtus was seen in the colder climate zones and the greatest reduction in kWhs was seen in the warmest climate zone.

Table 9. Summary of 2012 & 2013 Energy Use Results Comparing Steel Framing and ICFs

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Annual Natural Gas Use (kWh)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (MBtu)
Tyndall AFB, FL	Steel Frame (2012)	419,160	103.24	30.26	6,220	6.71
	ICF (2012)	412,940	96.53	28.29		
	Steel Frame (2013)	418,620	104.02	30.49	6,320	6.91
	ICF (2013)	412,300	97.11	28.46		
Holloman AFB, NM	Steel Frame (2012)	380,520	114.31	33.50	2,800	8.74
	ICF (2012)	377,720	105.57	30.94		
	Steel Frame (2013)	382,210	115.17	33.75	3,030	8.90
	ICF (2013)	379,180	106.27	31.15		
JB Langley-Eustis, VA	Steel Frame (2012)	370,930	175.51	51.44	4,040	24.20
	ICF (2012)	366,890	151.31	44.35		
	Steel Frame (2013)	371,090	180.76	52.98	4,090	24.73
	ICF (2013)	367,000	156.03	45.73		
Offutt AFB, NE	Steel Frame (2012)	350,510	416.67	122.12	5,000	62.57
	ICF (2012)	345,510	354.10	103.78		
	Steel Frame (2013)	350,880	431.26	126.40	4,990	64.62
	ICF (2013)	345,890	366.64	107.46		
Malmstrom AFB, MT	Steel Frame (2012)	312,550	523.66	153.48	3,740	80.98
	ICF (2012)	308,810	442.68	129.74		
	Steel Frame (2013)	313,720	546.30	160.11	3,790	79.84
	ICF (2013)	309,930	466.46	136.71		
Minot AFB, ND	Steel Frame (2012)	313,290	716.72	210.06	4,460	107.31
	ICF (2012)	308,830	609.41	178.61		
	Steel Frame (2013)	316,900	715.80	209.79	5,030	108.11
	ICF (2013)	311,870	607.69	178.10		

The energy simulations also show a higher energy efficiency of ICF over CMU mass walls in almost all cases. Table 10 shows the summarized energy usage for electricity and natural gas over the 24-month time span for each simulated location for the CMU mass wall models and ICF models. As with the comparison of steel framed and ICF walls, the CMU and ICF wall comparisons show a reduction of approximately 1 to 28 MBtus with the colder climate zones having the greatest reduction. In terms of electricity savings, there was a reduction of approximately 2,000 kWhs for the two warmer climate zones and approximately 500 kWhs for climate zone 5, while the other three climate zones showed a negligible or negative reduction in electricity usage.

Table 10. Summary of 2012 & 2013 Energy Use Results Comparing CMU and ICFs

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Annual Natural Gas Use (kWh)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (MBtu)
Tyndall AFB, FL	CMU (2012)	414,890	97.58	28.60	1,950	1.05
	ICF (2012)	412,940	96.53	28.29		
	CMU (2013)	414,390	98.81	28.96	2,090	1.70
	ICF (2013)	412,300	97.11	28.46		
Holloman AFB, NM	CMU (2012)	379,690	107.16	31.41	1,970	1.59
	ICF (2012)	377,720	105.57	30.94		
	CMU (2013)	381,230	108.23	31.72	2,050	1.96
	ICF (2013)	379,180	106.27	31.15		
JB Langley-Eustis, VA	CMU (2012)	366,860	165.81	48.60	-30	14.50
	ICF (2012)	366,890	151.31	44.35		
	CMU (2013)	366,990	170.70	50.03	-10	14.67
	ICF (2013)	367,000	156.03	45.73		
Offutt AFB, NE	CMU (2012)	346,050	382.25	112.03	540	28.15
	ICF (2012)	345,510	354.10	103.78		
	CMU (2013)	346,440	394.27	115.55	550	27.63
	ICF (2013)	345,890	366.64	107.46		
Malmstrom AFB, MT	CMU (2012)	308,770	470.75	137.97	-40	28.07
	ICF (2012)	308,810	442.68	129.74		
	CMU (2013)	309,410	491.84	144.15	-520	25.38
	ICF (2013)	309,930	466.46	136.71		
Minot AFB, ND	CMU (2012)	308,230	632.04	185.24	-600	22.63
	ICF (2012)	308,830	609.41	178.61		
	CMU (2013)	310,370	626.13	183.51	-1,500	18.44
	ICF (2013)	311,870	607.69	178.10		

Figure 16 shows the usage difference in electricity between steel frame and ICF, as well as CMU and ICF, for both test years. As seen from the tables, this graph illustrates a greater reduction in electricity usage between the steel frame and ICFs while the usage difference between CMU and ICF is smaller for climate zones 2, 3, and 5 and negligible or negative for the colder climate zones.

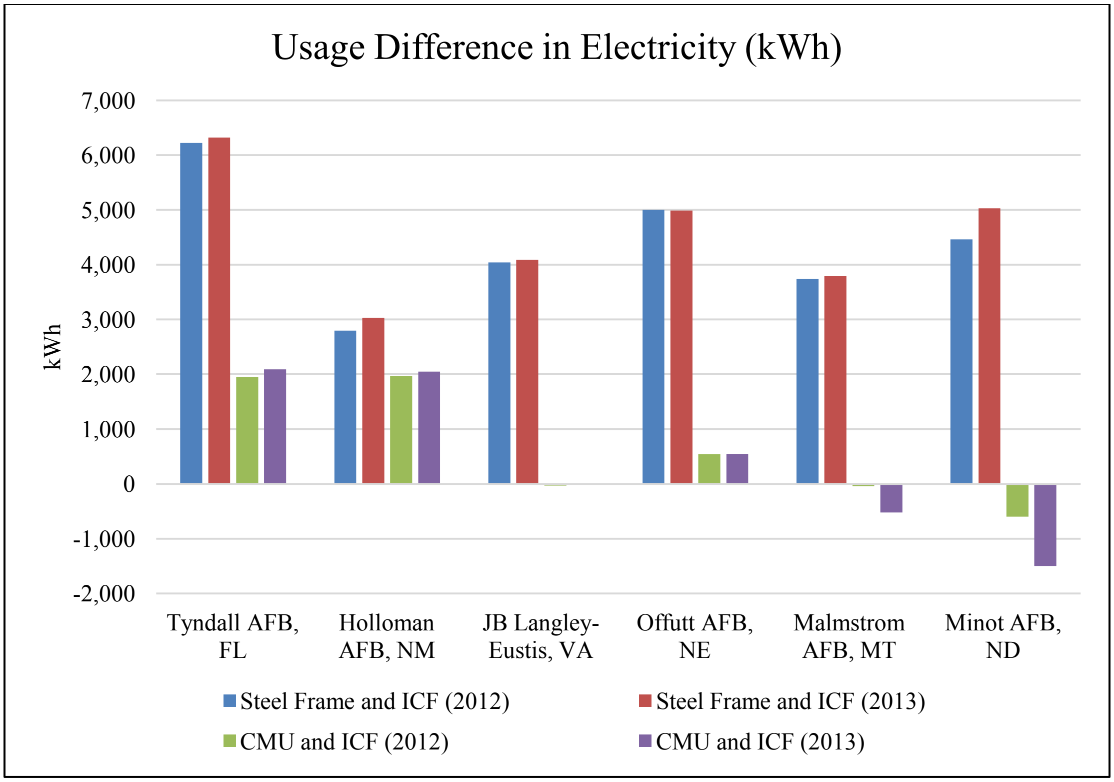


Figure 16. Usage Difference in Electricity (kWh)

Figure 17 shows the usage difference in natural gas between steel frame and ICF, as well as CMU and ICF, for both test years. As seen from the table, this graph illustrates a greater reduction in natural gas usage between the steel frame and ICFs with the largest savings occurring in the colder climate zones and decreasing towards the warmer climate zones. A difference in natural gas use was shown between the CMU and ICF facilities for climate zones 4, 5, 6, and 7, with the difference for climate zones 2 and 3 being negligible. These results show a reasonable savings trend; with natural gas being utilized for heating more in colder climate locations, it is expected to see a greater savings in natural gas for those locations. As mentioned in Chapter III, six different CMU walls utilized for the study with each wall conforming to the minimum insulation requirements for mass walls for that particular climate zone. However, only one type of ICF was utilized for the study which met the minimum requirement and in some climate zones far exceeded the minimum requirement. This choice could cause a potential error in the eQUEST results particularly for the warmer climate zones which require lower insulation R-values.

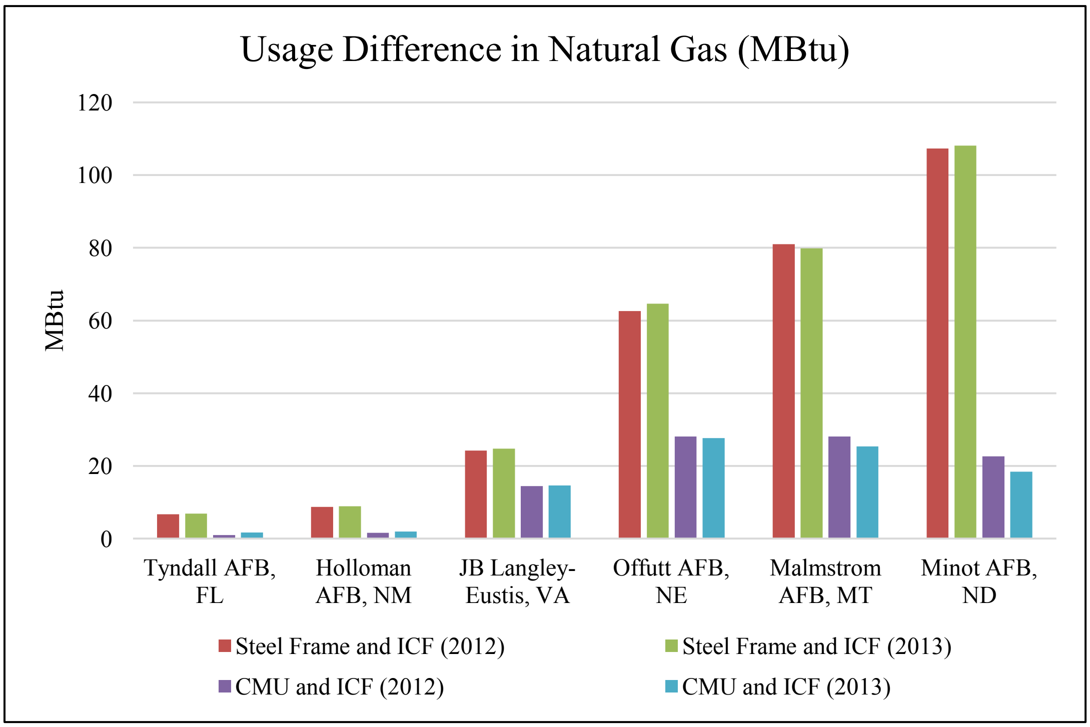


Figure 17. Usage Difference in Natural Gas (MBtu)

Discussion of Results Related to HPSB UFC

As previously mentioned in Chapter II, the HPSB UFC requires facilities to meet the minimum construction standards set forth in the ASHRAE 90.1 standard. This study utilized the newest release of ASHRAE 90.1-2010 for which the HPSB UFC requires a total reduction of 12% in energy consumption from ASHRAE 90.1-2010, baseline requirements. To assess the total percentage reduction of electricity and natural gas usage towards achieving the 12% requirement, the simulation results were converted to a common unit of measure before calculating the total percentage difference. For this study the natural gas usage (MBtu) was converted to kWh. Conversion was done by writing MBtus in terms of Btus, where 1 MBtu equal 1 million Btus, then utilizing the conversion factor of 1 kWh equaling 3,412 Btus. The converted rates are shown in Table 11 and Table 12 for CY 2012 and CY 2013, respectively. As shown in the tables, the natural gas, after converted to kWhs, is significantly smaller compared to electricity usage. The natural gas savings has almost negligible impact on the overall energy reduction, the energy savings really comes from electricity usage.

Table 11. Calculated percent difference for CY 2012 converting to kWh

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Annual Natural Gas Use (kWh)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (kWh)	Total Usage Difference (kWh)	Total Percent Reduction
Tyndall AFB, FL	Steel Frame	419,160	103.24	30.26	6,220	1.97	6,222	1.484
	CMU	414,890	97.58	28.60	1,950	0.31	1,950	0.470
	ICF	412,940	96.53	28.29				
Holloman AFB, NM	Steel Frame	380,520	114.31	33.50	2,800	2.56	2,803	0.736
	CMU	379,690	107.16	31.41	1,970	0.47	1,970	0.519
	ICF	377,720	105.57	30.94				
JB Langley-Eustis, VA	Steel Frame	370,930	175.51	51.44	4,040	7.09	4,047	1.091
	CMU	366,860	165.81	48.60	-30	4.25	-26	-0.007
	ICF	366,890	151.31	44.35				
Offutt AFB, NE	Steel Frame	350,510	416.67	122.12	5,000	18.34	5,018	1.431
	CMU	346,050	386.25	113.20	540	9.42	549	0.159
	ICF	345,510	354.10	103.78				
Malmstrom AFB, MT	Steel Frame	312,550	523.66	153.48	3,740	23.73	3,764	1.204
	CMU	308,770	470.75	137.97	-40	8.23	-32	-0.010
	ICF	308,810	442.68	129.74				
Minot AFB, ND	Steel Frame	313,290	716.72	210.06	4,460	31.45	4,491	1.433
	CMU	308,230	632.04	185.24	-600	6.63	-593	-0.192
	ICF	308,830	609.41	178.61				

Table 12. Calculated percent difference for CY 2013 converting to kWh

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Annual Natural Gas Use (kWh)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (kWh)	Total Usage Difference (kWh)	Total Percent Reduction
Tyndall AFB, FL	Steel Frame	418,620	104.02	30.49	6,320	2.03	6,322	1.510
	CMU	414,390	98.81	28.96	2,090	0.50	2,090	0.504
	ICF	412,300	97.11	28.46				
Holloman AFB, NM	Steel Frame	382,210	115.17	33.75	3,030	2.61	3,033	0.793
	CMU	381,230	108.23	31.72	2,050	0.57	2,051	0.538
	ICF	379,180	106.27	31.15				
JB Langley-Eustis, VA	Steel Frame	371,090	180.76	52.98	4,090	7.25	4,097	1.104
	CMU	366,990	170.7	50.03	-10	4.30	-6	-0.002
	ICF	367,000	156.03	45.73				
Offutt AFB, NE	Steel Frame	350,880	431.26	126.40	4,990	18.94	5,009	1.427
	CMU	346,440	394.27	115.55	550	8.10	558	0.161
	ICF	345,890	366.64	107.46				
Malmstrom AFB, MT	Steel Frame	313,720	546.30	160.11	3,790	23.40	3,813	1.215
	CMU	309,410	491.84	144.15	-520	7.44	-513	-0.166
	ICF	309,930	466.46	136.71				
Minot AFB, ND	Steel Frame	316,900	715.80	209.79	5,030	31.69	5,062	1.596
	CMU	310,370	626.13	183.51	-1,500	5.40	-1,495	-0.481
	ICF	311,870	607.69	178.10				

The converted total percent reductions from the above tables are illustrated in relationship to the 12% total reduction requirement in Figure 18. This graph shows the total percent reduction in kWh to be approximately 1.5% or less for all climate zones when utilizing ICFs over steel framing for both 2012 and 2013. When looking at percent reduction between CMU and ICF walls, the greatest percentage reduction occurred in the two warmer climate zones achieving approximately 0.5% for both test years. These results are reasonable when comparing a framed wall to a mass wall. CMU walls and ICF walls are both considered mass walls so the reduction in energy usage would be smaller than the reduction between a framed wall and mass wall.

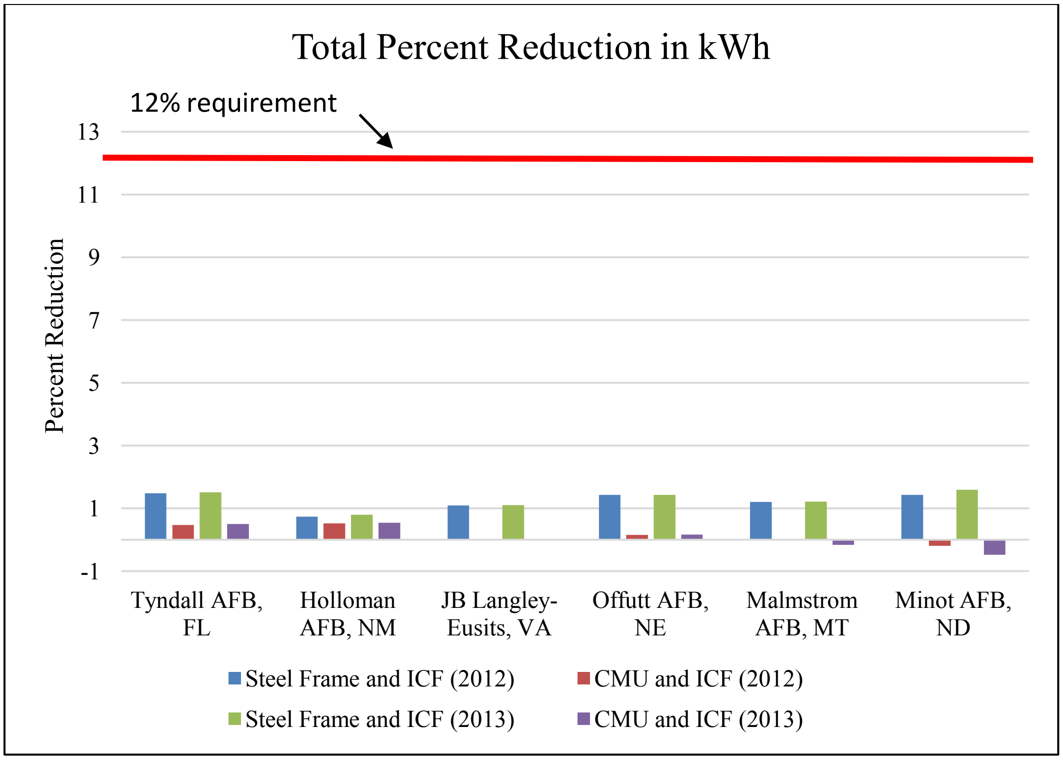


Figure 18. Total Percent Energy Reduction in kWh (MBtu)

ICFs are also commonly used as material for constructing below-grade, such as basements and foundations. Constructing a facility which utilizes ICFs below-grade where there is direct contact with the earth, a location of heat and moisture transfer, could change the overall numbers. This change would most likely be an increase in energy reduction, thereby improving the overall percentage reduction. While this simulation model did not include any below-grade construction, facilities with below-grade construction where ICFs can be utilized can be found on military installations.

All of the data and analysis just discussed considers the energy consumption for steel framed, CMU, and ICF facilities with a northern orientation, meaning the front doors of the facility faced the north. The orientation of a facility can cause a difference in energy consumption dependent on window and door locations along the walls in relation to the rising and setting of the sun in the eastern to western direction. Appendix G of ASHRAE 90.1-2010 directs energy modeling of proposed facilities to be done four times by rotating the building 90 degrees each time. This is done to determine which direction the building should face when constructed to achieve the greatest energy efficiency. For this reason, models at each location were also simulated in a Western, Southern, and Eastern direction. This was done to assess the possible energy reduction variation in the facilities based on building orientation.

Figure 19 shows the total energy reduction in electricity for each orientation between the steel framed and ICF facilities for CY 2012 at each location. The results in show that there is some variation in electricity reduction dependent on building orientation. In the case of climate zone 2, the greatest reduction in electricity usage occurred in a western oriented facility while climate zone 6 showed the greatest reduction in electricity usage with an eastern oriented facility. Similar results are shown in Figure 20 with the natural gas reduction between the steel framed and ICF facilities for CY 2012. This chart also shows a difference in natural gas reduction based on building orientation with the greatest reduction in natural gas usage occurring in a western orientation. It should be noted that the graphs only illustrate the total reduction in electricity and natural gas, respectively, and not the total energy reduction. While there are greater reductions in usage by looking at building orientation, the total electricity and natural gas usage was lower in all climate zones for facilities constructed in a northern orientation. Full results of energy consumption for the three wall types for both years with the all four building orientations are shown in Appendix F. As noted earlier in Chapter III, the overall shape of the facility, along with the location and selection of the windows, effects the energy usage of a facility especially when looking at the facility utilizing different directional orientations.

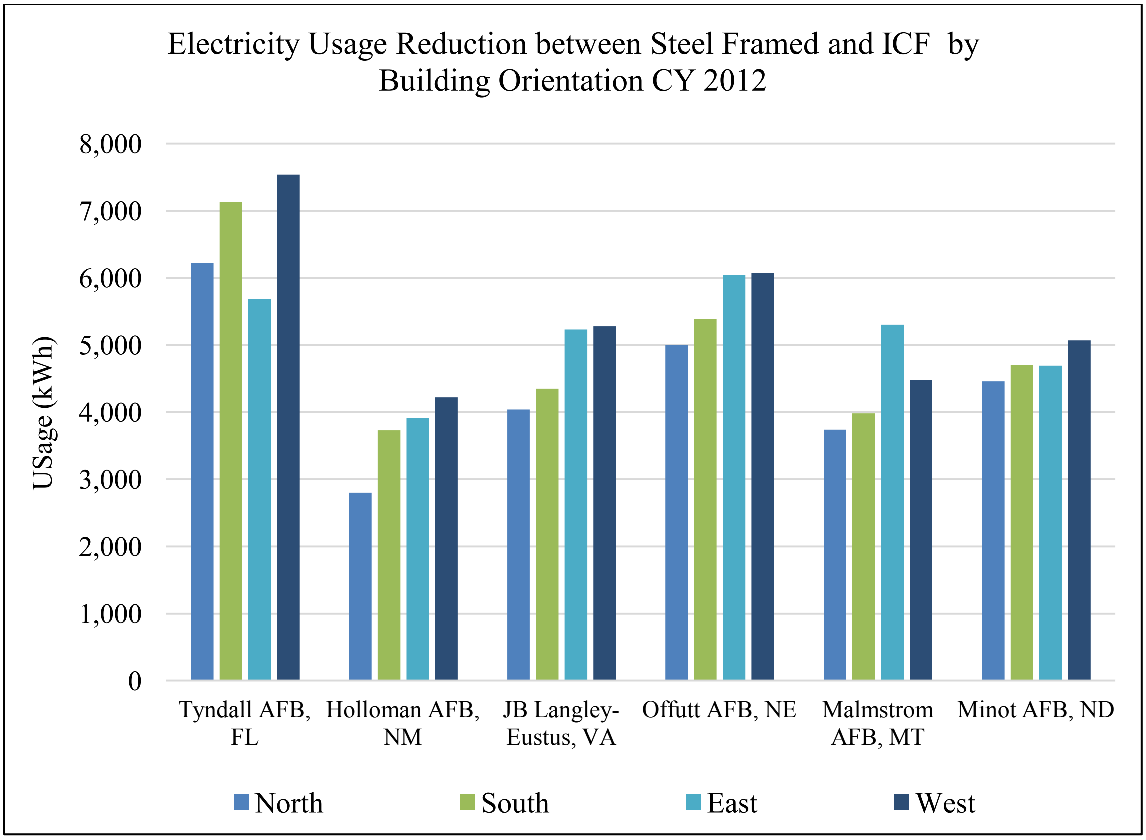


Figure 19. Electricity Usage Reduction between Steel Framed and ICF by Building Orientation for CY 2012

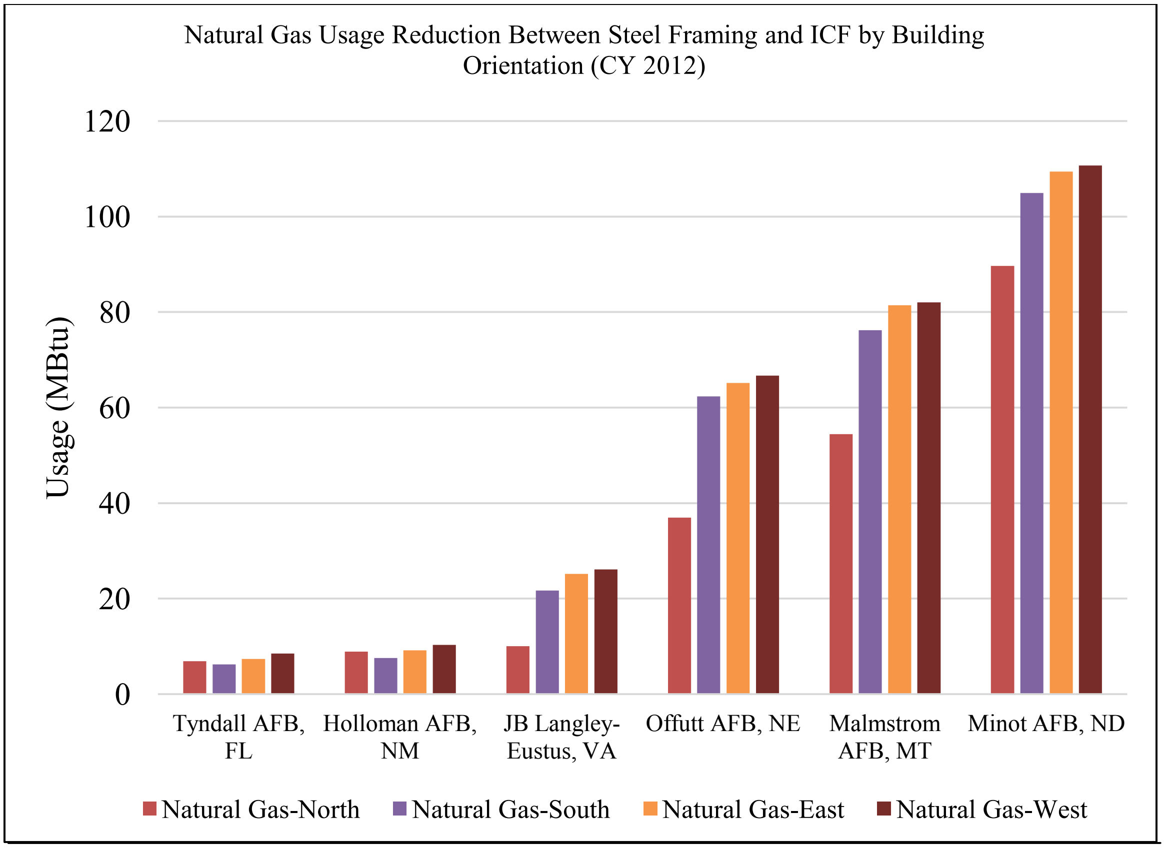


Figure 20. Natural Gas Usage Reduction between Steel Framed and ICF by Building Orientation for CY 2012

Life-Cycle Cost Analysis Results

This part of the study examined the overall life-cycle cost of utilizing ICFs over steel framing or CMU blocks for a 40-year facility life span. The LCCAs were conducted utilizing the BLCC5 software and modeled in accordance with the methodology outlined in Chapter III. The results are summarized below, with the full analysis being shown in Appendix G.

BLCC5 Results

For an alternative to be cost effective over the duration of its life-cycle, the savings to investment ratio (SIR) should be 1 or greater and the adjusted internal rate of return (AIRR) should be lower than the discounted rate. As mentioned in Chapter III, the discounted rate utilized was 3.5%. The results of the LCCAs for all locations are summarized in Table 13. Based on these results alone, neither the SIR nor AIRR met the minimum requirements for being cost effective in any location. There were instances, however, where the LCCA results came close to meeting these minimums. This was true in the case of steel framed and ICF comparisons for climate zones 2 and 6. It should be noted that in concurrence with the energy reduction shown by the eQUEST results, the life cycle energy consumption cost is less in the ICF buildings.

Discussion of Results

The results of these LCCAs show that simply changing the building envelope material from steel framing or CMU to ICFs is not cost effective. This could be due to errors in initial cost estimates or in the parameters used in the BLCC5 methodology. In some cases the AIRR resulted in a negative percentage meaning there was no return on investment after the 40-year lifespan of these facilities. This occurred in the CMU and ICF comparisons for facilities in all climate zones except zone 2. In the case of the CMU comparison for climate zone 7, the LCCA was unable to compute a meaningful SIR or AIRR because the incremental savings and total savings were both negative.

There are potential errors related to the initial cost calculation used for the analysis. Errors could come from assumptions made such as utilizing the same type of ICF block for all six locations instead of sizing the ICFs for each climate zone requirement. It should be noted, however, that these LCCAs do not tell the full story. This study also assumed an average price for the ICF blocks which could vary dependant on manufacturer and therefore effect the overall initial cost estimates. As previously discussed, the ICFs do not meet the full 12% energy reduction requirement per the HPSB UFC. However, by adding other sustainable practices, such as energy efficient HVAC systems and/or fenestrations in addition to the ICFs, reaching the minimum 12% energy reduction goal would more than likely provide the better LCCA and thus be the more optimal choice for construction.

Table 13. Summary of Life-Cycle Cost Analysis Results

Air Force Installation	Exterior Wall	Initial Capital Investment	Future Energy Consumption Costs	Savings to Investment Ration (SIR)	Adjusted Internal Rate of Return (AIRR)
Tyndall AFB, FL	Steel Frame	$90,873	$785,890	0.88	3.17%
	ICF	$121,479	$759,794		
	CMU	$98,586	$777,372	0.79	2.90%
	ICF	$121,479	$759,794		
Holloman AFB, NM	Steel Frame	$99,555	$602,721	0.18	-0.79%
	ICF	$133,084	$596,741		
	CMU	$108,005	$600,176	0.14	-1.44%
	ICF	$133,084	$596,741		
JB Langley-Eustis, VA	Steel Frame	$96,398	$597,726	0.36	0.92%
	ICF	$128,864	$586,269		
	CMU	$104,580	$589,395	0.13	-1.59%
	ICF	$128,864	$586,269		
Offutt AFB, NE	Steel Frame	$102,825	$358,336	0.40	1.17%
	ICF	$137,455	$344,814		
	CMU	$111,552	$349,258	0.18	-0.88%
	ICF	$137,455	$344,814		
Malmstrom AFB, MT	Steel Frame	$103,839	$903,746	0.67	2.46%
	ICF	$138,812	$881,126		
	CMU	$112,653	$883,827	0.11	-2.13%
	ICF	$138,812	$881,126		
Minot AFB, ND	Steel Frame	$99,217	$523,098	0.56	2.03%
	ICF	$132,632	$504,813		
	CMU	$107,683	$504,589	---	---
	ICF	$132,632	$504,813		

Survey Results

This part of the ICF study explored the potential barriers preventing the increased use of ICFs in military construction. The barrier analysis was conducted through individual interviews with ICF contractors in accordance with the methodology outlined in Chapter III. The results of the interviews are summarized below, and a full detail of all ICF contractor responses are shown in Appendix H.

Data Analysis

Analysis of the interview responses was conducted using the percent response for each question as well as the calculated mean and standard deviation. The mean shows the average of the responses from the 14 interviewed contractors and supports the percentage responses. The standard deviation shows the level of variance from the mean where a low standard deviation shows the data tends to be close to the mean value. Table 12 shows the percentage of responses, mean, and standard deviation for each question. Of the 14 ICF contractors interviewed, over 71% believed resistance to change (question 4) to be the strongest barrier towards utilizing ICFs. This is supported by the responses to question 7, which is a preconception towards traditional materials and methods with 57% rating it a 4 and 29% rating it a 5. Another proposed barrier would be a lack of knowledge (questions 1, 2, and 3) and lack of incentives (question 9). The cost differences between more traditional materials and ICFs (question 10) showed mixed results regarding its validity as a barrier.

Table 14. Percentage Responses to Survey Questions

	No Impact (1)	2	3	4	Strong Impact (5)	Mean	Std Dev
Question 1	0%	0%	7%	64%	29%	4.2	0.579
Question 2	0%	7%	0%	64%	29%	4.1	0.770
Question 3	0%	0%	7%	57%	36%	4.3	0.611
Question 4	0%	0%	7%	21%	71%	4.6	0.633
Question 5	14%	7%	71%	0%	7%	2.8	0.975
Question 6	0%	0%	64%	36%	0%	3.4	0.497
Question 7	7%	0%	7%	57%	29%	4.0	1.038
Question 8	0%	14%	64%	21%	0%	3.1	0.616
Question 9	0%	7%	21%	64%	7%	3.7	0.726
Question 10	0%	0%	29%	50%	21%	3.9	0.730
Question 11	0%	0%	71%	29%	0%	3.3	0.469
Question 12	0%	0%	71%	21%	7%	3.4	0.633
Question 13	21%	7%	57%	7%	7%	2.7	1.139
Question 14	0%	7%	14%	57%	21%	3.9	0.829
Question 15	21%	7%	57%	14%	0%	2.6	1.008
Question 16	0%	0%	29%	50%	21%	3.9	0.730
Question 17	7%	21%	43%	29%	0%	2.9	0.917
Question 18	14%	29%	57%	0%	0%	2.4	0.756
Question 19	7%	29%	57%	0%	7%	2.7	0.914
Question 20	0%	29%	36%	29%	7%	3.1	0.949
Question 21	7%	29%	50%	7%	7%	2.8	0.975
Question 22	7%	43%	29%	21%	0%	2.6	0.929
Question 23	0%	64%	29%	7%	0%	2.4	0.646

Discussion of Results

From the data shown in Table 14, the majority of the ICF contractors interviewed believe the greatest barrier to be a resistance to change and thus a tendency to follow traditional construction methods. While there is not sufficient data from this study to explain the reason for this resistance to change, some of the contractors speculated the resistance to result from a lack of broad understanding regarding the use of ICFs, including the pros and cons compared to more traditional methods. This is reinforced by the next greatest barrier which is the lack of knowledge and understanding of sustainability and the types of sustainable materials available, as well as a lack of information concerning what qualifies as sustainability. A lack of incentives was also noted as a possible barrier. The incentives referred to by this question are tax credits and discounts. ICF use currently counts towards LEED credits; however, the use of this material does not currently qualify for tax credits or deduction as part of the federal energy tax credit program. Some contractors commented that if ICFs qualified for tax credits and deductions there would likely be an increase in ICF use in public and private sector construction. The data collected showed mixed opinions on whether cost is a barrier. While it costs slightly more to construct with ICFs over steel framing and CMUs initially, there is the benefit of secondary cost savings in the form of energy savings. Some of the interviewed contractors commented that the increase in ICF manufacturers throughout the U.S. and the technological advances in design and manufacturing process have brought down the prices of ICFs over the last several years. It is this decrease in cost which the interviewed contractors believe to have led to the increase in ICF use among residential construction. This accounts for those who feel cost is not much of a barrier. There were contractors who disagreed and feel cost is still a barrier. More than one contractor noted the cost difference to be more of a factor for those who are limited to contracting by lowest bid procurement.

Summary

This chapter presented the findings of the eQUEST energy modeling and life-cycle cost analysis, as well as the results of the individual interviews with ICFs contractors regarding barriers to ICF implementation. Despite the study limitations the results are consistent with previous studies regarding ICF use in private sector and residential construction. Chapter V will summarize the research results and provide final recommendations.

V. Conclusions and Recommendations

This chapter provides the final conclusions of this study, as well as recommendations for possible further research. The first part of the chapter summarizes the original research objectives presented in Chapter I with the results found in Chapter IV. Following the summary is a brief discussion of benefits and limitations, which is followed by suggestions for possible future research.

Summary of Research

This study analyzed the value of using Insulated Concrete Forms (ICFs) as the primary structural construction materials in military construction as part of the requirements outlined in the *High Performance and Sustainable Buildings* UFC. The study utilized eQUEST energy modeling software to calculate the annual energy usage of a prototypical administrative facility on six different Air Force installations throughout the continental U.S. area. In addition to the energy modeling, a life-cycle cost analysis was conducted for the modeled facilities at each location. Finally, interviews were conducted with ICF contractors to identify perceived barriers preventing increased use of ICFs in sustainable military construction.

Research Objectives

Three research objectives were developed for study from the general problem statement discussed in Chapter I. These objectives were examined and the results directly answer the objectives as discussed below.

How do ICFs meet sustainability design requirements for optimized energy performance as outlined in the High Performance and Sustainable Buildings criteria?

The results of this study show a reduction in overall energy usage for both electricity and natural gas when using ICFs in the construction of external wall systems compared to the use of steel framing and CMUs. In all regions, choosing to construct with ICFs over steel framing reduced energy consumption in both electricity and natural gas; however, the greatest total percentage energy reduction given all tested scenarios was only approximately 1.5%. All eQUEST simulations were conducted for two calendar years, 2012 and 2013. The energy consumption in all simulations varied to small degrees between the two years. This shows that varying yearly weather patterns will effect annual energy consumption. To assess any significant changes in energy consumption related to weather more simulations will need to be conducted for a larger study timeframe.

Energy reduction comparisons were also conducted with the facility facing all four cardinal directions. The results of these comparisons showed how a change in building orientation can effect energy reduction in different climate zones. The results of the orientation analysis indicate that the overall use of electricity and natural gas was lower for the northern oriented facility; however, the greatest reduction in usage occurred in other directions for some climate zones. This difference directly relates to the solar gain on exterior walls attributed to the rising and setting of the sun in an east to west direction. As mentioned in Chapter IV, the size and shape of the facility as well as window type and layout along the exterior walls and how those walls are oriented in relation to the sun's movement factor into which orientation of the facility results in the most reduction of energy usage. Therefore, those factors should also be considered when working toward total energy reduction of a facility.

How do ICFs meet life-cycle cost requirements as outlined in the High Performance and Sustainable Buildings criteria?

The results of the life-cycle cost analysis for each location did not show a savings to investment ratio high enough to justify utilizing ICFs instead of steel framing or CMUs. There were two locations in which the SIR and AIRR came close to the required minimums. In the study, using ICFs over steel framing resulted in a cost increase of 34% and a cost increase of 23% over CMU facilities. The study utilized an average cost of ICFs blocks for calculating the initial cost and this cost could vary dependent on manufacturer. This initial cost increase is larger than the 0.5-4% estimated increase discussed in Chapter II. That cost increase estimate is for utilizing ICFs over wood framing for residential home construction and it would be expected that the cost increase of ICFs over steel framing or CMUs for larger commercial building would be larger. An average initial cost increase for ICF use in commercial facilities over steel framed or CMUs walls was not found when researching background information for the study. Therefore, the initial cost increase of 34% and 23% found for this study could be an error and would impact the overall LCCA results. Other factors which could reduce the initial cost further would savings for reduced project duration. ICFs are faster to assemble than framed or CMU walls and could result in a shorter project duration and could lower the initial cost. Reduction in energy consumption of the facility as a result of constructing with ICFs allows for HVAC systems to be sized to a smaller output capacity and also save in equipment costs. As mentioned previously, ICFs do not have to be used by themselves to achieve energy savings. When combined with other technologies, there could be the potential for increased energy reduction. This energy reduction would decrease the annual energy consumption of the facility for its life-span and could possibly improve LCCAs provided the utilization of additional energy efficient technologies does not greatly increase the initial cost thereby producing a poor SIR. It should be noted that the HPSB UFC discusses the concept of integrated design by taking into account multiple building attributes to achieve sustainable goals (UFC 1-200-02, 2013). Decision makers for new construction projects should also consider the other advantages of ICFs discussed in Chapter II. ICFs structural strength against natural disasters, fire resistance, and blast resistance are benefits which should be considered when choosing between steel, CMUs, or ICFs even if the LCCA numbers are not ideal.

What are the key barriers preventing increased use of ICFs in sustainable military construction?

Through the interviews with ICF contractors, it was found that the most significant barrier hindering ICF use was resistance to change and a preference for more traditional construction methods and materials such as wood and steel framing. ICFs are relatively new in the market compared to wood and steel framing; most contractors interviewed speculated that the resistance to change resulted from a lack of understanding regarding the full benefits of ICFs, as well as an apprehension to changing from a material and method that has been used for so long.

The second most significant barrier was found to be a lack of knowledge and understanding of ICFs and their benefits regarding sustainability. The idea of sustainable and 'green' construction has been on the rise over the last 10 years; however, a full understanding of what qualifies as sustainable and 'green' is more often unknown to non-construction professionals. All of the contractors interviewed noted the need for continual education so that the general public and subsequent future users fully understand the benefits of ICFs. This suggested education should include ICF manufacturer and contractor advertisements, as well as participations in building trade shows and expos. One contractor interviewed commented that education also needs to be given to the designers and architects. If they knew what ICFs were and were able to develop plans which incorporated them, potential owners would be able to see from the beginning the benefits of ICFs.

The results also showed that cost is still a factor but not as much of a barrier as was shown in previous research. As noted earlier, the initial mark-up of utilizing ICFs can increase the initial construction cost dependent on the size and overall architecture of the building. While there is an energy savings from utilizing ICFs over wood or steel framing and even CMUs, the higher initial cost often discourages users from choosing ICFs. With residential construction, homeowners recognize the secondary savings and realize that future savings will offset the higher initial cost, but owners building commercial and industrial facilities are, more often than not, working with a limited initial construction budget or are bound by lowest-bid price procurement. This is especially true for military construction where budgets are very limited and new facility construction or military construction (MILCON) projects are Congressionally approved. As mentioned before, in this study the initial cost increase of utilizing ICFs over steel framing was approximately 34% and approximately 24% over CMU construction and though ICFs use did show a reduction in electricity and natural gas cost for the facilities, the long term savings did not prove to offset the initial cost increase. Therefore, in terms of ICF use for sustainable military construction, cost could still be considered a barrier.

Research Limitations

This study investigated the use of ICFs for one type of facility. The overall shape and square footage can alter the energy performance and construction costs. It is for this reason that the results of this study should not be blindly applied to all building types throughout the military. The findings of this study are limited to the scope and boundaries set by the parameters within the methodology. When considering the use of ICFs for military construction, energy modeling and life-cycle cost analysis should be completed for each prospective project.

Recommendations for Future Research

Research of ICFs and their potential benefits to sustainable military construction should continue. This future research should explore other uses of ICFs. Similar studies can be conducted utilizing ICFs for other types of military facilities, such as aircraft hangers, maintenance bays, and munitions holding areas. Future research should also examine the use of ICFs for additions to and alterations of existing facilities which is also described in the HPSB UFC. Additionally, future research can be conducted to validate this study by collecting energy usage data from the few military installations which have utilized ICFs for new construction and/or existing facility alterations. Additional ICF studies should consider the methodology and parameters of this study but include other sustainable and energy efficient building materials or methods, in addition to ICFs.

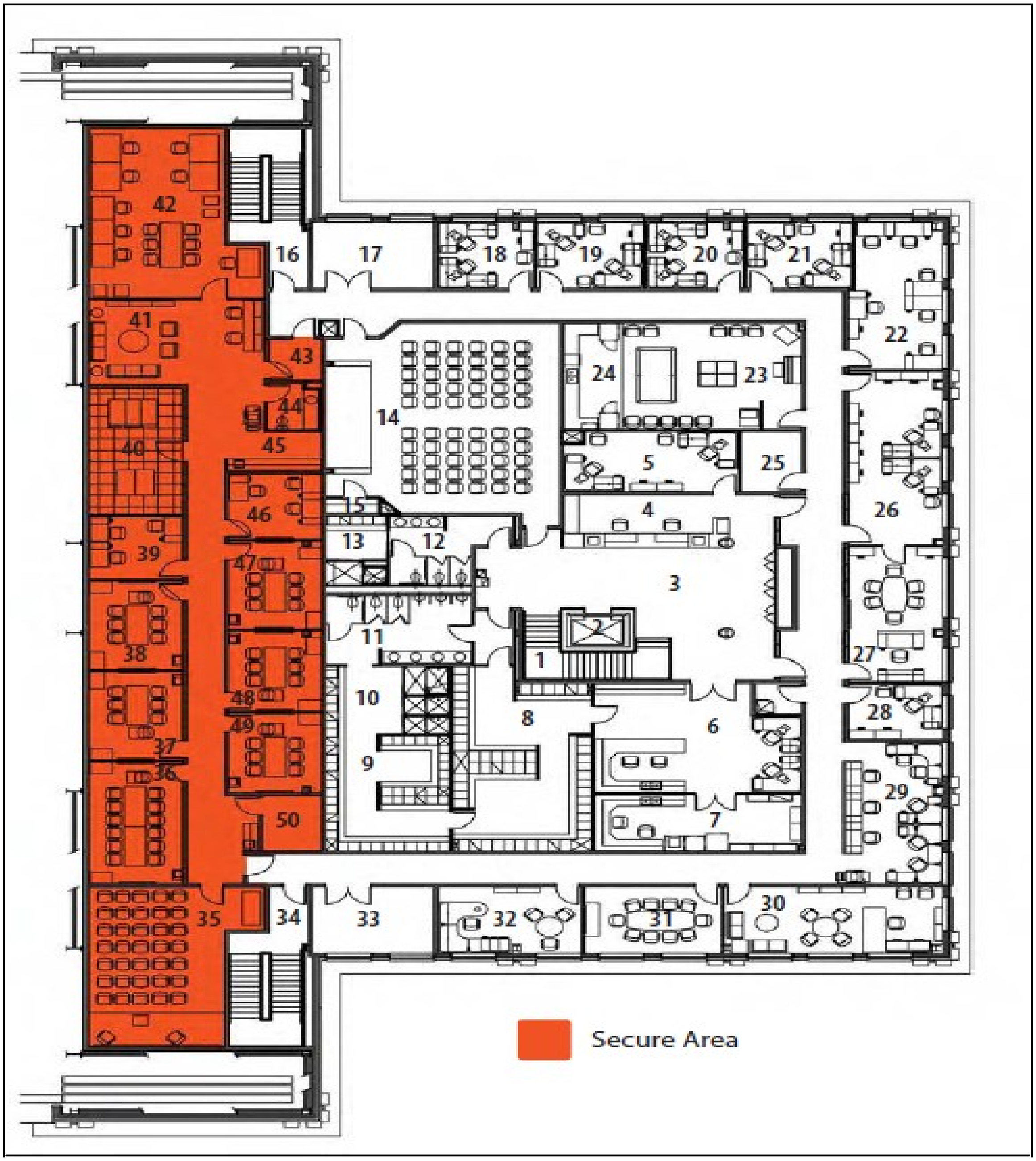
Conclusion

The goal of this research was twofold: to identify the value of using ICFs in military construction compared to the requirements in the HPSB UFC and to identify possible barriers preventing the use of ICFs in sustainable military construction. A was recognized by previous research, facilities will have greater energy efficiency by utilizing ICFs over steel framing and CMU mass walls. These savings are recognized in residential and commercial facilities in private construction and this study shows there is potential for these same saving to be seen when constructing a facility utilizing military construction requirements. This study showed ICFs were not cost effective given the specific methodology and parameters established; however, there are other uses for ICFs which were not explored with this study to include foundation use, smaller facilities, and additions to existing facilities, all of which could provide energy efficiency while being cost effective. The emphasis of sustainable construction and the premise behind the HPSB UFC is whole building design. ICFs are not the single solution to sustainable construction but rather one tool, one step, towards reaching the goal of developing sustainable military installations. This study has shown ICFs to be a beneficial and easy step towards achieving this goal by providing superior insulation for energy reduction as well as secondary benefits regarding strength, durability, and antiterrorism protection; they should be considered when planning sustainable construction projects throughout the military.

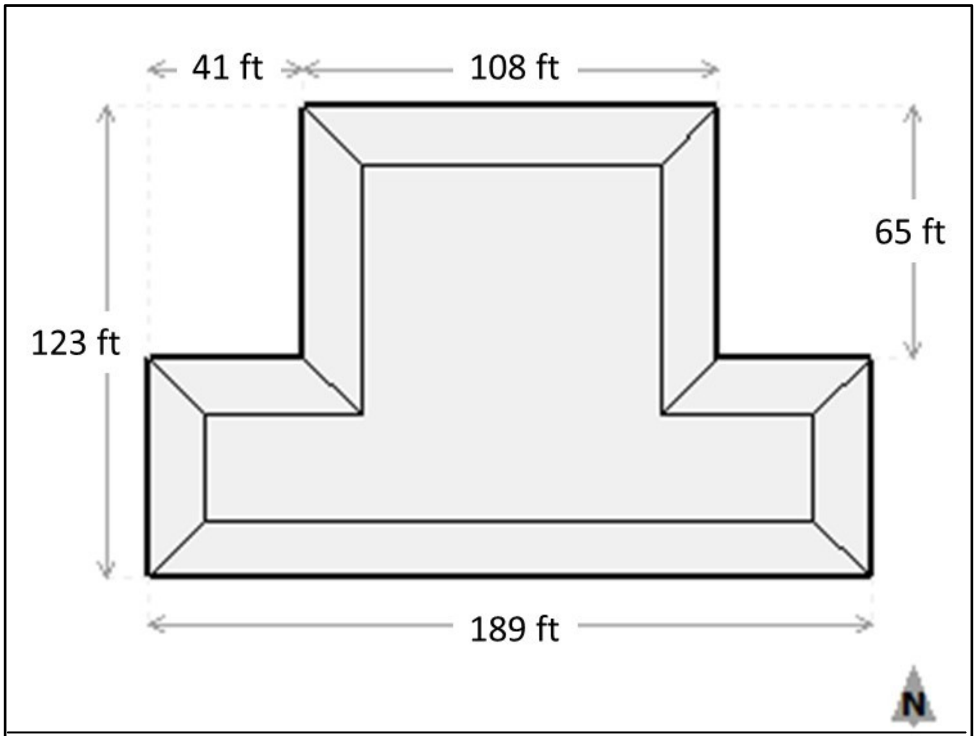
Appendix A

First Floor, Prototype Squadron Operations Facility
Used as template for designing layout of eQUEST model

Second Floor, Prototype Squadron Operations Facility
Used as template for designing layout of eQUEST model



Appendix B



Description	Baseline Parameter
Building Description	2 story (2 floors above grade) Oriented North Floor to floor height: 12 ft Floor to ceiling height: 9 ft 36,000 sf
Roof Construction	Metal Frame, > 24 in o.c. 3-ply built up roof (BUR) Gravel finish 4 in polysocyanurate (R-20) insulation
Doors	Opaque-Steel, Hollow core, Aluminum frame w/o thermal break Glass-Single pane, Aluminum frame w/o thermal break
Windows	Double Pane-Fixed ASHRAE Aluminum frame w/o thermal break Specified U-values and SHGC-values from ASHRAE 90.1-2010 ch 5 tables
Heating, Ventilation, and Air Conditioning (HVAC) system	Chilled Water & HW Coil Heating Packaged VAV w/ hot water reheat Ducted multizone

Appendix C

Description	Baseline Parameter	Unit	Amount	Unit Cost	Total Cost
Steel Framed Wall	Metal Frame, 2x6, 24 in o.c.	l.f	742	$17.70	$13,133
	Brick veneer exterior	s.f	17,788	$4.39	$78,089
	Batt insulation	s.f	17,788	$0.49	$8,716
	Insulation board	s.f	17,788	$0.72	$12,807
			Subtotal Cost		$112,746

ICF Wall	ICF, Polystyrene, 3 in, 6-in core	s.f	17,788	$3.50	$62,258
	Brick veneer exterior	s.f	17,788	$4.39	$78,089
	Rebar	l.f	742	$0.50	$371
	Concrete, 140 lbs	c.y	100	$100.00	$10,000
			Subtotal Cost		$150,718

CMU Wall	CMU Block	ea	20,012	$1.57	$31,419
	Insulation board	s.f	17,788	$0.72	$12,807
	Brick veneer exterior	s.f	17,788	$4.39	$78,089
			Subtotal Cost		$122,316

Appendix D

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction					
Lack of awareness & understanding of sustainable construction materials					
Lack of information about what qualifies as sustainability					
Resistance to change					
Lack of cooperation b/w owner and contractor					
Lack of training regarding sustainable construction methods/techniques					
Preconception towards traditional construction methods & materials					
Lack of interest & demand from client					
Lack of incentives for utilizing sustainable construction					
Cost Impact					
Relationship between construction cost and implementing sustainable construction					
Limited projects released in the market					
Fierce competition; enhance sustainable construction implementation					
Reduced profit margin					
Emphasizing on lowest price for subcontractors will facilitate sustainable construction					
Expenses for transportation of materials and equipment					
Limited project budgets prevent use of sustainable construction materials					
Time Impact					
Tight schedules					
Delays in material submittals					
Delays in material approvals					
Higher emphasis on speed of construction					
Availability of ICFs in construction area					
Market Impact					
Unique characteristics of each project					
Inefficiency of available equipment					

Additional comments (optional)

Appendix E

Tyndall AFB, FL, Climate Zone 2, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.49	2.51	5.44	8.23	13.44	21.00	20.17	22.83	16.95	12.54	5.28	2.69	133.56
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.04	1.09	1.75	1.67	2.61	2.87	2.83	3.05	2.53	2.29	1.54	1.13	24.39
Pumps & Aux.	1.06	1.01	1.22	1.06	1.17	1.17	1.06	1.22	1.06	1.12	1.06	1.06	13.29
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	24.69	23.49	30.83	30.92	38.86	46.53	44.18	49.52	40.49	36.82	27.84	24.99	419.16

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.10	2.82	0.65	-	-	-	-	-	-	-	0.56	3.42	12.55
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	7.85	7.62	9.16	7.91	8.20	7.74	6.75	7.43	6.50	7.01	7.05	7.48	90.68
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.95	10.44	9.81	7.91	8.20	7.74	6.75	7.43	6.50	7.01	7.61	10.90	103.24

Tyndall AFB, FL, Climate Zone 2, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.26	2.29	5.14	7.85	12.92	20.17	19.43	21.82	16.23	12.01	4.98	2.54	127.64
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.98	1.11	2.01	1.97	3.12	3.51	3.44	3.73	3.07	2.76	1.79	1.15	28.63
Pumps & Aux.	0.86	0.81	0.99	0.86	0.94	0.94	0.86	0.99	0.86	0.90	0.86	0.86	10.72
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	24.20	23.09	30.55	30.63	38.62	46.11	43.84	48.94	40.12	36.55	27.59	24.65	414.89

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.00	1.27	0.21	-	-	-	-	-	-	-	-	1.51	6.99
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	7.85	7.61	9.15	7.90	8.19	7.73	6.74	7.42	6.49	7.00	7.04	7.47	90.59
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	11.85	8.88	9.36	7.90	8.19	7.73	6.74	7.42	6.49	7.00	7.04	8.98	97.58

Tyndall AFB, FL, Climate Zone 2, Energy Usage, ICF Facility, CY 2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.43	2.50	5.29	7.97	12.64	19.53	18.80	21.20	15.88	11.98	5.12	2.70	126.06
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.16	1.36	2.18	2.04	2.90	3.12	3.05	3.35	2.85	2.71	2.03	1.43	28.18
Pumps & Aux.	0.86	0.82	0.99	0.86	0.95	0.95	0.86	0.99	0.86	0.91	0.86	0.86	10.80
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	24.56	23.56	30.88	30.82	38.14	45.10	42.82	47.96	39.55	36.47	27.97	25.10	412.94

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.91	0.29	-	-	-	-	-	-	-	-	-	0.74	5.94
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	7.84	7.60	9.15	7.90	8.20	7.73	6.74	7.42	6.49	7.00	7.04	7.46	90.59
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.76	7.89	9.15	7.90	8.20	7.73	6.74	7.42	6.49	7.00	7.04	8.20	96.53

Tyndall AFB, FL, Climate Zone 2, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.93	2.42	5.21	8.50	14.51	18.97	22.25	21.67	16.67	12.29	4.08	2.58	132.07
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.08	1.11	1.60	1.91	2.56	2.59	3.09	2.92	2.58	2.35	1.58	1.12	24.48
Pumps & Aux.	1.12	1.01	1.12	1.17	1.17	1.07	1.17	1.17	1.07	1.17	1.01	1.12	13.40
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	26.01	23.42	28.81	33.07	39.88	42.58	48.17	47.40	40.27	37.46	25.86	25.69	418.62

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.93	3.53	0.42	-	-	-	-	-	-	-	0.35	2.78	13.00
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.21	7.62	8.41	8.65	8.20	7.08	7.37	7.13	6.49	7.32	6.72	7.82	91.02
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	14.14	11.15	8.83	8.65	8.20	7.08	7.37	7.13	6.49	7.32	7.07	10.60	104.02

Tyndall AFB, FL, Climate Zone 2, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.70	2.23	4.92	8.13	13.92	18.18	21.41	20.70	15.96	11.79	3.85	2.43	126.25
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.03	1.11	1.83	2.23	3.09	3.15	3.75	3.55	3.12	2.82	1.83	1.11	28.62
Pumps & Aux.	0.91	0.82	0.91	0.95	0.95	0.86	0.95	0.95	0.86	0.95	0.82	0.91	10.85
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	25.51	23.04	28.54	32.81	39.61	42.16	47.76	46.84	39.90	37.21	25.69	25.33	414.39

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	4.72	1.83	-	-	-	-	-	-	-	-	-	1.34	7.88
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.20	7.61	8.41	8.64	8.20	7.07	7.36	7.12	6.49	7.31	6.71	7.81	90.93
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.92	9.44	8.41	8.64	8.20	7.07	7.36	7.12	6.49	7.31	6.71	9.15	98.81

Tyndall AFB, FL, Climate Zone 2, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.86	2.42	5.04	8.25	13.57	17.61	20.69	20.11	15.61	11.78	3.96	2.59	124.47
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.22	1.38	2.01	2.29	2.85	2.81	3.32	3.19	2.89	2.79	2.05	1.45	28.25
Pumps & Aux.	0.91	0.83	0.91	0.96	0.96	0.87	0.96	0.96	0.87	0.96	0.83	0.91	10.91
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	25.86	23.50	28.84	32.99	39.02	41.24	46.62	45.90	39.33	37.17	26.02	25.83	412.30

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.48	0.69	-	-	-	-	-	-	-	-	-	-	6.18
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.20	7.60	8.40	8.64	8.20	7.08	7.37	7.12	6.49	7.31	6.71	7.80	90.93
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	13.69	8.29	8.40	8.64	8.20	7.08	7.37	7.12	6.49	7.31	6.71	7.80	97.11

Holloman AFB, NM, Climate Zone 3, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.01	1.60	3.85	5.33	10.25	15.80	17.22	17.94	12.91	7.29	2.33	1.08	96.63
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.95	1.15	1.67	1.59	2.38	2.98	3.11	3.22	2.55	2.19	1.66	1.14	24.59
Pumps & Aux.	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.40
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.99	22.49	28.98	27.79	35.28	41.28	41.36	44.61	36.33	31.32	24.85	23.24	380.52

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	12.58	2.47	1.06	0.37	-	-	-	-	-	0.11	0.55	3.83	20.97
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.25	8.06	9.71	8.35	8.53	7.90	6.77	7.37	6.44	7.03	7.18	7.75	93.34
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	20.83	10.53	10.77	8.72	8.53	7.90	6.77	7.37	6.44	7.13	7.73	11.58	114.31

Holloman AFB, NM, Climate Zone 3, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.87	1.48	3.61	5.02	10.01	15.57	16.81	17.50	12.62	7.11	2.20	0.94	93.73
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.84	1.15	1.82	1.87	2.85	3.66	3.86	4.04	3.14	2.59	1.83	1.12	28.76
Pumps & Aux.	0.74	0.71	0.86	0.74	0.82	0.82	0.74	0.86	0.74	0.78	0.74	0.74	9.31
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.56	22.22	28.70	27.59	35.33	41.54	41.51	44.81	36.45	31.35	24.73	22.91	379.69

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	10.48	1.36	0.35	-	-	-	-	-	-	-	-	1.71	13.91
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.24	8.05	9.70	8.35	8.53	7.89	6.76	7.36	6.44	7.02	7.17	7.74	93.25
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	18.73	9.41	10.05	8.35	8.53	7.89	6.76	7.36	6.44	7.02	7.17	9.45	107.16

Holloman AFB, NM, Climate Zone 3, Energy Usage, ICF Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.89	1.55	3.72	5.06	9.81	14.97	16.28	17.10	12.39	7.09	2.30	0.98	92.13
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.97	1.33	2.04	1.93	2.70	3.26	3.42	3.66	2.91	2.59	2.08	1.41	28.32
Pumps & Aux.	0.75	0.71	0.86	0.75	0.82	0.82	0.75	0.86	0.75	0.79	0.75	0.75	9.37
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.71	22.47	29.04	27.70	34.98	40.55	40.56	44.03	36.00	31.34	25.08	23.25	377.72

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	10.81	0.81	-	-	-	-	-	-	-	-	-	0.69	12.32
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.24	8.05	9.70	8.35	8.53	7.90	6.77	7.37	6.44	7.02	7.17	7.73	93.25
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	19.05	8.86	9.70	8.35	8.53	7.90	6.77	7.37	6.44	7.02	7.17	8.43	105.57

Holloman AFB, NM, Climate Zone 3, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.13	1.82	3.76	5.92	10.82	14.43	18.97	17.49	12.79	7.02	2.31	1.12	97.57
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.01	1.15	1.52	1.72	2.31	2.70	3.42	3.00	2.54	2.36	1.58	1.20	24.50
Pumps & Aux.	0.96	0.87	0.96	1.01	1.01	0.91	1.01	1.01	0.91	1.01	0.87	0.96	11.47
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.97	22.72	27.12	30.14	35.77	38.00	45.03	43.14	36.20	32.03	23.94	24.15	382.21

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.60	3.02	0.91	0.25	-	-	-	-	-	0.11	0.35	5.22	21.46
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.63	8.06	8.92	9.14	8.53	7.23	7.40	7.08	6.44	7.33	6.85	8.11	93.71
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	20.23	11.08	9.83	9.39	8.53	7.23	7.40	7.08	6.44	7.44	7.20	13.33	115.17

Holloman AFB, NM, Climate Zone 3, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.98	1.68	3.53	5.58	10.59	14.19	18.47	17.06	12.55	6.82	2.18	0.97	94.61
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.89	1.15	1.69	2.02	2.77	3.33	4.24	3.75	3.10	2.78	1.74	1.15	28.60
Pumps & Aux.	0.78	0.71	0.78	0.82	0.82	0.75	0.82	0.82	0.75	0.82	0.71	0.78	9.35
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.52	22.41	26.88	29.91	35.83	38.22	45.17	43.28	36.35	32.06	23.81	23.78	381.23

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	9.58	1.67	0.14	0.10	-	-	-	-	-	-	-	3.12	14.61
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.62	8.05	8.91	9.13	8.53	7.22	7.39	7.07	6.44	7.32	6.84	8.10	93.62
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	18.21	9.72	9.05	9.23	8.53	7.22	7.39	7.07	6.44	7.32	6.84	11.21	108.23

Holloman AFB, NM, Climate Zone 3, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.01	1.74	3.63	5.67	10.37	13.67	17.91	16.67	12.30	6.82	2.27	1.01	93.06
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.00	1.30	1.86	2.07	2.62	2.97	3.77	3.39	2.89	2.78	1.96	1.42	28.04
Pumps & Aux.	0.79	0.71	0.79	0.83	0.83	0.75	0.83	0.83	0.75	0.83	0.71	0.79	9.41
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.67	22.64	27.15	30.05	35.46	37.34	44.14	42.53	35.90	32.08	24.13	24.10	379.18

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	10.02	1.05	-	-	-	-	-	-	-	-	-	1.59	12.65
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.62	8.05	8.91	9.13	8.53	7.23	7.39	7.07	6.44	7.33	6.84	8.09	93.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	18.64	9.09	8.91	9.13	8.53	7.23	7.39	7.07	6.44	7.33	6.84	9.68	106.27

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.13	1.13	2.14	3.71	8.63	14.54	18.53	17.82	13.06	6.22	1.72	1.16	89.80
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.82	0.78	1.14	1.55	2.03	2.40	2.52	2.66	2.14	2.14	1.25	0.88	20.32
Pumps & Aux.	1.03	0.98	1.19	1.03	1.14	1.14	1.03	1.19	1.03	1.09	1.03	1.03	12.92
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	23.10	21.78	26.88	26.25	33.44	39.57	42.19	44.08	36.19	30.32	23.96	23.19	370.93

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	29.50	21.12	4.12	0.20	-	-	-	-	-	0.34	0.82	20.02	76.12
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.76	8.56	10.29	8.84	9.07	8.43	7.24	7.90	6.91	7.51	7.65	8.24	99.39
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	38.26	29.67	14.41	9.04	9.07	8.43	7.24	7.90	6.91	7.85	8.48	28.26	175.51

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.97	0.97	1.89	3.48	8.26	14.09	17.78	17.23	12.56	6.02	1.57	1.01	85.82
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.69	0.65	1.07	1.66	2.32	2.88	3.03	3.21	2.55	2.44	1.26	0.78	22.52
Pumps & Aux.	0.85	0.81	0.98	0.85	0.93	0.93	0.85	0.98	0.85	0.89	0.85	0.85	10.62
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.61	21.31	26.35	25.95	33.15	39.39	41.77	43.82	35.91	30.22	23.64	22.74	366.86

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	27.60	18.40	2.90	0.07	-	-	-	-	-	-	0.07	17.45	66.50
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.75	8.55	10.28	8.84	9.06	8.42	7.23	7.89	6.90	7.50	7.65	8.24	99.31
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	36.36	26.95	13.18	8.91	9.06	8.42	7.23	7.89	6.90	7.50	7.72	25.68	165.81

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, ICF Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.97	1.01	1.97	3.57	8.33	13.88	17.44	17.04	12.50	6.09	1.66	1.04	85.50
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.72	0.67	1.24	1.75	2.35	2.72	2.82	3.07	2.49	2.59	1.50	0.89	22.81
Pumps & Aux.	0.85	0.81	0.98	0.85	0.94	0.94	0.85	0.98	0.85	0.90	0.85	0.85	10.68
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.65	21.37	26.61	26.13	33.26	39.03	41.22	43.51	35.79	30.44	23.96	22.90	366.89

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	25.47	12.90	1.65	-	-	-	-	-	-	-	-	12.00	52.02
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	8.75	8.54	10.27	8.84	9.06	8.42	7.23	7.89	6.90	7.50	7.64	8.23	99.29
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	34.23	21.44	11.92	8.84	9.06	8.42	7.23	7.89	6.90	7.50	7.64	20.23	151.31

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.21	0.97	1.58	3.62	8.18	14.24	19.00	17.24	13.15	6.88	1.68	1.16	88.91
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.85	0.77	1.05	1.71	2.18	2.18	2.76	2.51	2.22	2.23	1.19	0.91	20.56
Pumps & Aux.	1.08	0.98	1.08	1.13	1.13	1.03	1.13	1.13	1.03	1.13	0.98	1.08	12.94
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	24.02	21.60	24.60	27.96	33.14	37.41	44.54	42.53	36.35	31.88	23.04	24.03	371.09

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	29.09	24.03	4.83	0.91	-	-	-	-	-	0.16	0.81	21.17	81.00
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.16	8.55	9.45	9.67	9.06	7.71	7.91	7.58	6.90	7.84	7.30	8.62	99.76
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	38.25	32.58	14.27	10.58	9.06	7.71	7.91	7.58	6.90	8.00	8.11	29.80	180.76

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.04	0.82	1.39	3.38	7.87	13.75	18.33	16.63	12.60	6.65	1.55	0.99	84.97
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.70	0.64	0.98	1.82	2.48	2.63	3.31	3.03	2.60	2.51	1.18	0.81	22.69
Pumps & Aux.	0.89	0.81	0.89	0.93	0.93	0.85	0.93	0.93	0.85	0.93	0.81	0.89	10.65
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.50	21.15	24.13	27.62	32.92	37.18	44.21	42.24	36.01	31.74	22.73	23.57	366.99

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	26.94	20.86	3.55	0.71	-	-	-	-	-	0.13	0.18	18.64	71.01
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.16	8.55	9.44	9.66	9.06	7.70	7.90	7.57	6.90	7.84	7.29	8.62	99.69
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	36.10	29.41	12.99	10.37	9.06	7.70	7.90	7.57	6.90	7.97	7.47	27.26	170.70

JB Langley-Eustis, VA, Climate Zone 4, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.05	0.84	1.45	3.47	7.91	13.53	17.98	16.46	12.55	6.73	1.64	1.02	84.63
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.72	0.66	1.13	1.93	2.51	2.48	3.09	2.91	2.57	2.64	1.40	0.94	22.99
Pumps & Aux.	0.90	0.81	0.90	0.94	0.94	0.85	0.94	0.94	0.85	0.94	0.81	0.90	10.71
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.54	21.19	24.35	27.83	33.01	36.82	43.65	41.95	35.93	31.95	23.04	23.73	367.00

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	25.27	15.43	2.51	0.39	-	-	-	-	-	-	0.07	12.70	56.37
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.16	8.54	9.43	9.66	9.06	7.70	7.90	7.58	6.90	7.83	7.29	8.61	99.66
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	34.43	23.97	11.94	10.05	9.06	7.70	7.90	7.58	6.90	7.83	7.36	21.31	156.03

Offutt AFB, NE, Climate Zone 5, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.96	0.91	1.32	2.16	5.94	13.73	16.29	16.15	7.89	3.09	0.97	0.96	70.38
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.03	0.90	1.07	1.18	1.94	2.20	2.39	2.74	2.00	1.60	0.93	0.90	18.87
Pumps & Aux.	1.07	1.02	1.23	1.07	1.18	1.18	1.07	1.23	1.07	1.12	1.07	1.07	13.36
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	23.17	21.70	26.03	24.37	30.70	38.60	39.86	42.53	30.91	26.68	22.92	23.03	350.51

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	96.99	77.11	31.61	2.99	0.25	-	-	-	-	0.93	22.87	74.42	307.17
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.89	9.71	11.69	10.00	10.08	9.20	7.75	8.34	7.29	8.02	8.35	9.17	109.49
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	106.89	86.83	43.30	12.99	10.33	9.20	7.75	8.34	7.29	8.96	31.22	83.59	416.67

Offutt AFB, NE, Climate Zone 5, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.81	0.77	1.13	1.94	5.59	13.28	15.67	15.53	7.54	2.86	0.82	0.81	66.74
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.88	0.76	0.95	1.23	2.14	2.61	2.86	3.28	2.27	1.75	0.85	0.76	20.33
Pumps & Aux.	0.89	0.84	1.02	0.89	0.97	0.97	0.89	1.02	0.89	0.93	0.89	0.89	11.07
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.69	21.25	25.51	24.01	30.35	38.36	39.52	42.24	30.65	26.42	22.51	22.56	346.05

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	87.94	69.58	26.86	1.68	0.10	-	-	-	-	0.11	18.68	67.88	272.83
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.90	9.71	11.69	9.99	10.08	9.19	7.74	8.34	7.28	8.01	8.34	9.16	109.42
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	97.84	79.29	38.54	11.67	10.18	9.19	7.74	8.34	7.28	8.13	27.02	77.04	382.25

Offutt AFB, NE, Climate Zone 5, Energy Usage, ICF Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.81	0.76	1.14	1.99	5.58	13.10	15.39	15.33	7.58	2.94	0.82	0.80	66.23
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.86	0.75	0.97	1.31	2.16	2.51	2.71	3.18	2.32	1.93	0.91	0.75	20.36
Pumps & Aux.	0.88	0.84	1.01	0.88	0.97	0.97	0.88	1.01	0.88	0.93	0.88	0.88	11.02
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.66	21.23	25.54	24.13	30.35	38.07	39.09	41.93	30.74	26.67	22.56	22.54	345.51

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	82.82	63.63	22.82	1.28	0.07	-	-	-	-	0.10	13.88	60.10	244.70
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	9.90	9.70	11.68	9.99	10.08	9.19	7.74	8.34	7.28	8.01	8.34	9.16	109.40
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	92.71	73.33	34.51	11.27	10.15	9.19	7.74	8.34	7.28	8.11	22.21	69.25	354.10

Offutt AFB, NE, Climate Zone 5, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.99	0.89	1.36	2.50	6.02	11.86	16.72	17.60	6.41	3.39	0.90	0.98	69.62
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.07	0.89	0.99	1.25	1.97	2.13	2.73	2.46	2.24	1.67	0.86	0.99	19.26
Pumps & Aux.	1.12	1.01	1.12	1.17	1.17	1.06	1.17	1.17	1.06	1.17	1.01	1.12	13.33
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	24.05	21.67	24.35	26.41	30.81	35.00	42.26	42.87	29.66	27.88	21.96	23.96	350.88

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	103.83	78.03	32.47	3.42	0.08	-	-	-	-	1.02	20.02	82.48	321.35
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.34	9.72	10.73	10.94	10.08	8.41	8.47	8.01	7.28	8.38	7.96	9.60	109.91
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	114.18	87.75	43.20	14.36	10.16	8.41	8.47	8.01	7.28	9.39	27.98	92.07	431.26

Offutt AFB, NE, Climate Zone 5, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.83	0.75	1.16	2.23	5.67	11.43	16.12	16.89	6.17	3.15	0.76	0.83	65.99
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.92	0.75	0.89	1.29	2.19	2.51	3.26	2.95	2.54	1.81	0.78	0.83	20.72
Pumps & Aux.	0.93	0.84	0.93	0.97	0.97	0.88	0.97	0.97	0.88	0.97	0.84	0.93	11.06
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.55	21.21	23.85	25.98	30.47	34.77	42.00	42.45	29.54	27.57	21.57	23.46	346.44

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	94.16	69.93	28.09	1.83	-	-	-	-	-	0.39	16.16	73.86	284.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.34	9.71	10.73	10.93	10.08	8.40	8.46	8.00	7.28	8.37	7.96	9.59	109.84
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	104.51	79.64	38.82	12.76	10.08	8.40	8.46	8.00	7.28	8.76	24.12	83.45	394.27

Offutt AFB, NE, Climate Zone 5, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.83	0.74	1.17	2.28	5.67	11.28	15.83	16.69	6.21	3.22	0.76	0.82	65.49
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.90	0.75	0.90	1.38	2.19	2.42	3.09	2.86	2.60	1.98	0.84	0.82	20.73
Pumps & Aux.	0.92	0.83	0.92	0.96	0.96	0.88	0.96	0.96	0.88	0.96	0.83	0.92	11.00
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.52	21.20	23.87	26.11	30.47	34.53	41.53	42.16	29.64	27.81	21.62	23.43	345.89

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	88.22	64.64	24.17	1.31	-	-	-	-	-	0.30	12.00	66.19	256.82
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.34	9.71	10.72	10.93	10.07	8.40	8.46	8.00	7.28	8.37	7.95	9.58	109.82
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	98.57	74.34	34.89	12.24	10.07	8.40	8.46	8.00	7.28	8.67	19.95	75.77	366.64

Malmstrom AFB, MT, Climate Zone 6, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.81	0.76	0.92	1.16	2.80	6.44	8.89	7.74	3.70	1.54	0.80	0.80	36.37
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.11	0.97	1.03	0.94	1.46	2.03	2.20	2.27	1.51	1.13	0.93	0.95	16.55
Pumps & Aux.	0.94	0.89	1.08	0.94	1.03	1.03	0.94	1.08	0.94	0.99	0.94	0.94	11.73
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.96	21.51	25.45	23.00	26.94	30.99	32.14	33.51	26.10	24.54	22.63	22.79	312.55

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	108.70	79.10	59.73	12.68	2.72	-	-	-	0.30	7.01	56.98	79.22	406.45
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.40	10.15	12.23	10.49	10.71	9.91	8.47	9.22	8.06	8.80	9.03	9.74	117.21
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	119.11	89.25	71.96	23.17	13.42	9.91	8.47	9.22	8.36	15.82	66.02	88.97	523.66

Malmstrom AFB, MT, Climate Zone 6, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.67	0.64	0.77	1.02	2.57	6.19	8.66	7.48	3.46	1.42	0.67	0.67	34.22
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.95	0.81	0.86	0.84	1.54	2.33	2.61	2.66	1.69	1.11	0.78	0.79	16.98
Pumps & Aux.	0.77	0.73	0.89	0.77	0.85	0.85	0.77	0.89	0.77	0.81	0.77	0.77	9.67
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.51	21.06	24.93	22.58	26.61	30.87	32.15	33.44	25.88	24.21	22.18	22.34	308.77

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	97.19	68.52	53.07	9.29	1.91	-	-	-	0.08	4.07	49.06	70.45	353.62
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.40	10.14	12.22	10.48	10.70	9.90	8.46	9.21	8.05	8.79	9.02	9.74	117.13
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	107.59	78.67	65.29	19.77	12.61	9.90	8.46	9.21	8.13	12.86	58.08	80.18	470.75

Malmstrom AFB, MT, Climate Zone 6, Energy Usage, ICF Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.68	0.64	0.77	1.04	2.59	6.13	8.57	7.45	3.51	1.46	0.67	0.67	34.17
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.94	0.81	0.86	0.89	1.59	2.28	2.52	2.66	1.75	1.21	0.79	0.78	17.06
Pumps & Aux.	0.77	0.74	0.89	0.77	0.85	0.85	0.77	0.89	0.77	0.81	0.77	0.77	9.68
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.49	21.06	24.94	22.66	26.67	30.75	31.97	33.41	25.99	24.35	22.19	22.33	308.81

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	93.83	64.89	47.74	7.88	1.27	-	-	-	-	2.79	43.46	63.72	325.57
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.40	10.14	12.22	10.48	10.70	9.90	8.46	9.21	8.05	8.79	9.02	9.73	117.11
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	104.23	75.03	59.96	18.36	11.97	9.90	8.46	9.21	8.05	11.58	52.47	73.45	442.68

Malmstrom AFB, MT, Climate Zone 6, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.87	0.78	0.87	1.03	2.75	6.19	9.87	7.37	3.72	1.58	0.78	0.87	36.69
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.14	1.02	0.93	1.02	1.50	1.76	2.34	2.21	1.52	1.18	0.90	1.00	16.52
Pumps & Aux.	0.99	0.90	0.99	1.04	1.04	0.94	1.04	1.04	0.94	1.04	0.90	0.99	11.84
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.88	21.58	23.67	24.58	26.93	28.84	34.89	32.27	26.14	25.44	21.77	23.73	313.72

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	107.95	97.01	55.35	13.69	2.00	-	-	-	0.41	6.21	58.96	87.06	428.64
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.88	10.15	11.23	11.48	10.71	9.06	9.26	8.84	8.06	9.19	8.61	10.19	117.66
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	118.82	107.16	66.58	25.16	12.71	9.06	9.26	8.84	8.47	15.40	67.58	97.26	546.30

Malmstrom AFB, MT, VA, Climate Zone 6, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.70	0.63	0.70	0.85	2.51	5.89	9.59	7.06	3.46	1.41	0.63	0.69	34.11
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.97	0.86	0.78	0.92	1.60	2.00	2.77	2.59	1.68	1.17	0.76	0.84	16.93
Pumps & Aux.	0.81	0.73	0.81	0.85	0.85	0.77	0.85	0.85	0.77	0.85	0.73	0.81	9.69
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.36	21.10	23.17	24.11	26.60	28.62	34.85	32.15	25.86	25.07	21.31	23.22	309.41

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	96.74	85.36	49.48	9.90	1.15	-	-	-	0.10	3.37	50.57	77.60	374.27
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.87	10.15	11.22	11.47	10.70	9.05	9.25	8.84	8.05	9.18	8.60	10.19	117.58
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	107.61	95.51	60.70	21.37	11.85	9.05	9.25	8.84	8.15	12.55	59.18	87.78	491.84

Malmstrom AFB, MT, Climate Zone 6, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.73	0.66	0.73	0.89	2.55	5.89	9.50	7.07	3.55	1.48	0.66	0.72	34.42
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.96	0.85	0.78	0.97	1.64	1.97	2.68	2.59	1.76	1.27	0.76	0.83	17.07
Pumps & Aux.	0.82	0.74	0.82	0.86	0.86	0.78	0.86	0.86	0.78	0.86	0.74	0.82	9.77
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.38	21.13	23.20	24.21	26.69	28.59	34.68	32.16	26.04	25.25	21.34	23.24	309.93

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	92.85	82.33	44.55	8.08	0.90	-	-	-	0.08	2.60	46.14	71.37	348.91
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	10.88	10.14	11.22	11.47	10.70	9.05	9.25	8.84	8.05	9.18	8.60	10.18	117.56
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	103.73	92.47	55.77	19.55	11.60	9.05	9.25	8.84	8.13	11.78	54.74	81.56	466.46

Minot AFB, ND, Climate Zone 7, Energy Usage, Steel Framed Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.82	0.77	0.95	1.33	2.54	7.73	9.39	8.35	2.35	1.31	0.82	0.81	37.16
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.31	1.15	1.05	0.95	1.37	1.88	1.85	2.15	1.46	1.02	0.93	1.08	16.20
Pumps & Aux.	0.96	0.91	1.11	0.96	1.06	1.06	0.96	1.11	0.96	1.01	0.96	0.96	12.02
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	23.20	21.71	25.52	23.19	26.61	32.15	32.31	34.02	24.72	24.22	22.67	22.96	313.29

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	162.60	133.41	71.84	27.71	3.09	-	-	-	0.75	10.06	70.13	114.71	594.30
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.03	10.83	13.02	11.15	11.25	10.29	8.69	9.38	8.19	9.01	9.36	10.23	122.42
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	173.63	144.24	84.86	38.86	14.34	10.29	8.69	9.38	8.93	19.08	79.49	124.94	716.72

Minot AFB, ND, VA, Climate Zone 7, Energy Usage, CMU Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.68	0.64	0.79	1.17	2.30	7.32	8.92	7.93	2.15	1.15	0.69	0.67	34.42
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.12	0.97	0.86	0.83	1.42	2.09	2.09	2.43	1.62	0.96	0.77	0.90	16.07
Pumps & Aux.	0.79	0.75	0.91	0.79	0.87	0.87	0.79	0.91	0.79	0.83	0.79	0.79	9.85
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.69	21.24	24.97	22.74	26.23	31.77	31.91	33.68	24.51	23.82	22.20	22.47	308.23

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	141.84	117.52	60.87	22.48	1.63	-	-	-	-	6.28	59.66	99.42	509.70
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.03	10.82	13.01	11.14	11.25	10.28	8.68	9.37	8.18	9.00	9.35	10.22	122.34
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	152.87	128.34	73.88	33.63	12.87	10.28	8.68	9.37	8.18	15.28	69.01	109.64	632.04

Minot AFB, ND, VA, Climate Zone 7, Energy Usage, ICF Facility, CY 2012

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.67	0.64	0.78	1.18	2.32	7.35	8.98	8.03	2.20	1.18	0.68	0.67	34.68
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.10	0.95	0.85	0.84	1.47	2.13	2.13	2.52	1.75	1.04	0.77	0.89	16.45
Pumps & Aux.	0.78	0.74	0.90	0.78	0.86	0.86	0.78	0.90	0.78	0.82	0.78	0.78	9.79
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.11	9.41	11.02	9.98	10.72	10.59	10.11	11.02	9.98	10.41	9.98	10.11	123.41
Task Lights	0.91	0.87	1.05	0.91	1.00	1.00	0.91	1.05	0.91	0.96	0.91	0.91	11.41
Area Lights	9.09	8.60	10.34	9.07	9.93	9.90	9.09	10.34	9.07	9.51	9.07	9.09	113.09
Total	22.67	21.21	24.95	22.75	26.30	31.84	32.00	33.86	24.69	23.92	22.19	22.45	308.83

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	139.67	113.78	56.49	20.32	1.27	-	-	-	-	4.80	54.92	95.85	487.08
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.04	10.82	13.01	11.14	11.24	10.28	8.68	9.37	8.18	9.00	9.35	10.22	122.33
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	150.71	124.60	69.50	31.46	12.51	10.28	8.68	9.37	8.18	13.80	64.26	106.06	609.41

Minot AFB, ND, Climate Zone 7, Energy Usage, Steel Framed Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.96	0.86	0.97	1.62	3.17	6.94	10.01	7.93	2.85	1.29	0.86	0.96	38.44
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.32	1.12	0.96	1.04	1.39	1.72	2.16	2.05	1.48	1.13	0.87	1.15	16.38
Pumps & Aux.	1.12	1.01	1.12	1.17	1.17	1.07	1.17	1.17	1.07	1.17	1.01	1.12	13.40
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	24.28	21.88	23.93	25.32	27.38	29.68	34.99	32.80	25.35	25.24	21.94	24.10	316.90

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	157.00	127.53	71.64	31.50	2.50	-	-	-	0.82	13.35	66.11	122.47	592.91
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.53	10.83	11.95	12.20	11.25	9.40	9.50	8.99	8.19	9.41	8.92	10.70	122.89
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	168.53	138.36	83.59	43.70	13.76	9.40	9.50	8.99	9.00	22.76	75.03	133.17	715.80

Minot AFB, ND, Climate Zone 7, Energy Usage, CMU Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.72	0.65	0.73	1.34	2.83	6.53	9.58	7.53	2.58	1.03	0.65	0.72	34.89
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.12	0.95	0.79	0.91	1.48	1.99	2.56	2.44	1.70	1.11	0.72	0.95	16.71
Pumps & Aux.	0.84	0.76	0.84	0.89	0.89	0.80	0.89	0.89	0.80	0.89	0.76	0.84	10.10
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.56	21.24	23.24	24.62	26.84	29.28	34.67	32.50	25.03	24.67	21.32	23.39	310.37

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	137.69	111.76	59.60	24.41	1.36	-	-	-	0.15	7.92	55.32	105.13	503.35
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.53	10.82	11.94	12.19	11.25	9.40	9.49	8.99	8.18	9.40	8.91	10.69	122.79
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	149.22	122.59	71.54	36.60	12.61	9.40	9.49	8.99	8.33	17.33	64.23	115.82	626.13

Minot AFB, ND, Climate Zone 7, Energy Usage, ICF Facility, CY 2013

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.79	0.71	0.80	1.43	2.92	6.59	9.59	7.61	2.69	1.11	0.71	0.79	35.74
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.10	0.92	0.78	0.91	1.48	1.94	2.47	2.40	1.74	1.16	0.72	0.93	16.55
Pumps & Aux.	0.91	0.83	0.91	0.96	0.96	0.87	0.96	0.96	0.87	0.96	0.83	0.91	10.91
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	10.41	9.41	10.41	10.59	10.72	9.98	10.72	10.72	9.98	10.72	9.67	10.41	123.71
Task Lights	0.96	0.87	0.96	1.00	1.00	0.91	1.00	1.00	0.91	1.00	0.87	0.96	11.45
Area Lights	9.51	8.60	9.51	9.90	9.93	9.07	9.93	9.93	9.07	9.93	8.65	9.51	113.51
Total	23.69	21.34	23.37	24.78	27.00	29.36	34.66	32.61	25.25	24.87	21.44	23.50	311.87

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	135.47	108.46	57.09	22.86	1.25	-	-	-	0.15	6.91	51.90	100.81	484.90
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.54	10.82	11.94	12.19	11.25	9.40	9.49	8.99	8.18	9.40	8.91	10.69	122.79
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	147.01	119.28	69.03	35.05	12.50	9.40	9.49	8.99	8.33	16.31	60.81	111.50	607.69

Appendix F

Energy Usage for all facilities with Northern Orientation, CY 2012

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (MBtu)
Tyndall AFB, FL	Steel Frame	419,160	103.24	6,220	6.71
	CMU	414,890	97.58	1,950	1.05
	ICF	412,940	96.53		
Holloman AFB, NM	Steel Frame	380,520	114.31	2,800	8.74
	CMU	379,690	107.16	1,970	1.59
	ICF	377,720	105.57		
JB Langley-Eustis, VA	Steel Frame	370,930	175.51	4,040	24.20
	CMU	366,860	165.81	-30	14.50
	ICF	366,890	151.31		
Offutt AFB, NE	Steel Frame	350,510	416.67	5,000	62.57
	CMU	346,050	386.25	540	32.15
	ICF	345,510	354.10		
Malmstrom AFB, MT	Steel Frame	312,550	523.66	3,740	80.98
	CMU	308,770	470.75	-40	28.07
	ICF	308,810	442.68		
Minot AFB, ND	Steel Frame	313,290	716.72	4,460	107.31
	CMU	308,230	632.04	-600	22.63
	ICF	308,830	609.41		

Annual Energy Consumption for all facilities with Northern Orientation, CY 2013

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Usage Difference Electricity (kWh)	Usage Difference Natural Gas (MBtu)
Tyndall AFB, FL	Steel Frame	418,620	104.02	6,320	6.91
	CMU	414,390	98.81	2,090	1.70
	ICF	412,300	97.11		
Holloman AFB, NM	Steel Frame	382,210	115.17	3,030	8.90
	CMU	381,230	108.23	2,050	1.96
	ICF	379,180	106.27		
JB Langley-Eustis, VA	Steel Frame	371,090	180.76	4,090	10.06
	CMU	366,990	170.7	-10	14.67
	ICF	367,000	156.03		
Offutt AFB, NE	Steel Frame	350,880	431.26	4,990	36.99
	CMU	346,440	394.27	550	27.63
	ICF	345,890	366.64		
Malmstrom AFB, MT	Steel Frame	313,720	546.30	3,790	54.46
	CMU	309,410	491.84	-520	25.38
	ICF	309,930	466.46		
Minot AFB, ND	Steel Frame	316,900	715.80	5,030	89.67
	CMU	310,370	626.13	-1,500	18.44
	ICF	311,870	607.69		

Annual Energy Consumption for all facilities with Western Orientation, CY 2012

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh x000)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (Mbtu)
Tyndall AFB, FL	Steel Frame	427,900	106.78	7,540	6.48
	CMU	424,000	101.38	3,640	1.08
	ICF	420,360	100.30		
Holloman AFB, NM	Steel Frame	393,040	122.02	4,220	11.04
	CMU	391,100	112.27	2,280	1.29
	ICF	388,820	110.98		
JB Langley-Eustis, VA	Steel Frame	379,750	188.27	5,280	24.53
	CMU	374,660	176.49	190	12.75
	ICF	374,470	163.74		
Offutt AFB, NE	Steel Frame	359,270	442.39	6,070	64.71
	CMU	353,820	405.41	620	27.73
	ICF	353,200	377.68		
Malmstrom AFB, MT	Steel Frame	319,410	551.82	4,480	79.52
	CMU	315,120	498.79	190	26.49
	ICF	314,930	472.30		
Minot AFB, ND	Steel Frame	319,750	754.85	5,070	108.16
	CMU	314,110	669.51	-570	22.82
	ICF	314,680	646.69		

Annual Energy Consumption for all facilities with Western Orientation, CY 2013

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (MBtu)
Tyndall AFB, FL	Steel Frame	429,380	109.59	7,920	8.48
	CMU	423,730	102.49	2,270	1.38
	ICF	421,460	101.11		
Holloman AFB, NM	Steel Frame	394,790	122.01	4,400	10.32
	CMU	392,720	112.91	2,330	1.22
	ICF	390,390	111.69		
JB Langley-Eustis, VA	Steel Frame	379,850	193.84	5,290	26.08
	CMU	374,760	181.35	200	13.59
	ICF	374,560	167.76		
Offutt AFB, NE	Steel Frame	359,410	456.92	6,030	66.69
	CMU	354,030	419.42	650	29.19
	ICF	353,380	390.23		
Malmstrom AFB, MT	Steel Frame	320,290	572.62	4,510	82.02
	CMU	315,750	517.78	-30	27.18
	ICF	315,780	490.60		
Minot AFB, ND	Steel Frame	323,440	756.96	5,630	110.68
	CMU	316,510	663.87	-1,300	17.59
	ICF	317,810	646.28		

Annual Energy Consumption for all facilities with Southern Orientation, CY 2012

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh x000)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (Mbtu)
Tyndall AFB, FL	Steel Frame	425,660	100.61	7,130	5.85
	CMU	420,280	95.16	1,750	0.40
	ICF	418,530	94.76		
Holloman AFB, NM	Steel Frame	389,960	106.31	3,730	6.23
	CMU	388,660	100.05	2,430	-0.03
	ICF	386,230	100.08		
JB Langley-Eustis, VA	Steel Frame	375,700	161.34	4,350	21.19
	CMU	371,070	151.53	-280	11.38
	ICF	371,350	140.15		
Offutt AFB, NE	Steel Frame	356,250	394.26	5,390	60.82
	CMU	351,110	359.57	250	26.13
	ICF	350,860	333.44		
Malmstrom AFB, MT	Steel Frame	318,080	501.44	3,980	77.34
	CMU	313,780	450.42	-320	26.32
	ICF	314,100	424.10		
Minot AFB, ND	Steel Frame	318,370	694.20	4,700	104.00
	CMU	312,920	611.70	-750	21.50
	ICF	313,670	590.20		

Annual Energy Consumption for all facilities with Southern Orientation, CY 2013

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh x000)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (Mbtu)
Tyndall AFB, FL	Steel Frame	425,070	101.89	6,830	6.19
	CMU	419,770	96.24	1,530	0.54
	ICF	418,240	95.70		
Holloman AFB, NM	Steel Frame	392,100	107.52	3,440	7.58
	CMU	389,660	100.88	1,000	0.94
	ICF	388,660	99.94		
JB Langley-Eustis, VA	Steel Frame	377,560	165.87	6,470	21.66
	CMU	372,480	156.03	1,390	11.82
	ICF	371,090	144.21		
Offutt AFB, NE	Steel Frame	356,910	408.10	5,450	62.31
	CMU	351,710	373.95	250	28.16
	ICF	351,460	345.79		
Malmstrom AFB, MT	Steel Frame	318,890	520.70	4,000	76.19
	CMU	314,560	469.51	-330	25.00
	ICF	314,890	444.51		
Minot AFB, ND	Steel Frame	318,550	693.03	3,610	104.92
	CMU	313,970	604.59	-970	16.48
	ICF	314,940	588.11		

Annual Energy Consumption for all facilities with Eastern Orientation, CY 2012

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh x000)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (MBtu)
Tyndall AFB, FL	Steel Frame	428,180	103.82	5,690	5.36
	CMU	424,720	99.77	2,230	1.31
	ICF	422,490	98.46		
Holloman AFB, NM	Steel Frame	394,260	115.61	3,910	8.43
	CMU	392,670	108.34	2,320	1.16
	ICF	390,350	107.18		
JB Langley-Eustis, VA	Steel Frame	379,980	185.01	5,230	23.97
	CMU	375,970	173.88	1,220	12.84
	ICF	374,750	161.04		
Offutt AFB, NE	Steel Frame	359,520	437.65	6,040	64.35
	CMU	354,090	401.78	610	28.48
	ICF	353,480	373.30		
Malmstrom AFB, MT	Steel Frame	320,620	548.44	5,300	79.30
	CMU	316,080	496.40	760	27.26
	ICF	315,320	469.14		
Minot AFB, ND	Steel Frame	320,410	751.77	4,690	106.69
	CMU	314,630	667.71	-1,090	22.63
	ICF	315,720	645.08		

Annual Energy Consumption for all facilities with Eastern Orientation, CY 2013

Air Force Installation	Exterior Wall	Annual Electricity Use (kWh x000)	Annual Natural Gas Use (MBtu)	Usage Reduction in Electricity (kWh)	Usage Recution in Natural Gas (Mbtu)
Tyndall AFB, FL	Steel Frame	429,880	107.35	7,950	7.37
	CMU	424,290	101.24	2,360	1.26
	ICF	421,930	99.98		
Holloman AFB, NM	Steel Frame	396,130	116.80	4,110	9.15
	CMU	394,360	109.24	2,340	1.59
	ICF	392,020	107.65		
JB Langley-Eustis, VA	Steel Frame	380,030	190.29	5,250	25.18
	CMU	375,020	178.80	240	13.69
	ICF	374,780	165.11		
Offutt AFB, NE	Steel Frame	359,580	451.93	6,690	65.12
	CMU	354,260	415.77	1,370	28.96
	ICF	352,890	386.81		
Malmstrom AFB, MT	Steel Frame	321,410	569.73	5,330	81.44
	CMU	316,850	515.79	770	27.50
	ICF	316,080	488.29		
Minot AFB, ND	Steel Frame	323,550	752.97	5,750	109.43
	CMU	318,080	661.24	280	17.70
	ICF	317,800	643.54		

Appendix G

LCCA for Tyndall AFB, FL comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$90,873	$121,479	-$30,606
Future Costs:			
Energy Consumption Costs	$785,890	$759,794	$26,096
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$2,802	-$3,746	$944
Subtotal (for Future Cost Items)	$783,088	$756,048	$27,040
Total PV Life-Cycle Cost	$873,961	$877,527	-$3,566

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$26,096
- Increased Total Investment	$29,662
Net Savings	-$3,566

Savings-to-Investment Ratio (SIR)

SIR = 0.88

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 3.17%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Discounted Payback never reached during study period.

Simple Payback occurs in year 27

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	418,620.0 kWh	412,300.0 kWh	6,320.0 kWh	252,782.7 kWh
Natural Gas	104.0 MBtu	97.1 MBtu	6.9 MBtu	276.4 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,428.4 MBtu	1,406.8 MBtu	21.6 MBtu	862.5 MBtu
Natural Gas	104.0 MBtu	97.1 MBtu	6.9 MBtu	276.4 MBtu

LCCA for Tyndall AFB, FL comparing CMU and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$98,586	$121,479	-$22,893
Future Costs:			
Energy Consumption Costs	$777,372	$759,794	$17,577
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,040	-$3,746	$706
Subtotal (for Future Cost Items)	$774,331	$756,048	$18,283
Total PV Life-Cycle Cost	$872,917	$877,527	-$4,610

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$17,577
- Increased Total Investment	$22,187
Net Savings	-$4,610

Savings-to-Investment Ratio (SIR)

SIR = 0.79

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 2.90%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Discounted Payback never reached during study period.

Simple Payback occurs in year 30

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	414,390.0 kWh	412,300.0 kWh	2,090.0 kWh	83,594.3 kWh
Natural Gas	98.8 MBtu	97.1 MBtu	1.7 MBtu	68.0 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,414.0 MBtu	1,406.8 MBtu	7.1 MBtu	285.2 MBtu
Natural Gas	98.8 MBtu	97.1 MBtu	1.7 MBtu	68.0 MBtu

LCCA for Holloman AFB, NM comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$99,555	$133,084	-$33,529
Future Costs:			
Energy Consumption Costs	$602,721	$596,741	$5,980
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,070	-$4,104	$1,034
Subtotal (for Future Cost Items)	$599,651	$592,637	$7,014
Total PV Life-Cycle Cost	$699,206	$725,721	-$26,515

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$5,980
- Increased Total Investment	$32,495
Net Savings	-$26,515

Savings-to-Investment Ratio (SIR)

SIR = 0.18

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -0.79%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	382,210.0 kWh	379,180.0 kWh	3,030.0 kWh	121,191.7 kWh
Natural Gas	115.2 MBtu	106.3 MBtu	8.9 MBtu	356.0 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,304.2 MBtu	1,293.8 MBtu	10.3 MBtu	413.5 MBtu
Natural Gas	115.2 MBtu	106.3 MBtu	8.9 MBtu	356.0 MBtu

LCCA for Holloman AFB, NM comparing CMU and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$108,005	$133,084	-$25,079
Future Costs:			
Energy Consumption Costs	$600,176	$596,741	$3,435
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,330	-$4,104	$773
Subtotal (for Future Cost Items)	$596,845	$592,637	$4,208
Total PV Life-Cycle Cost	$704,850	$725,721	-$20,871

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$3,435
- Increased Total Investment	$24,306
Net Savings	-$20,871

Savings-to-Investment Ratio (SIR)

SIR = 0.14

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -1.44%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.
Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	381,230.0 kWh	379,180.0 kWh	2,050.0 kWh	81,994.4 kWh
Natural Gas	108.2 MBtu	106.3 MBtu	2.0 MBtu	78.4 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,300.8 MBtu	1,293.8 MBtu	7.0 MBtu	279.8 MBtu
Natural Gas	108.2 MBtu	106.3 MBtu	2.0 MBtu	78.4 MBtu

LCCA for JB Langley-Eustis, VA comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$96,398	$128,864	-$32,466
Future Costs:			
Energy Consumption Costs	$597,726	$586,269	$11,456
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$2,973	-$3,974	$1,001
Subtotal (for Future Cost Items)	$594,753	$582,296	$12,458
Total PV Life-Cycle Cost	$691,151	$711,160	-$20,008

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$11,456
- Increased Total Investment	$31,465
Net Savings	-$20,008

Savings-to-Investment Ratio (SIR)

SIR = 0.36

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 0.92%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.
Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	371,090.0 kWh	367,000.0 kWh	4,090.0 kWh	163,588.8 kWh
Natural Gas	180.8 MBtu	156.0 MBtu	24.7 MBtu	989.1 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,266.2 MBtu	1,252.3 MBtu	14.0 MBtu	558.2 MBtu
Natural Gas	180.8 MBtu	156.0 MBtu	24.7 MBtu	989.1 MBtu

LCCA for JB Langley-Eustis, VA comparing CMU and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$104,580	$128,864	-$24,284
Future Costs:			
Energy Consumption Costs	$589,395	$586,269	$3,126
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,225	-$3,974	$749
Subtotal (for Future Cost Items)	$586,170	$582,296	$3,875
Total PV Life-Cycle Cost	$690,750	$711,160	-$20,409

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$3,126
- Increased Total Investment	$23,535
Net Savings	-$20,409

Savings-to-Investment Ratio (SIR)

SIR = 0.13

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -1.59%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	366,990.0 kWh	367,000.0 kWh	-10.0 kWh	-400.0 kWh
Natural Gas	170.7 MBtu	156.0 MBtu	14.7 MBtu	586.8 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,252.2 MBtu	1,252.3 MBtu	-0.0 MBtu	-1.4 MBtu
Natural Gas	170.7 MBtu	156.0 MBtu	14.7 MBtu	586.8 MBtu

LCCA for Offutt AFB, NE comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$102,825	$137,455	-$34,630
Future Costs:			
Energy Consumption Costs	$358,336	$344,814	$13,522
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,171	-$4,239	$1,068
Subtotal (for Future Cost Items)	$355,165	$340,575	$14,590
Total PV Life-Cycle Cost	$457,990	$478,030	-$20,040

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$13,522
- Increased Total Investment	$33,562
Net Savings	-$20,040

Savings-to-Investment Ratio (SIR)

SIR = 0.40

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 1.17%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	350,880.0 kWh	345,890.0 kWh	4,990.0 kWh	199,586.3 kWh
Natural Gas	431.3 MBtu	366.6 MBtu	64.6 MBtu	2,584.6 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,197.3 MBtu	1,180.2 MBtu	17.0 MBtu	681.0 MBtu
Natural Gas	431.3 MBtu	366.6 MBtu	64.6 MBtu	2,584.6 MBtu

LCCA for Offutt AFB, NE comparing CMU and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$111,552	$137,455	-$25,903
Future Costs:			
Energy Consumption Costs	$349,258	$344,814	$4,445
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,440	-$4,239	$799
Subtotal (for Future Cost Items)	$345,819	$340,575	$5,244
Total PV Life-Cycle Cost	$457,371	$478,030	-$20,659

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$4,445
- Increased Total Investment	$25,104
Net Savings	-$20,659

Savings-to-Investment Ratio (SIR)

SIR = 0.18

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -0.88%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	346,440.0 kWh	345,890.0 kWh	550.0 kWh	21,998.5 kWh
Natural Gas	394.3 MBtu	366.6 MBtu	27.6 MBtu	1,105.1 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,182.1 MBtu	1,180.2 MBtu	1.9 MBtu	75.1 MBtu
Natural Gas	394.3 MBtu	366.6 MBtu	27.6 MBtu	1,105.1 MBtu

LCCA for Malmstrom AFB, MT comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$103,839	$138,812	-$34,973
Future Costs:			
Energy Consumption Costs	$903,746	$881,126	$22,620
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,202	-$4,280	$1,078
Subtotal (for Future Cost Items)	$900,544	$876,845	$23,698
Total PV Life-Cycle Cost	$1,004,383	$1,015,657	-$11,275

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$22,620
- Increased Total Investment	$33,895
Net Savings	-$11,275

Savings-to-Investment Ratio (SIR)

SIR = 0.67

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 2.46%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Discounted Payback never reached during study period.

Simple Payback occurs in year 34

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	313,720.0 kWh	309,930.0 kWh	3,790.0 kWh	151,589.6 kWh
Natural Gas	546.3 MBtu	466.5 MBtu	79.8 MBtu	3,193.4 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,070.5 MBtu	1,057.5 MBtu	12.9 MBtu	517.2 MBtu
Natural Gas	546.3 MBtu	466.5 MBtu	79.8 MBtu	3,193.4 MBtu

LCCA for Malmstrom AFB, MT comparing CMU and ICF facilites.
Analysis start date: January 1, 2013   Study period: 40 years   Interest rate: 0.5%
Discount Rate: 3.5%   Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$112,653	$138,812	-$26,159
Future Costs:			
Energy Consumption Costs	$883,827	$881,126	$2,702
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,474	-$4,280	$807
Subtotal (for Future Cost Items)	$880,354	$876,845	$3,508
Total PV Life-Cycle Cost	$993,007	$1,015,657	-$22,651

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$2,702
- Increased Total Investment	$25,352
Net Savings	-$22,651

Savings-to-Investment Ratio (SIR)

SIR = 0.11

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -2.13%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	309,410.0 kWh	309,930.0 kWh	-520.0 kWh	-20,798.6 kWh
Natural Gas	491.8 MBtu	466.5 MBtu	25.4 MBtu	1,015.1 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,055.8 MBtu	1,057.5 MBtu	-1.8 MBtu	-71.0 MBtu
Natural Gas	491.8 MBtu	466.5 MBtu	25.4 MBtu	1,015.1 MBtu

LCCA for Minot AFB, ND comparing Steel Frame and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$99,217	$132,632	-$33,415
Future Costs:			
Energy Consumption Costs	$523,098	$504,813	$18,285
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,059	-$4,090	$1,030
Subtotal (for Future Cost Items)	$520,038	$500,723	$19,315
Total PV Life-Cycle Cost	$619,255	$633,355	-$14,100

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$18,285
- Increased Total Investment	$32,385
Net Savings	-$14,100

Savings-to-Investment Ratio (SIR)

SIR = 0.56

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 2.03%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Discounted Payback never reached during study period.

Simple Payback occurs in year 38

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	316,900.0 kWh	311,870.0 kWh	5,030.0 kWh	201,186.2 kWh
Natural Gas	715.8 MBtu	607.7 MBtu	108.1 MBtu	4,324.1 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,081.3 MBtu	1,064.1 MBtu	17.2 MBtu	686.5 MBtu
Natural Gas	715.8 MBtu	607.7 MBtu	108.1 MBtu	4,324.1 MBtu

LCCA for Minot AFB, ND comparing CMU and ICF facilites.
Analysis start date: January 1, 2013 Study period: 40 years Interest rate: 0.5%
Discount Rate: 3.5% Current year amount using CY 2013 utility rates

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$107,683	$132,632	-$24,949
Future Costs:			
Energy Consumption Costs	$504,589	$504,813	-$224
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	-$3,321	-$4,090	$769
Subtotal (for Future Cost Items)	$501,269	$500,723	$545
Total PV Life-Cycle Cost	$608,952	$633,355	-$24,404

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	-$224
- Increased Total Investment	$24,180
Net Savings	-$24,404

NOTE: Meaningful SIR, AIRR and Payback can not be computed unless incremental savings and total savings are both positive.

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	310,370.0 kWh	311,870.0 kWh	-1,500.0 kWh	-59,995.9 kWh
Natural Gas	626.1 MBtu	607.7 MBtu	18.4 MBtu	737.5 MBtu

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	1,059.0 MBtu	1,064.1 MBtu	-5.1 MBtu	-204.7 MBtu
Natural Gas	626.1 MBtu	607.7 MBtu	18.4 MBtu	737.5 MBtu

Appendix H

Interview Response from ICF Contractor #1

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction					X
Lack of awareness & understanding of sustainable construction materials					X
Lack of information about what qualifies as sustainability					X
Resistance to change					X
Lack of cooperation b/w owner and contractor		X			
Lack of training regarding sustainable construction methods/techniques				X	
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction					X
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation				X	
Reduced profit margin				X	
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment				X	
Limited project budgets prevent use of sustainable construction materials					X
Time Impact					
Tight schedules				X	
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction				X	
Availability of ICFs in construction area				X	
Market Impact					
Unique characteristics of each project				X	
Inefficiency of available equipment			X		

Additional comments (optional)

Cost seems to be the impact I have seen, particularly when the emphasis is solely on lowest bid.

Interview Response from ICF Contractor #2

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction					X
Lack of awareness & understanding of sustainable construction materials					X
Lack of information about what qualifies as sustainability					X
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques				X	
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market				X	
Fierce competition; enhance sustainable construction implementation				X	
Reduced profit margin					X
Emphasizing on lowest price for subcontractors will facilitate sustainable construction					X
Expenses for transportation of materials and equipment	X				
Limited project budgets prevent use of sustainable construction materials			X		
Time Impact					
Tight schedules	X				
Delays in material submittals	X				
Delays in material approvals	X				
Higher emphasis on speed of construction		X			
Availability of ICFs in construction area		X			
Market Impact					
Unique characteristics of each project		X			
Inefficiency of available equipment		X			

Additional comments (optional)

Residential use of ICFs is ahead of commercial use. Biggest barrier I have seen is in the comparison of first costs vs. second costs. More commercial builders focus on first costs while residential builders look more on second costs. Right now the costs are about 10-15% more for ICFs of wood framing in the residential market for first costs. The ideal users is one who is willing to pay a percentage more upfront in order to gain savings in the future. As building codes are updated ICFs will begin to surpass wood and other more traditional materials.

Interview Response from ICF Contractor #3

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability					X
Resistance to change				X	
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client				X	
Lack of incentives for utilizing sustainable construction			X		
Cost Impact					
Relationship between construction cost and implementing sustainable construction					X
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation				X	
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials					X
Time Impact					
Tight schedules				X	
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction				X	
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project			X		
Inefficiency of available equipment		X			

Additional comments (optional)

One of the better aspects of ICFs over wood or steel is its overall strength. ICFs are 70-75% stronger during high winds of tornados and hurricanes over wood. This material is more weather resistant than other materials. ICFs have a better insulation factor of R-27 to 45. The cost of the ICFs themselves are coming down but the cost of the concrete can add about 10% to the construction costs. For military application, ICFs can provide strong blast protection. This has been proven in past tests.

Interview Response from ICF Contractor #4

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change				X	
Lack of cooperation b/w owner and contractor	X				
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials	X				
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction			X		
Limited projects released in the market				X	
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin	X				
Emphasizing on lowest price for subcontractors will facilitate sustainable construction			X		
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials			X		
Time Impact					
Tight schedules			X		
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction			X		
Availability of ICFs in construction area	X				
Market Impact					
Unique characteristics of each project	X				
Inefficiency of available equipment		X			

Additional comments (optional)

Biggest barrier is the resistance to change from traditional materials as well as a preconception of added costs. Added 3-5% cost for ICFs at initial construction.

Interview Response from ICF Contractor #5

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability					X
Resistance to change			X		
Lack of cooperation b/w owner and contractor	X				
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials			X		
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction		X			
Limited projects released in the market		X			
Fierce competition; enhance sustainable construction implementation					X
Reduced profit margin	X				
Emphasizing on lowest price for subcontractors will facilitate sustainable construction					X
Expenses for transportation of materials and equipment	X				
Limited project budgets prevent use of sustainable construction materials			X		
Time Impact					
Tight schedules				X	
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction					X
Availability of ICFs in construction area					X
Market Impact					
Unique characteristics of each project		X			
Inefficiency of available equipment		X			
Additional comments (optional)					
Cost can be a barrier but the better aspects of ICFs is the speed in which construction is completed which can help to balance the cost aspect as well as the strength of ICFs particularly in areas prone to tornadoes and hurricanes.					

Interview Response from ICF Contractor #6

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability					X
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment				X	
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules				X	
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction				X	
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project				X	
Inefficiency of available equipment				X	

Additional comments (optional)

Cost is an issue for those who are unwilling to pay upfront for better cost return in the future. Best pro is the strength for those in locations with high winds and natural disaster vulnerabilities as well as the longer life span of ICFs over wood framing.

Interview Response from ICF Contractor #7

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction			X		
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules			X		
Delays in material submittals		X			
Delays in material approvals		X			
Higher emphasis on speed of construction			X		
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project				X	
Inefficiency of available equipment			X		

Additional comments (optional)

Cost is more of an issue on the commercial side where users are often limited to selecting lowest bid price of open market bidding. One disadvantage of ICFs is cantilevered walls, not impossible with ICFs but more of a challenge and can drive costs up. ICFs have grown in the residential market because of a slow increase in knowledge of what this material is and its advantages.

Interview Response from Contractor #8

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials					X
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules			X		
Delays in material submittals		X			
Delays in material approvals		X			
Higher emphasis on speed of construction			X		
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project			X		
Inefficiency of available equipment		X			

Additional comments (optional)

Added construction cost 3-5%. ICFs provide better climate control over steel buildings. ICFs have a pro over steel in the speed of construction mostly because so many steps are combined into one. Only issue with building ICFs is when trying to do a cantilevered wall, not impossible but very challenging because the blocks are not stacked but free standing.

Interview Response from ICF Contractor #9

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction			X		
Lack of awareness & understanding of sustainable construction materials		X			
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor					X
Lack of training regarding sustainable construction methods/techniques				X	
Preconception towards traditional construction methods & materials					X
Lack of interest & demand from client		X			
Lack of incentives for utilizing sustainable construction					X
Cost Impact					
Relationship between construction cost and implementing sustainable construction			X		
Limited projects released in the market				X	
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin	X				
Emphasizing on lowest price for subcontractors will facilitate sustainable construction					X
Expenses for transportation of materials and equipment	X				
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules		X			
Delays in material submittals	X				
Delays in material approvals					X
Higher emphasis on speed of construction			X		
Availability of ICFs in construction area		X			
Market Impact					
Unique characteristics of each project				X	
Inefficiency of available equipment				X	

Additional comments (optional)

Emphasizing the lowest price for subcontractors often means sacrificing quality and can negatively impact construction. Architects if they design a project as ICFs from the start and not CMU then clients can see the differences. ICFs are not the same as concrete walls and should not be assumed to be comparable. QA/QC could drive some of the costs but if you as an owner own all cost, first and second, then ICFs are an overall advantage.

Interview Response from ICF Contractor #10

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction			X		
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials			X		
Time Impact					
Tight schedules		X			
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction		X			
Availability of ICFs in construction area		X			
Market Impact					
Unique characteristics of each project		X			
Inefficiency of available equipment		X			

Additional comments (optional)

Lack of knowledge is a big problem. The newer ICFs have more advantage than older models and are helping to improve the overall ICF market. Right now ICFs do not qualify for tax breaks the way other energy efficiency products do. Correcting this could improve the ICF market. There is still an added cost but secondary/payback will outweigh in the end. ICFs are a benefit when speed of construction is a factor and is versatile with regards to architectural shapes.

Interview Response from ICF Contractor #11

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change				X	
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client			X		
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction			X		
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin		X			
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials					X
Time Impact					
Tight schedules			X		
Delays in material submittals		X			
Delays in material approvals		X			
Higher emphasis on speed of construction		X			
Availability of ICFs in construction area		X			
Market Impact					
Unique characteristics of each project			X		
Inefficiency of available equipment			X		

Additional comments (optional)

Cost has come down considerably. Too many users look at the end number of initial cost rather than payback. Cannot compare ICFs to traditional CMU, concrete poured wall…not comparable. It is all about the building envelope, ICFs are steps above other materials with regards to thermal bridging.

Interview Response from ICF Contractor #12

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction					X
Lack of awareness & understanding of sustainable construction materials					X
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques			X		
Preconception towards traditional construction methods & materials					X
Lack of interest & demand from client		X			
Lack of incentives for utilizing sustainable construction				X	
Cost Impact					
Relationship between construction cost and implementing sustainable construction					X
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction		X			
Expenses for transportation of materials and equipment		X			
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules		X			
Delays in material submittals		X			
Delays in material approvals		X			
Higher emphasis on speed of construction		X			
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project		X			
Inefficiency of available equipment		X			

Additional comments (optional)

ICFs seem to be better known in areas which are subject to natural disasters where the strength of ICFs outweighs other materials. Resistance to change is a very large factor especially for the older contractors and users. The younger builders and owners seem to me more open to using ICFs. When the initial cost is only slightly more than traditional materials most are willing to pay that upfront cost. It is when the initial cost gets higher than other materials is when owners become more hesitant to use ICF even if they will get a payback down the line. They put emphasis on the now cost. There does seem to be less ICF contracts in the commercial market as compared to residential where the ICF market is still growing. Speed is where ICFs shine, they are a faster construction than other materials. Transportation isn't much of an issue dependent on location. The lower 48 have ICF contractors in nearly all states. In Alaska, however, where ICFs would be a better material for its insulated properties it is more expensive do to its location. The biggest issue is just a lack of knowledge of what ICFs are and all they can do for the homeowner. For the military application, the ICF blast resistance could be the biggest benefit.

Interview Response from ICF Contractor #13

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction				X	
Lack of awareness & understanding of sustainable construction materials					X
Lack of information about what qualifies as sustainability			X		
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques				X	
Preconception towards traditional construction methods & materials					X
Lack of interest & demand from client				X	
Lack of incentives for utilizing sustainable construction		X			
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market			X		
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules			X		
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction				X	
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project			X		
Inefficiency of available equipment			X		

Additional comments (optional)

No tax credit yet but should and could help improve the ICF market. Cost increase regarding materials and transportation is really site specific but does not have much of a negative impact. One negative seen in residential side I have see is 'do it yourselfers', ICFs should be constructed by an experienced contractor. On the military side, ICFs have high blast ratings for AT/FP requirements.

Interview Response from ICF Contractor #14

People Impact	No Impact (1)	2	3	4	Strong Impact (5)
Lack of awareness & understanding of sustainable construction					X
Lack of awareness & understanding of sustainable construction materials				X	
Lack of information about what qualifies as sustainability				X	
Resistance to change					X
Lack of cooperation b/w owner and contractor			X		
Lack of training regarding sustainable construction methods/techniques				X	
Preconception towards traditional construction methods & materials				X	
Lack of interest & demand from client				X	
Lack of incentives for utilizing sustainable construction			X		
Cost Impact					
Relationship between construction cost and implementing sustainable construction				X	
Limited projects released in the market				X	
Fierce competition; enhance sustainable construction implementation			X		
Reduced profit margin			X		
Emphasizing on lowest price for subcontractors will facilitate sustainable construction				X	
Expenses for transportation of materials and equipment			X		
Limited project budgets prevent use of sustainable construction materials				X	
Time Impact					
Tight schedules			X		
Delays in material submittals			X		
Delays in material approvals			X		
Higher emphasis on speed of construction			X		
Availability of ICFs in construction area			X		
Market Impact					
Unique characteristics of each project		X			
Inefficiency of available equipment		X			
Additional comments (optional)					
ICFs provide superior sound proofing. Cost increase can be a factor when considering custom designs vices more standard block shapes. Currently less ICF use in commercial market vs. residential.					

References

Air Combat Command. (n.d.). Squadron Operations & Aircraft Maintenance Unit Design Guide. Air Combat Command.

Al-Homoud, M. S. (2005). Performance characteristics and practical applications of common building thermal insulation materials. *Building and Environment*, 353-366.

Army, U. (2014, January 28). *Key Energy Directives*. Retrieved from Army Energy Program: http://army-energy.hqda.pentagon.mil/policies/key_directives.asp

ASHRAE Handbook-Fundamentals (SI ed.). (2009). Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.

ASHRAE Standards Commitee. (2012). *ASHRAE 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings.* Atlanta, GA.

Bhatia, A. (2014). Centralized vs Decentralized Air Conditioning Systems. *M05-012*. CED Engineering. Retrieved 2014

Binsacca, R. (2008, June). What (Green) Buyers Want. *Builder*.

BuildCentral, Inc. (2014). *Overview of ICF systems*. Retrieved from Green Building Talk: http://www.greenbuildingtalk.com/buildcentral/icf/overview.aspx

Callan, D. P. (2013, January 23). *ASHRAE 90.1-2010 sets the energy standard.* Retrieved from Engineer: Consulting-Specifying: http://www.csemag.com/single-article/ashrae-901-2010-sets-the-energy-standard/e9b5f53395ccb6bdceff841f79bfd407.html

Chasar, D., Moyer, N., Rudd, A. F., Parker, D., & Chandra, S. (2002). *Measured and Simulated Cooling Performance Comparision; Insulated Concrete Form Versus Frame Construction.* University of Central Florida: Florida Solar Energy Center.

Concrete Homes. (1997). *Fire Resistance of Concrete Homes.* Retrieved from EPS Industry Alliance: http://www.forms.org/index.cfm/fireresistance

Concrete Homes. (1998). *Concrete Homes: Built-In Safety.* Retrieved from EPS Industry Alliance: http://www.forms.org/index.cfm/wind

Eulberg, D. (2008). Meeting our Energy Challenges. *Air Force Civi Engineer, 16*(3).

Executive Order 13423. (2007, January 24). *Strengthening Federal Environmental, Energy, and Transportation Management, 72(17)*. Presidential Document.

Executive Order 13514. (2009, October 5). *Federal Leadership in Environmental, Energy and Economic Performance, 74(194)*. Presidential Documents.

Fuller, S. (2010). Life Cycle Cost Analysis (LCCA). *National Institute of Standards and Technology (NIST)*. Whole Building Design Guide.

Gajda, J., & VanGeem, M. (2000). *Energy Use in Residential Housing: A Comparision of Insulating Concrete Form and Wood Frame Walls.* Portland Cement Association.

Gromicko, N., & Wart, E. (2014). *Solar Heat-Gain Coefficient Ratings for Windows.* Retrieved from InterNACHI: http://www.nachi.org/shgc-ratings-windows.htm

History of ICFs. (2011, February/March). *ICF Builder*.

HQ USAF/A7C. (2011, June 2). Air Force Sustainable Design and Development Implementing Guidance. Department of the Air Force.

ICF Construction. (2013, December). Retrieved from Houser Custom Homes: http://housercustomhomebuilders.com/icf-construction/

ICF Direct. (2006). *Basic Types of Forms.* Retrieved from ICF Direct: http://www.icfdirect.net/formtypes.html

ICF Photo Gallery. (2013). Retrieved from Silver Spur Construction: http://www.silverspurconstruction.com/icfphotogallery.htm

ICF, L. (2012). R-Value Comparison: Logix ICF vs Stud Walls. *(No. 13-021508)*. LogixICF.

IECC/ASHRAE. (2010). *Guide to Determining Climate Regions by Country.* U.S. Department of Energy.

Insulated Concrete Forms. (2014). Retrieved from U.S. Department of Energy, Energy Efficiency & Renewable Energy: https://basc.pnnl.gov/resource-guides/insulated-concrete-forms-icfs#block-views-guide-static-blocks-block-2

Insulating Concrete Forms Come Under Fire (and Blast). (2003, May 27). Retrieved from Quad-Lock Concrete Building Solutions: http://www.quadlock.com/insulated-concrete-forms/news/030527blast_test.htm

Landman, M. (1999). *Breaking through the Barriers to Sustainbale Building: Insights from Building Professionals on Government Initatives to Promote Environmentally Sound Practices.* Tufts University.

Lee, S. M. (2009). *Daylighting Strategies for U.S. Air Force Office Facilities: Economic Analysis of Building Energy Performance and Life-Cycle Cost Modeling with Monte Carlo Method.* Air Force Institute of Technology.

Lemieux, D. J., & Totten, P. E. (2010, October 08). *Building Envelope Design Guide - Wall Systems.* Retrieved from Whole Building Design Guide: http://www.wbdg.org/design/env_wall.php

NAHB Research Center. (2014). *Comparative Cost of ICFs.* Retrieved from EPS Industry Alliance: http://www.forms.org/content.cfm?act=constructioncost

Naval Energy Office. (2009). *Naval Energy: A Strategic Approach.* Washington, DC: Office of the Secretary of the Navy.

Osaily, N. Z. (2010). *The Key Barriers to Implementing Sustainable Construction in West Bank - Palestine.* University of Whales.

Quad-Lock. (2014). *Insulated Concrete Forms vs other Building Materials.* Retrieved from Quad-Lock Concrete Building Solutions: http://www.quadlock.com/concrete_forms/advantage.htm

RSMeans. (2011). *Green Building Cost Data* (1st ed.). Norwell, MA: Construction Publishers & Consultants.

Saber, H. H., Wahid, M., Armstrong, M., Swinton, M. C., Rousseau, M. Z., & Gnanamurugan, G. (2010). Benchmarking Three-Dimensional Thermal Model against Field Measurement on the Thermal Response of an Insulating Concrete Form (ICF) Wall in Cold Climate. *ASHRAE*.

Steel Stud Wall Framing. (2013, December). Retrieved from Extruded Polystyrene Foam Association: http://www.xpsa.com/comm-stud-wall.html

The Quick Energy Simulation Tool (eQUEST). (2014). Retrieved from Open EI: http://en.openei.org/wiki/The_Quick_Energy_Simulation_Tool_(eQUEST)

Tomkiewicz, H. S. (2011). *Barriers to Implementation of sustainable Construction Practices in the Homebuilding Industry: A Case study of Rochester, NY.* University of Nebraska-Lincoln.

U.S. Environmental Protection Agency. (2012, December 19). *Green Building: Basic Information*. Retrieved from http://www.epa.gov/greenbuilding/pubs/about.htm

Uebersax, J. S. (2006, August 31). *Likert Scales: Dispelling the Confusion.* Retrieved 2014, from Statistical Methods for Rater Agreement: http://john-uebersax.com/stat/likert.htm

UFC 1-200-02. (2013, March 1). High Performace and Sustainable Building Requirements. *Unified Facilities Criteria*. U.S. Department of Defense.

UFC 3-110-03. (2012). *Roofing*. Department of Defense.

UFC- 4-610-01. (2013, May 1). *Unified Facilities Criteria: Administration Facilities*. Department of Defense.

UFGS 03-11-19.00-10. (2012). Insulating Concrete Forming. *Unified Facilities Guide Specification*. USACE.

Using Cantilevers in House Design. (2013). Retrieved from renovation-headquarters.com: http://www.renovation-headquarters.com/cantilevers-1.html

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14. ABSTRACT

Insulated Concrete Forms are a block style construction material more typically comprised of expanded polystyrene which fit together and are filled with reinforced concrete to construct the exterior wall systems of a building. By design, this material provides a higher level of insulation and greater structural integrity that stands up to damaging winds, fire, and explosive blasts. This study shows that utilizing this material is not the most cost effective material choice when constructing new facilities, however, it does reduce energy consumption and contributes towards total energy reduction goals established by the Department of Defense. This study also showed there are multiple barriers preventing increased use of Insulated Concrete Forms to include a lack of knowledge of the advantages of this material, a resistance to change from more traditional materials, and to some degree the increased initial cost of utilizing this material. This study concludes there is merit in considering Insulated Concrete Forms for use in sustainable military construction.

15. SUBJECT TERMS: Insulated Concrete Forms, Sustainable Military Construction

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