**AN ENERGY BENCHMARKING CATEGORIZATION SCHEME AND CONSUMPTION DATA VALIDATION FOR AIR FORCE FACILITIES**

THESIS


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AFIT-ENV-MS-17-M-207

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## Abstract

The purpose of this research was to provide a proof of concept for an Air Force facility energy benchmarking program which utilizes the meter data currently available at installations. It also sought to explore the effectiveness of utilizing real property category labels as energy consumption peer groupings. Specifically, this thesis strove to answer three research questions regarding energy consumption data validity, and the ability Facility Analysis Codes and Category Codes possess in predicting facility electrical energy consumption. These research questions were answered through an empirical approach, which included the statistical technique of analysis of variance. The data used in this study included over 550,000 combined data points collected from two Air Force installations.

The results of this study demonstrated the validity of the electrical energy consumption information currently available at Air Force installations, and its ability to form the basis a robust benchmarking program. It also revealed the limited effectiveness of applying real property labels as facility usage type categories. The culmination of this research effort was the identification of the category codes which do or do not accurately represent facility usage types as they relate to energy consumption.

## Acknowledgments

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Mary C. Olive

## Table of Contents

## List of Figures

## List of Tables

# AN ENERGY BENCHMARKING CATEGORIZATION SCHEME AND CONSUMPTION DATA VALIDATION FOR AIR FORCE FACILITIES

## I. Introduction

Events such as the 1979 energy crisis and the spike in cost for crude oil in the 1990s have spurred concerns over the availability and access to energy resources. With the United States' heavy reliance on energy from regions with political unrest, there is more reason than ever to reduce consumption needs. A meaningful place to begin this effort is with commercial buildings, which account for 18% of energy usage in the U.S. (United States Department of Energy, 2008). As facilities get larger, and resources scarcer and more expensive, the race to energy efficiency or energy freedom becomes ever present.

The U.S. Department of Defense (DoD), specifically the Air Force (USAF), relies on the availability of energy to power not only its operational assets, but also its installations – the platforms which it uses to project air power, and successfully carry out missions (U.S. Air Force, 2017). In order to ensure USAF's future ability to protect and defend the U.S., careful measures must be taken to reduce the dependence on energy. This study focuses on energy benchmarking at U.S. Air Force's installations in order to measure and optimize energy consumption.

## **Background**

Energy benchmarking is a vital piece in enterprise-wide energy management and conservation. Although benchmarking is formally defined as, "a point of reference from which measurements may be made" (Merriam-Webster Online, 2016), in the energy world, it holds a much more complex and involved meaning. Energy benchmarking does not only imply the comparison of one facility's consumption patterns to a similar facility; there is an attached connotation of change, and improvement. A successful energy benchmarking program will not only inform energy managers of where the facilities in their portfolio compare with their peers, it will pin-point weaknesses and lead them to solutions. Energy benchmarking provides actionable information for resource-saving behavioral and facility improvements. It is estimated that buildings which are benchmarked benefit from a 2.4% reduction in energy per year (EnergyStar, 2016). For these reasons, the vast majority of industry has implemented, at varying levels, an energy benchmarking program.

Similar to the private sector, the Department of Defense (DoD) has also begun to implement energy-saving measures. The following Federal statutes have been levied upon the DoD regarding energy data collection and reporting:

National Energy Conservation Policy Act, as amended (42 U.S.C. 8253-8258); the Energy Policy Act of 2005 (42 U.S.C. 15852); and Executive Order 13693, requires Federal agencies to report their energy management strategies to Congress.

Energy Independence Security Act (EISA), Section 432 (42 U.S.C. 8253(f)), requires the DoD to report energy usage at the facility level to Congress.

These mandates essentially require that each branch of the U.S. military establishes a benchmarking plan and reports their progress and findings to Congress (U.S. Department of Energy, 2016). The statutes also require that each branch establish attainable goals to reduce energy consumption in accordance with the DoD's Operational Energy Strategy.

Each branch has taken a unique approach in order to comply with the Federal energy requirements. The U.S. Army stood up the Office of Energy Initiatives in 2014, and in concert with the U.S. Army Corps of Engineers, have their scope set on dramatic energy reductions at each Post (Electricchoice, 2016). The U.S. Navy has established a robust energy management branch which is not only focused on energy reduction, but also on diversifying their energy sources. Finally, the U.S. Air Force has formed the Energy Directorate at the Air Force Civil Engineer Center (AFCEC) at Tyndall, AFB in Florida. They are responsible for determining the strategies which will be used at each installation to help USAF reach their energy consumption goals (U.S. Air Force Civil Engineer Center, 2013).

## **Motivation**

The Air Force has a diverse array of facility types to serve its unique mission set. Although the large majority of its infrastructure portfolio is comparable to private sector facilities, there are still many facility types which do not fit neatly into any existing category. For this reason, it is currently impossible to compare the energy usage in every type of Air Force facility to an accurate standard, other than its own historical energy consumption. Without the ability to benchmark the energy usage of each facility type, it is extremely difficult to create a functioning installation energy management program. This directly affects the Air Force's ability to identify weaknesses in its infrastructure, and subsequently strategize and defend improvement actions.

## Problem Statement

The objective of this research is to test the validity of the energy consumption data currently being collected at two individual USAF installations. If validated, this data will be used in an empirical approach to determine the most accurate categorization of USAF facilities into electrical energy consumption peer groups, based on the existing usage taxonomy. This will allow installation and AFCEC decision makers alike to monitor the state of their facilities energy use. The results will aid in the creation of a tool for use in determining weaknesses and energy over-consumers in the Air Force building portfolio.

## Research Questions

This research will focus on answering the following research questions:

1. Is the electrical energy consumption data collected at Ellsworth and Tinker Air Force Bases valid?
2. Are Facility Analysis Category Codes significant predictors of facility electrical energy consumption?
3. Are Category Codes significant predictors of facility electrical energy consumption?

## Methodology

Analysis will be performed on facility electrical energy consumption data collected from utility meters by the energy managers at Tinker AFB, OK, and Ellsworth AFB, SD from 2014 to 2016. Facility characteristics data will be collected from the Real Property office at each respective installation. Weather data will be collected from the National Oceanic and Atmospheric Administration (NOAA).

This research will evaluate the validity of the two electrical energy consumption datasets by analyzing for consistency with literature and industry standards. This study will also explore the correlation facility usage types such as category (CAT) code and facility analysis category (FAC) code have on electrical energy consumption. Analysis of variance will be used to determine the relationship between electrical energy usage intensity (EUI) on facility features. This will be used to determine which of the Air Force's inventory usage codes should be used for energy consumption comparison.

## Assumptions and Limitations

This research is conducted with the assumption that the electrical meter data, real property information, and weather archive data is accurate. The study is limited by the fact that energy consumption was only collected at facilities from two installations. Although these bases are scattered geographically, they do not fully represent the diversity of the Air Force's installation locations, mission sets, and infrastructure portfolio. Natural gas consumption data was also not included in this study. This prohibits a full energy consumption picture from being viewed for each facility. Because natural gas may be used for HVAC, water heating, food preparation, or other energy loads, the complete energy draw for a particular facility can only be determined when electrical energy consumption and natural gas consumption are combined. This has the potential to weaken this study's ability to establish energy usage peer groups. Only when each USAF installation's facilities are all metered, and data compiled, can a full energy benchmarking system be established.

## Implications

The results of this study may be used by AFCEC in their endeavor to establish a robust, branch-wide, energy management program. The facility energy consumption data validation and peer groupings are true "first steps" in building an energy conservation focused enterprise. This study will also provide installation-level energy managers with information regarding which types of information and data to collect in order to facilitate a proper benchmarking system.

## Thesis Organization

This thesis follows the traditional five-chapter format. Chapter 1 establishes the framework for the study by defining the motivation for a USAF energy benchmarking program, outlining the methods in which the data will be analyzed, and delving into the potential implications of the study. Chapter 2 examines the current body of knowledge on facility energy benchmarking and the existing practices of USAF. Chapter 3 describes the methodology used to quantitatively evaluate the validity of existing energy consumption data, and the feasibility of CAT and FAC codes as categorization factors in energy consumption peer groups. Chapter 4 outlines the analysis and results of the empirical study. Chapter 5 provides the discussion and conclusions of the study along with recommendations for future research.

# II. Literature Review

## Chapter Overview

The purpose of this chapter is to review the existing body of knowledge and research efforts on energy benchmarking. Relevant terms will be defined, and the state of U.S. Air Force's energy program practices will be established.

## Introduction

It is projected that the global energy demand will increase 48% between 2012 and 2040 (U.S. Energy Information Administration, 2016). As more countries experience economic growth, and technological advancements are made, the reliance on fossil fuels and alternative energy sources will sky rocket. It is reported that at 97 quadrillion BTUs annually, the United States (U.S.) accounts for approximately 19% of the world's energy consumption (U.S. Energy Information Administration, 2016). The U.S.'s staggering reliance on heavily demanded global energy sources introduces concerns about energy security, long term costs, and emissions.

Corporations such as ENERGY STAR have branded energy efficiency. Their off-the-shelf programs and large data repositories make a successful facility energy management program attainable to most corporations and industries. As they continue to collect more granular data, and improve their analytical software, energy over-consumption may become a thing of the past. The next section introduces specific terms which will be used extensively throughout this paper.

## Building Energy Benchmarking

In the past, the term *benchmarking* was used almost exclusively to describe a geological or topographical reference point. However, in the 1970s, companies began developing benchmarking programs which would measure the impact of adjusting various production parameters. In the 1990s, the term facility energy benchmarking emerged, and referred to the relative energy consumption ranking of one facility against another with similar characteristics (Perez-Lombard, Ortiz, Gonzalez, Maestre, 2009). Today, with the advent of the internet and advanced data collection tools, there are corporations, and entire education streams dedicated toward the science and implementation of facility energy benchmarking (Matson, Piette, 2005). Building energy benchmarking can provide a building owner or operator the following abilities (Matson, Piette, 2005):

1. Determine how well their building is performing
2. Compare their building's energy consumption to that of like buildings
3. Track and set goals for improved future performance
4. Enable assessments of property values

## USAF State of Energy Practice

Hoping to realize some of the benefits aforementioned, there is no surprise that the majority of commercial sector industries have adopted energy benchmarking programs like ENERGY STAR's Portfolio Manager. In fact, 40% of industry has adopted this program alone (Dunn, Macpherson, Maples, 2015)**.** This tool has led to 2.4% in annual energy savings (EnergyStar, 2016). Not wanting to miss out on this rich savings opportunity, USAF has also begun to explore energy benchmarking solutions for their unique building stock. Adding to the list of motivators are Congressional mandates, executive orders, and federal, state, and local guidance (Department of Energy, 2014).

This begs the question: is an off-the-shelf program like ENERGY STAR's Portfolio Manager appropriate for USAF, like it is for so much of industry? The short answer is, partially. The military, and USAF in particular, have mission-specific facilities which are not all easily compared to commercial use averages (Dunn, Macpherson, Maples, 2015). The most robust repository of national energy usage, Commercial Buildings Energy Consumption Survey (CBECS), which Portfolio Manager relies on, does not even have a category for aircraft hangars–one of the more prevalent facility types found on an Air Force installation (US Energy Information Administration, 2013). While Energy Star may be applicable to a certain percentage of USAF facilities, it is far from a 100% solution. This fact highlights the need for a branch-specific energy benchmarking categorization scheme, which will be the framework around a successful energy management program for all of the USAF's building stock.

To answer this need, in fiscal year (FY) 13, AFCEC was overseeing a contract which would install advanced meters and the accompanying reading/analysis/benchmarking software, at 80 AF installations. This network of systems would collect the meter information from individual facilities and store it on a central server. From there, installation energy managers and branch-level energy managers alike could access this data for analysis. If energy benchmarking is "step one" in an energy management program, then metering is "step zero". Unfortunately, this lofty endeavor was not brought to fruition. However, the Air Force, specifically AFCEC, is working tirelessly to find a solution to their infrastructure energy benchmarking needs.

Benchmarking cannot exist without the energy consumption data collected by meters. This is a big step for the USAF and will be the basis of their future energy program. However, until an enterprise-wide solution is brought forth, there are installations which are manually collecting analog meter readings, and may provide useful data to create an interim benchmarking program of sorts. In order to capitalize on the data currently found at the installation-level, an exploration into benchmarking schemes must be conducted to ensure the available information is granular enough to establish a usable benchmarking program.

## Benchmarking Scheme

Since an off-the-shelf energy benchmarking program is not currently suitable for immediate use in USAF, one must be established from the ground up. This section delves into the existing literature on the subject of benchmarking schemes and implementation techniques.

### *Overview of Benchmarking Scheme Establishment*

The establishment of a benchmarking scheme consists of four distinct stages (Perez-Lombard, Ortiz, Gonzalez, Maestre, 2009). First, a database must be developed which contains information on the energy performance of a significant number of facilities. This database must contain, at least, building usage type and size. Second, information must be collected for use in calculating the energy usage intensity (EUI), which is energy consumption (both electrical and natural gas) per square foot of building space, for the actual facility. Third, a comparative analysis of the building's energy performance is conducted against the stock held in the database. This comparative analysis yields a quantification of the performance of the building in terms of energy consumption. Finally, based on the results of the comparative analysis, energy efficiency measures may be explored based on feasibility, and both technical and economical perspectives.

### *Facility Characteristic Variables*

Since energy usage is influenced by many variables, it is important to account for the unique characteristics of each facility in order to ensure there is a commensurable comparison. With the overarching goal of this study being the determination of which USAF facilities are consumption peers, it is paramount to understand which factors play a role in a facility's energy consumption patterns. In the private sector, there is currently a surge in building energy and characteristic data collection. As more industries collect data on the energy usage, weather, and other characteristics (number of windows, occupants, computers, operating hours, etc.) of their facilities, the granularity of data increases. As data collection gains more fidelity, energy programs are beginning to use more complex and refined measures to compare facilities (Perez-Lombard, Ortiz, Gonzalez, Maestre, 2009). These refined measures improve energy modeling simulations, decrease computer learning requirements and result in better, more inclusive categories. This greatly improves the standard to which facilities are compared. These data allow industries to either normalize by these characteristics or form tight groupings of facilities, which share many of the same characteristics. These categories, again, allow for commensurate comparison, which energy benchmarking so strongly relies on in order to provide any sort of meaningful information.

To determine which variables are the most influential on energy usage, the **Review of California and National Methods for Energy-Performance Benchmarking of Commercial Buildings** study is explored (Matson, Piette, 2005). This study examined two prevalent energy benchmarking tools, Energy Star's Portfolio Manager, and Lawrence Berkely National Laboratory's Cal-Arch. Energy Star's Portfolio Manager represents a regression-based model. Energy Star utilizes the CBECS data repository, a national survey-based energy usage and facility information archive. Energy Star uses this CBECS data to create a linear-regression model which uses building characteristics to predict energy consumption. Energy Star uses four main facility characteristic variables: usage type, location, floor area, and monthly energy consumption. However, it also uses more specific occupancy and usage data for various building types. The facility characteristics used for each commercial building usage type is found in Table 1 (Adapted from Matson, Piette, 2005).

*Table 1 - Energy Star's Required Information*

| | K-12 Schools | Offices | Hotels/Motels | Medical Offices | Supermarkeets | Warehouses | Dorms | Hospitals |
|---|---|---|---|---|---|---|---|---|
| **Zip Code** | X | X | X | X | X | X | X | X |
| **Year Built** | X | X | X | X | X | X | - | - |
| **Area** | X | X | X | X | X | X | X | - |
| **Number of Floors** | - | - | - | - | X | - | X | - |
| **Number of Rooms** | - | - | X | - | - | - | X | - |
| **Hours of Use** | X | X | - | X | X | X | - | - |
| **Number of Occupants** | X | X | - | X | X | X | - | - |
| **Above Ground Parking** | - | - | - | - | - | - | - | X |
| **Number of Computers** | X | X | - | - | X | - | - | X |
| **On-site Cooking** | X | - | X | - | X | - | - | - |
| **On-site Laundry** | - | - | X | - | - | - | - | - |
| **% Floor Area Air Conditioned** | X | - | - | X | - | X | X | - |
| **% Floor Area Heated** | X | - | - | X | - | X | X | - |

Zip code is used to obtain climatological data, such as heating and cooling degree data, from the nearest weather station. The heating and cooling degree days are then used to perform weather normalization on the energy consumption data. This eliminates the variability of energy demand associated with heating and cooling loads, and allows for inter-climate comparison. Energy Star's facility floor area input is defined as: all areas enclosed by the exterior walls of the building, including hallways, lobbies, stairways, elevator shafts, and electrical/mechanical/janitorial closets (EPA, 2003). In developing the Energy Star regression-models, EPA explored the correlation of building energy consumption to a number of building characteristics and parameters.

They discovered that building floor area was the single most significant input to the Energy Star regression-models, and provided a fit represented by the "Floor Area-Based" $R^2$ values in Table 2 (Adapted from Matson, Piette, 2005). Additional characteristics like occupancy, operating hours, computers, etc. only marginally added to the model's robustness, as seen in the "Full Model" column in Table 2. When evaluated individually, these additional variables were not as significant to energy usages as the building floor areas.

*Table 2 - Energy Star's R2*

| Building Type | Model $R^2$ | |
|---|---|---|
| | Floor area Based | Full Model |
| K-12 Schools | 0.85 | 0.87 |
| Offices | 0.91 | 0.93 |
| Hotels/Motels | Not Reported | 0.60 to 0.88 |
| Medical Offices | 0.91 | 0.93 |
| Supermarkeets | 0.63 | 0.79 |
| Warehouses | Not Reported | 0.80 |
| Dorms | 0.86 | 0.88 |
| Hospitals | Not Reported | 0.93 |

Once a facility's data is entered into the Energy Star Portfolio Manager, the main output is a rating, from 0-100. A rating of 75 is aligned with the $75^{th}$ percentile EUI. Cal-Arch is a distributional based model (Matson, Piette, 2005). It also utilizes four parameters to compare its buildings: building type, floor area, energy consumption, and zip code. The main difference between this model and Energy Star's is the weather normalization. The zip code factor is used to identify which of the four pre-determined California climate zones the facility falls into. This has the potential to cause errors and skewedness, and does not allow for year-to-year comparisons with accuracy. Despite this fact, the models compared very similarly to each other.

### *Usage Type*

Because of the influence building usage type has on energy consumption, facilities must be grouped together in a methodical taxonomy. Figure 1 (Adapted from U.S. Energy Information Administration , 2012), shows a sample of the building types which CBECS defines as commercial.

| Building type | Definition | Examples |
|---|---|---|
| Education | Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly." | elementary or middle school |
| | | high school |
| | | college or university |
| | | preschool or daycare |
| | | adult education |
| | | career or vocational training |
| | | religious education |
| Food Sales | Buildings used for retail or wholesale of food. | grocery store or food market |
| | | gas station with a convenience store |
| | | convenience store |
| Food Service | Buildings used for preparation and sale of food and beverages for consumption. | fast food |
| | | restaurant or cafeteria |
| | | bar |
| | | catering service or reception hall |
| | | coffee, bagel, or doughnut shop |
| | | ice cream or frozen yogurt shop |
| Health Care (Inpatient) | Buildings used as diagnostic and treatment facilities for inpatient care. | hospital |
| | | inpatient rehabilitation |
| Lodging | Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings. | motel or inn |
| | | hotel |
| | | dormitory, fraternity, or sorority |
| | | retirement home |
| | | nursing home, assisted living, or other residential care |
| | | convent or monastery |
| | | shelter, orphanage, or children's home |
| Mercantile (Retail Other Than Mall) | Buildings used for the sale and display of goods other than food. | retail store |
| | | beer, wine, or liquor store |
| | | rental center |
| | | dealership or showroom for vehicles or boats |
| | | studio/gallery |
| Office | Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building). | administrative or professional office |
| | | government office |
| | | mixed-use office |
| | | bank or other financial institution |
| | | medical office (see previous column) |
| | | sales office |
| | | contractor's office (e.g. construction, plumbing, HVAC) |
| | | non-profit or social services |
| | | city hall or city center |
| | | religious office |
| | | call center |
| Public Assembly | Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls. | social or meeting (e.g. community center, lodge, meeting hall, convention center,senior center) |
| | | recreation (e.g. gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) |
| | | entertainment or culture (e.g. museum, theater, cinema, sports arena, casino, night club) |
| | | library |
| | | student activities center |
| | | armory |
| | | transportation terminal |

*Figure 1 - CBECS Commercial Building Types*

While USAF classifies their facilities in a uniform and consistent manner, the usage labels they maintain do not neatly align to the CBECS categories. They were not created with energy consumption comparison in mind. USAF Real Property guidance governs the definitions of their usage types, and label each facility with a CAT code and FAC code. Appendix E – USAF Real Property DD Form 1354, provides an example of the form required to enter a newly commissioned, renovated, or transferred facility into USAF Real Property Records. Below is a sample of the usage types associated with FAC and CAT codes. FAC codes are entered as 4-digit labels. CAT codes further refine usage categories, and are 6-digits.

| Code | Title |
|---|---|
| 12 | Liquid Fueling and Dispensing Facilities |
| 17 | Training Facilities |
| 21 | Maintenance Facilities |
| 22 | Production Facilities |
| 31 | RDT&E Buildings |
| 41 | Liquid Storage - Fuel and Nonpropellants |
| 42 | Ammunition Storage |
| 44 | Covered Storage |
| 45 | Open Storage |
| 51 | Medical Centers and Hospitals |
| 54 | Dental Clinics |

*Figure 2 - USAF Building Types*

Because of the impact facility usage has on EUI, FAC and CAT codes will be explored extensively to determine which factor is more influential on energy consumption.

The United States Navy has begun using its Goals Package to aid in achieving its energy efficiency goal to reduce energy consumption by 50% by 2020 (Booz Allen Hamilton, 2014). This product, produced by Booz Allan Hamilton, starts by assigning Navy facilities into a category. They begin by using the Facility Analysis Category Code (FAC Code), which is assigned to all DoD facilities for accounting purposes. This broad grouping contains categories such as medical facilities and offices. However, after analysis, it was determined that some of these categories actually represented more than one grouping. For this reason, certain FAC Codes were broken out into smaller categories. Energy production facilities were split into high and low intensity; office buildings were separated into small, medium, and large; these categories named just a few of the adjustments made to the Navy's categorization scheme. These groupings are then used to calculate benchmarks or an average usage across a category. The more data points there are, the more representative the benchmark will be. The Navy requires that all facilities be metered, so that usage information can be analyzed and reported to Congress (DON, 2014).

Alternately, the U.S. Army uses a program developed by the U.S. Army Corps of Engineers, called the Comprehensive Army Master Planning System (National Renewable Energy Laboratory, 2013). This system serves as a database and analytical tool. Not only has the Army categorized their facilities into meaningful groups, they have also established baseline energy usage intensities for these groupings. For example, when an administrative office building at Fort Hood is metered for energy consumption, the data can be compared with the average energy usage across that category. They are able to ascertain the relative standing of that particular facility against its true peers. They could even assign a percentile ranking, and show which facilities, at which installations, in which categories, are the superstars or weakest performers.

***Variable Effects***

There are two ways to account for these factors: data normalization and facility categorization (ENERGY STAR, 2008). Data normalization removes the effect of a particular factor by scaling energy usage to remove the effect of differing conditions between one facility and another. For example, if two versions of the exact same facility are built in two different climates, the energy usage for these facilities will likely be different, especially during summer and winter months. If the energy usage for these facilities is normalized by weather, this difference is essentially eliminated, and the facilities can be compared as equals. Likewise, if there is an appropriately sized grouping of these facilities in each geological area, they could be grouped into climate zones, which would assume they experience similar weather conditions.

The literature reveals that a combination of both grouping (usage type), and normalization (weather and building size), culminate in the most accurate benchmarking scheme.

## Summary

Energy benchmarking is a rapidly growing method of energy management, which compares the energy consumption data of facilities to other similar facilities. A large portion of industry, and much of the Department of Defense, are utilizing energy benchmarking to some degree. It is a proven method to identify the weak points in a portfolio, and a method which can help identify the specific explanatory factors contributing to poor performance. This information has led to large savings and consumption reduction across the globe.

As these programs progress, benchmarking practices are seeing a decided trend towards multi-regression analysis. This marked departure from simple weather and area normalized analysis shows a vast improvement in the science of energy performance measurement**.** This research will focus on collecting only those data points which accurately predict the energy consumption of a facility**.** As is the case with commercial industry, regression analysis will be used to determine if further categorization refinement must be made to accurately classify a particular USAF facility into an energy usage class.

# III. Methodology

This chapter describes the methods used to characterize building electrical energy consumption data into categories. The techniques used in this study are organized into three sections: data sources, data collection practices, and data analysis methods. Each section will detail the definitions, practices, and criteria used.

## Data Source

One of the first steps involved with this study was to identify accurate, reliable, and consistent facility energy consumption data. In fiscal year (FY) 13, AFCEC was overseeing a contract which would install advanced meters and accompanying reading and analysis software, at 80 AF installations. Since that endeavor was put on hold, for the purposes of this research, data requests were instead sent out to USAF installation energy managers individually.

As covered in Chapter 2, facility meter readings and consumption data is handled uniquely at each installation.  For example, an installation may have local meter reading infrastructure which collects and stores readings for all metered facilities at 15-minute intervals; while at another USAF installation, the only available data may be what the local energy municipality manually collects each month for billing purposes. This non-uniformity in which energy consumption data is treated across USAF made it especially difficult to obtain usable information for the purposes of this study.

Despite the varied collection techniques, units of measure, and meter reading frequencies, electrical energy usage data for use in this research was captured from the energy managers at both Tinker Air Force Base in Oklahoma, and Ellsworth Air Force Base in South Dakota. Real Property records from both installations was also collected, and provided fields such as: building age, size, and primary usage information.

## Data Collection

### *Ellsworth Air Force Base*

Electrical energy consumption data was collected via utility meters installed on 66 facilities. Readings were obtained daily from January, 2014, through October, 2016. The data was transferred from Ellsworth AFB to the researcher via the Aviation and Missile Research, Development, and Engineering Center Safe Access File Exchange (AMRDEC SAFE). This is a DoD system used to transfer large files. Both the meter readings and Real Property data were organized in excel spreadsheets.

The energy data set contained an extensive amount of information, including: facility number, meter identification, reading date, meter reading, unit of measure, etc. The Real Property report included information such as building age, size, CAT and FAC codes, facility name, and name of occupying unit.

### *Tinker Air Force Base*

Energy consumption data was collected from Tinker AFB via manual reading of meters installed on 173 facilities. Meter readings were conducted on a monthly basis from January to December, 2015. The data was stored as an excel spreadsheet, and transferred from the installation energy management office to the researcher via SharePoint, a web-based data hub utilized by USAF to share various types of information. The Real Property records were shared via email.

### *Data Reorganization*

Although the data from Tinker and Ellsworth contained largely the same type of information, they were organized vastly different. In order to merge the two data sets into one, usable repository of information for analysis, data preparation was conducted to ensure uniformity. This was accomplished through the following set of actions:

1. **Convert meter reading to *electrical energy consumption*.**
    a. Tinker took a notable departure from Ellsworth in the manner which they presented electrical energy consumption. While Tinker reported the actual monthly electrical consumption for each facility, Ellsworth required a conversion calculation. Table 3 shows an example computation:

*Table 3 - Conversion Calculation from Meter Reading to Consumption*

| Meter Reading Date | Reading |
|---|---|
| 1-Jan-14 | 42,000 kWh |
| 2-Jan-14 | 43,000 kWh |
| Actual Consumption for 2-Jan-14 | 1,000 kWh |

    b. Meter rollover could not be ignored in the above computation. The meters on Ellsworth AFB each had rollover points. For example, after 99,999 kWh, a meter may reset to 0 and begin counting again. This was handled with a simple algorithm which would detect when a meter had rolled over, and determine the value at which it rolls over. Based on these values, computation similar to the one shown in Table 3 was conducted.

2. **Ensure standard unit of measure.**

a. For the purposes of this study, kilowatt-hours (kWh) was the unit of choice for all electrical consumption data. Although the collected meter data was generally characterized in kilowatt-hours, there were instances where British Thermal Units were observed. In these instances, the units were converted using the factor below (U.S. Energy Information Administration, 2016).

$$1 \text{ MBTU} = 0.29307 \text{ kWh}$$

**3. Convert all meter data to monthly interval.**

a. It is typically more desirable to have higher granularity in energy consumption data. However, Tinker's data was presented in a monthly form, while Ellsworth was collected on a daily interval. For the purposes of comparison, Ellsworth's data was reorganized into monthly readings. This was executed by adding all of the daily energy consumption values in a given calendar month, and using that sum as the new monthly consumption data. Table 4 shows an example of daily consumption data. Table 5 shows the reorganized consumption data as monthly values.

*Table 4 - Daily Meter Data Example*

| Installation | Facility # | Size | Date | FAC | CAT | CONSUMPTION |
|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 67440 | 1-Jan-14 | 2141 | 214425 | 1341.75 |
| Ellsworth AFB | 102 | 67440 | 2-Jan-14 | 2141 | 214425 | 1536 |
| Ellsworth AFB | 102 | 67440 | 3-Jan-14 | 2141 | 214425 | 1458.25 |
| Ellsworth AFB | 102 | 67440 | 4-Jan-14 | 2141 | 214425 | 751 |
| Ellsworth AFB | 102 | 67440 | 5-Jan-14 | 2141 | 214425 | 885.25 |
| Ellsworth AFB | 102 | 67440 | 6-Jan-14 | 2141 | 214425 | 1694.25 |
| Ellsworth AFB | 102 | 67440 | 7-Jan-14 | 2141 | 214425 | 1612 |
| Ellsworth AFB | 102 | 67440 | 8-Jan-14 | 2141 | 214425 | 1597.75 |

| Installation | Facility # | Size | Date | FAC | CAT | CONSUMPTION |
|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 67440 | 9-Jan-14 | 2141 | 214425 | 1517.5 |
| Ellsworth AFB | 102 | 67440 | 10-Jan-14 | 2141 | 214425 | 1496.5 |
| Ellsworth AFB | 102 | 67440 | 11-Jan-14 | 2141 | 214425 | 607 |
| Ellsworth AFB | 102 | 67440 | 12-Jan-14 | 2141 | 214425 | 641.5 |
| Ellsworth AFB | 102 | 67440 | 13-Jan-14 | 2141 | 214425 | 1699.5 |
| Ellsworth AFB | 102 | 67440 | 14-Jan-14 | 2141 | 214425 | 1843.25 |
| Ellsworth AFB | 102 | 67440 | 15-Jan-14 | 2141 | 214425 | 1710.75 |
| Ellsworth AFB | 102 | 67440 | 16-Jan-14 | 2141 | 214425 | 1910.5 |
| Ellsworth AFB | 102 | 67440 | 17-Jan-14 | 2141 | 214425 | 1492.75 |
| Ellsworth AFB | 102 | 67440 | 18-Jan-14 | 2141 | 214425 | 631.75 |
| Ellsworth AFB | 102 | 67440 | 19-Jan-14 | 2141 | 214425 | 615.75 |
| Ellsworth AFB | 102 | 67440 | 20-Jan-14 | 2141 | 214425 | 1442.25 |
| Ellsworth AFB | 102 | 67440 | 21-Jan-14 | 2141 | 214425 | 1749.25 |
| Ellsworth AFB | 102 | 67440 | 22-Jan-14 | 2141 | 214425 | 1826.75 |
| Ellsworth AFB | 102 | 67440 | 23-Jan-14 | 2141 | 214425 | 1671.5 |
| Ellsworth AFB | 102 | 67440 | 24-Jan-14 | 2141 | 214425 | 1686.75 |
| Ellsworth AFB | 102 | 67440 | 25-Jan-14 | 2141 | 214425 | 617.25 |
| Ellsworth AFB | 102 | 67440 | 26-Jan-14 | 2141 | 214425 | 705.25 |
| Ellsworth AFB | 102 | 67440 | 27-Jan-14 | 2141 | 214425 | 1579.75 |
| Ellsworth AFB | 102 | 67440 | 28-Jan-14 | 2141 | 214425 | 1584.25 |
| Ellsworth AFB | 102 | 67440 | 29-Jan-14 | 2141 | 214425 | 1506 |
| Ellsworth AFB | 102 | 67440 | 30-Jan-14 | 2141 | 214425 | 1746.25 |
| Ellsworth AFB | 102 | 67440 | 31-Jan-14 | 2141 | 214425 | 1475 |
| Ellsworth AFB | 102 | 67440 | 1-Feb-14 | 2141 | 214425 | 811.75 |
| Ellsworth AFB | 102 | 67440 | 2-Feb-14 | 2141 | 214425 | 811.5 |
| Ellsworth AFB | 102 | 67440 | 3-Feb-14 | 2141 | 214425 | 1606.75 |
| Ellsworth AFB | 102 | 67440 | 4-Feb-14 | 2141 | 214425 | 1634.5 |
| Ellsworth AFB | 102 | 67440 | 5-Feb-14 | 2141 | 214425 | 1826.75 |
| Ellsworth AFB | 102 | 67440 | 6-Feb-14 | 2141 | 214425 | 1731 |
| Ellsworth AFB | 102 | 67440 | 7-Feb-14 | 2141 | 214425 | 1691 |
| Ellsworth AFB | 102 | 67440 | 8-Feb-14 | 2141 | 214425 | 832.5 |
| Ellsworth AFB | 102 | 67440 | 9-Feb-14 | 2141 | 214425 | 859.25 |
| Ellsworth AFB | 102 | 67440 | 10-Feb-14 | 2141 | 214425 | 1574.75 |
| Ellsworth AFB | 102 | 67440 | 11-Feb-14 | 2141 | 214425 | 1454.25 |

| Installation | Facility # | Size | Date | FAC | CAT | CONSUMPTION |
|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 67440 | 12-Feb-14 | 2141 | 214425 | 1606.25 |
| Ellsworth AFB | 102 | 67440 | 13-Feb-14 | 2141 | 214425 | 1407.5 |
| Ellsworth AFB | 102 | 67440 | 14-Feb-14 | 2141 | 214425 | 1430.5 |
| Ellsworth AFB | 102 | 67440 | 15-Feb-14 | 2141 | 214425 | 649.25 |
| Ellsworth AFB | 102 | 67440 | 16-Feb-14 | 2141 | 214425 | 681.25 |
| Ellsworth AFB | 102 | 67440 | 17-Feb-14 | 2141 | 214425 | 1041.75 |
| Ellsworth AFB | 102 | 67440 | 18-Feb-14 | 2141 | 214425 | 1573 |
| Ellsworth AFB | 102 | 67440 | 19-Feb-14 | 2141 | 214425 | 1612 |
| Ellsworth AFB | 102 | 67440 | 20-Feb-14 | 2141 | 214425 | 1601 |
| Ellsworth AFB | 102 | 67440 | 21-Feb-14 | 2141 | 214425 | 1462.5 |
| Ellsworth AFB | 102 | 67440 | 22-Feb-14 | 2141 | 214425 | 713.25 |
| Ellsworth AFB | 102 | 67440 | 23-Feb-14 | 2141 | 214425 | 757.25 |
| Ellsworth AFB | 102 | 67440 | 24-Feb-14 | 2141 | 214425 | 1626.25 |
| Ellsworth AFB | 102 | 67440 | 25-Feb-14 | 2141 | 214425 | 1693 |
| Ellsworth AFB | 102 | 67440 | 26-Feb-14 | 2141 | 214425 | 1600.25 |
| Ellsworth AFB | 102 | 67440 | 27-Feb-14 | 2141 | 214425 | 1478.25 |
| Ellsworth AFB | 102 | 67440 | 28-Feb-14 | 2141 | 214425 | 1718.25 |

*Table 5 - Monthly Meter Data Example*

| Installation | Facility # | Sq Ft | FAC | CAT | Date | Consumption |
|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jan-14 | 231840.1387 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Feb-14 | 244833.5076 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Mar-14 | 228668.9746 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Apr-14 | 192142.1516 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | May-14 | 122883.9823 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jun-14 | 69699.27489 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jul-14 | 56247.74875 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Aug-14 | 54230.72025 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Sep-14 | 92148.55131 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Oct-14 | 132403.1391 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Nov-14 | 265209.164 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Dec-14 | 243411.7449 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jan-15 | 218365.4266 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Apr-15 | 119741.6039 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | May-15 | 119815.9336 |

| Installation | Facility # | Sq Ft | FAC | CAT | Date | Consumption |
|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jun-15 | 52459.88475 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Jul-15 | 47993.31364 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Aug-15 | 50089.52006 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Sep-15 | 57828.21872 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Oct-15 | 95925.12822 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Nov-15 | 172284.3114 |
| Ellsworth AFB | 102 | 67440 | 2141 | 214425 | Dec-15 | 249214.4876 |

4. **Identification of Erroneous Data and Outliers**

    a. Meters were identified which appeared to have been malfunctioning, removed, or replaced, and had an unvaried and consistent readings (either of 0 or some other constant value). This data was removed.

    b. Because of the limited size of the dataset, the observations had to be within certain bounds (not unusually high or low), to prevent overly influencing the analysis. Outliers were removed from the dataset. This is discussed further in the Statistical Analysis section.

***Climatological Data***

Historical climate data was collected from the National Oceanic and Atmospheric Administration (NOAA). The data was ordered for each installation (using zip-code as the regional identifier) via NOAA's web-based archive services and delivered by email in comma-separated values (CSV) format. It was then imported into excel for further use. This weather data contained daily average ambient temperature (degrees Fahrenheit), cooling degree days (CDD), and heating degree days (HDD). Degree days are equivalent to the number of days it would take to heat or cool a particular facility by 1 degree Fahrenheit (ENERGY STAR, 2016). This factor is the industry standard used to normalize energy consumption for weather. It is assumed that for occupied facilities, a balance point of 65 degrees is desired. Thus, if the average temperature ambient temperature on a particular day is 55 degrees, the HDD would be 10 degree * days for the day. Figure 3 (EPA, 2016) shows the typical relationship between energy use and temperature. This illustrates need to incorporate degree days into energy consumption analysis and calculations.

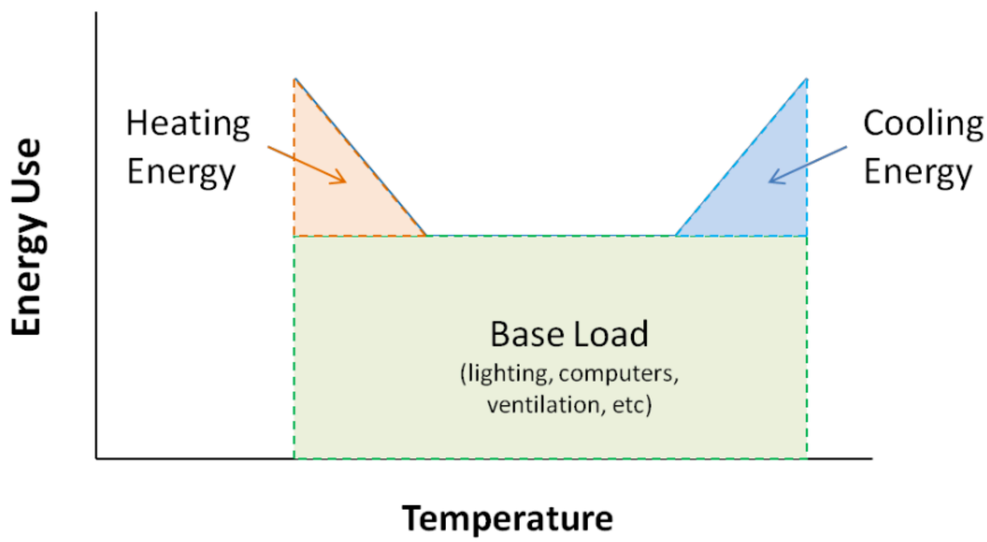


*Figure 3 - Energy Use by Temperature*

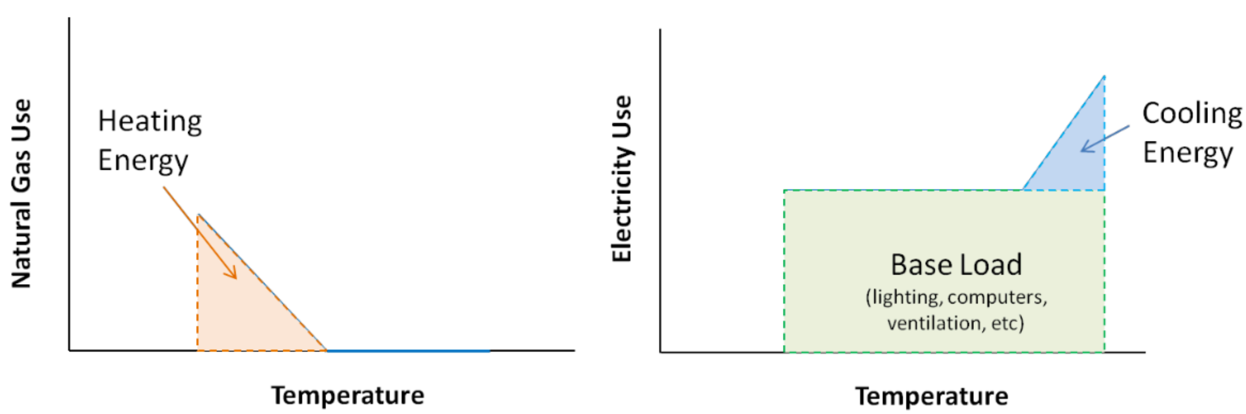


*Figure 4 - Electrical and Gas Use by Temperature*

Figure 4 (EPA, 2016) shows the breakdown of natural gas usage to temperature, and electricity usage to temperature. In locations where natural gas is used to heat facilities, heating degree days are typically a large indicator of gas consumption. Similarly, electricity usage is attributed largely to a baseline load, along with cooling energy requirements. Since natural gas usage data is not available for this study, the heating and cooling degree days will be added together to form total degree days (TDD) for each month. This factor will be explored as an independent variable to observe its relationship with energy consumption.

## Data Analysis

Now that the data sources and data reorganization techniques have been established, the methodology with which the data will be analyzed must be defined.

### *Facility Characteristics*

The literature identified characteristics of facilities which are known to significantly influence electrical energy consumption: building size, climatological data (HDD, CDD), primary usage, and age. Since USAF classifies its facilities into more than one usage type, using CAT and FAC Codes, statistical analysis will be performed to determine which parameter is more influential. This investigation utilizes principles of statistical analysis, namely linear regression and analysis of variance (ANOVA).

## Statistical Analysis

This section provides an overview of the development and testing procedures of each model which will be used to determine the primary usage parameter, along with the statistical tests performed. Each test will be run using the statistical software JMP, taking the following steps:

1. Perform ANOVA
    a. Complete F-Test to determine the level of influence CAT and FAC Codes have on energy consumption. The level of significance, α, is associated with the amount of risk of encountering a Type I error, where the null hypothesis is rejected when in fact, it is true. For this test, a p-value less than $\alpha=0.05$ will be considered statistically significant.

        $H_o$: NONE of the factors explain variability

        $H_a$: AT LEAST ONE of the factors explains variability

    b. Complete Interaction Effect Test to see if combination of variables causes the effect. This ensures the model is not skewed by multicollinearity.
2. Test for Outliers
    a. The studentized residuals are displayed on a histogram for a visual test to determine if any data points are outliers.
3. Test for Overly Influential Points
    a. Cook's Distance values are derived from the linear regression model and displayed on an overlay plot to determine all data points are valid and not over 0.5, and therefore overly influential.

**Summary**

This study utilizes analysis of variance (ANOVA), and compares many combinations of factors to determine the validity of the datasets by comparing its behavior with that of Energy Star's dataset. ANOVA will be also used to determine the correlation of FAC and CAT codes in identifying usage type. The results will be further discussed in Chapter 4.

# IV. Analysis and Results

## Chapter Overview

This chapter presents the results of the study based on the techniques and practices outlined in Chapter 3. The results are presented both graphically and with tables. A more in-depth narrative description of the results and their implications is presented in Chapter 5, Conclusion.

## Data Screening, Scrubbing and Conversions

Because of the non-standardized ways in which each installation collected and represented their facility energy consumption data, a robust and rigorous data screening and scrubbing was necessitated.

### *Facility Type Screening*

For this study, only enclosed facilities were explored. This is due to the fact that many open air storage facilities do not consume any power, or may only contain lights for example. They generally do not possess the energy consumption reduction opportunities that an enclosed facility does. Docks, open storage, depots, and other types of unenclosed structures were removed from the data set. This was conducted in two stages. First, FAC codes known to only include unenclosed structures were identified and removed. Second, for those FAC and CAT codes that included a combination of open and closed facilities, a search was conducted using terms such as “unenclosed, open, course, range, etc.” Once these types of facilities were identified, the corresponding data was removed from the dataset.

***Electrical EUI Calculation***

Since the size of a facility is the single most predictive measure of a facility's energy consumption, it is industry standard to normalize by this factor (ENERGY STAR, 2015). This new measurement is known as the energy usage intensity (EUI) and is measure in kWh/SF. This factor typically contains both electrical and natural gas consumption, for a *total* EUI. However, for this study, only an electrical EUI was able to be calculated. This was conducted for every consumption data point using the equation below.

$$EUI\ (kWh/SF) = \frac{Monthly\ Electrical\ Energy\ Consumption\ (kWh)}{Gross\ SF\ of\ Facility\ (SF)}$$

***Removal of Outliers***

Due to the nature of the data collection process, and the extremely high volume of data points in the sample, errors were expected. Errors may have been introduced into the dataset for any number of reasons. Examples may include: misinterpreting a meter's reading value, or logging/transcription errors. A visual pass of the data identified extreme outliers (1000% or more above average reading for a particular facility, for example). Remaining anomalous points were identified by plotting the distribution of electrical EUI, finding the quantiles, and trimming those data points which were above 99.5% or below 0.5% percentiles. This eliminated 359 data point which contained either erroneous data, or overly influential points which would skew the ANOVA.

## Data Validation

This section explores the relationship between variables to address the first research question: Is the energy consumption data collected at Ellsworth and Tinker Air Force Bases valid?

As the literature review in Chapter 2 illuminated, usage type, square footage, and weather are the three biggest parameters in predicting the electrical energy usage. Since the facility usage type which USAF currently uses (CAT and FAC codes) has yet to be analyzed at this point in the study, the data validation analysis included scenarios without usage type as a factor. Square footage and climate (TDD as described in Chapter 3), were used as independent variables, with electrical energy consumption being the dependent variable, to examine data validity. Analysis of variance was utilized to determine the correlations between variables, test the significance of the relationships between variables, and to establish if any of the independent variables possess the ability to predict electrical energy consumption.

### *Descriptive Statistics*

Table 6 provides the descriptive statistics for all continuous variables used in this study: the mean, standard deviation, and number of occurrences.

*Table 6 - Descriptive Statistics for All Continuous Variables*

| Variable | Mean | Standard Deviation | N |
|---|---|---|---|
| **Electrical Energy Consumption (kWh)** | 99205.478 | 143844.280 | 2646 |
| **Building Size (SF)** | 67269.209 | 85031.743 | 2646 |
| **Total Degree Days** | 986.581 | 864.121 | 2646 |
| **EUI (kWh/SF)** | 1.607 | 1.635 | 2646 |

***ANOVA Results***

Numerous ANOVAs were run on the data collected at Tinker AFB, and Ellsworth AFB independently. These tests were performed to test for validity, by exploring if each dataset conforms with what the literature predicts: facility size and weather are statistically significant factors in relation to electrical energy consumption. The literature also demonstrates primary usage type as a major indicator of consumption, however, since that factor has yet to be determined in this study, it is being omitted from this section. It will be explored extensively in the following section.

Tinker AFB was evaluated first. Square footage was found to have a statistically significant correlation with electrical energy consumption, $F(1, 1482) = 394.05$, $p<0.05$, adjusted $R^2 = 0.210$. Similarly, TDD possessed a high correlation with Tinker AFB's electrical energy consumption, $F(1, 1482) = 333.41$, $p<0.05$, adjusted $R^2 = 0.1837$. Figure 5 shows the results of the two-way ANOVA, which tests the influence of both facility size and climate (TDD) together, $F(2, 1483) = 264.98$, $p<0.05$, adjusted $R^2 = 0.2625$.

**Summary of Fit**

| | |
|---|---|
| RSquare | 0.263534 |
| RSquare Adj | 0.262539 |
| Root Mean Square Error | 144298.1 |
| Mean of Response | 101300.5 |
| Observations (or Sum Wgts) | 1484 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Model | 2 | 1.1035e+13 | 5.517e+12 | 264.9775 |
| Error | 1481 | 3.0837e+13 | 2.082e+10 | **Prob > F** |
| C. Total | 1483 | 4.1872e+13 | | <.0001* |

**Effect Tests**

| Source | Nparm | DF | Sum of Squares | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Sq Ft | 1 | 1 | 3.3447e+12 | 160.6347 | <.0001* |
| TDD | 1 | 1 | 2.2397e+12 | 107.5653 | <.0001* |

*Figure 5 - Tinker AFB, Electrical Energy Consumption by Sq Ft and TDD*

Similar ANOVAs were run for Ellsworth AFB. Square footage was found to have a statistically significant correlation with electrical energy consumption, F(1, 1160) = 297.02, p<0.05, adjusted $R^2$ = 0.2032. TDD was also observed to possess a high correlation with electrical energy consumption, F(1, 1160) = 294.50, p<0.05, adjusted $R^2$ = 0.1763. Figure 6 shows the results of the two-way ANOVA, which tests the influence of both facility size and climate (TDD) together, F(2, 1160) = 244.86, p<0.05, adjusted $R^2$ = 0.2958.

**Summary of Fit**

| | |
|---|---|
| RSquare | 0.297027 |
| RSquare Adj | 0.295814 |
| Root Mean Square Error | 88253.59 |
| Mean of Response | 96529.91 |
| Observations (or Sum Wgts) | 1162 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Model | 2 | 3.8142e+12 | 1.907e+12 | 244.8561 |
| Error | 1159 | 9.0271e+12 | 7.7887e+9 | **Prob > F** |
| C. Total | 1161 | 1.2841e+13 | | <.0001* |

**Effect Tests**

| Source | Nparm | DF | Sum of Squares | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Sq Ft | 1 | 1 | 1.5412e+12 | 197.8730 | <.0001* |
| TDD | 1 | 1 | 1.1965e+12 | 153.6186 | <.0001* |

*Figure 6 - Ellsworth AFB, Electrical Energy Consumption by Sq Ft and TDD*

These results demonstrate that both datasets behave in a manner consistent with the literature review.

**Usage Category**

Ambiguity between existing benchmarking schemes is found in the factor known as usage category. Since USAF buildings tend to have an extremely specific or narrow mission, there is a tendency to categorize infrastructure into very specific usage types. The Air Force utilizes infrastructure categories to evaluate the worth, strategic importance, and maintenance budgets for installations. Real Property records are maintained which assign labels to facilities in a tiered format. There are two-digit general facility identifiers, four-digit FAC codes, and finally, six-digit CAT codes.

It may be necessary to refine or even redefine some of the existing groupings for the purposes of energy benchmarking. To explore the relationship between the current naming taxonomy and electrical energy consumption, this study utilized analysis of variance to determine the level of significance between each of the two usage type variables on electrical energy consumption: CAT and FAC codes. The goal is to determine which of the two existing labeling schemes provide the most meaningful categories to facilitate energy consumption comparison. Table 7 shows the number of levels of each of the three nominal variables used in this study.

*Table 7 - Number of Levels of Each Nominal Variable*

| Variable | Levels |
|---|---|
| 2-Digit | 11 |
| FAC Code | 50 |
| CAT Code | 74 |

**Energy Consumption and Usage Type**

Five separate one-way ANOVA tests were run to explore the relationship between electrical energy consumption and usage type. The first one-way ANOVA explores the relationship between energy consumption and FAC Code, using the Tinker AFB and Ellsworth AFB merged dataset. Figure 7 shows that FAC Code is a statistically significant predictor variable of electrical energy usage, $F(49, 2596) = 34.42$, $p<0.05$, adjusted $R^2 = 0.3824$.

**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.393826 |
| Adj Rsquare | 0.382384 |
| Root Mean Square Error | 113045.1 |
| Mean of Response | 99205.48 |
| Observations (or Sum Wgts) | 2646 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| FAC | 49 | 2.1553e+13 | 4.399e+11 | 34.4204 | <.0001* |
| Error | 2596 | 3.3175e+13 | 1.278e+10 | | |
| C. Total | 2645 | 5.4728e+13 | | | |

*Figure 7 - One-Way ANOVA, Electrical Energy Consumption vs. FAC Code*

A similar ANOVA was run which replaced consumption with electrical EUI as the DV. This allowed a one-way ANOVA to be used to find the predictive ability of FAC Code as a usage type, after normalizing for the most significant variable, building size. This test yielded an improved model, $F(49, 2596) = 45.79$, $p<0.05$, adjusted $R^2 = 0.4535$.

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.463599 |
| Adj Rsquare | 0.453475 |
| Root Mean Square Error | 1.208477 |
| Mean of Response | 1.60717 |
| Observations (or Sum Wgts) | 2646 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| FAC | 49 | 3276.6907 | 66.8712 | 45.7891 | <.0001* |
| Error | 2596 | 3791.2438 | 1.4604 | | |
| C. Total | 2645 | 7067.9345 | | | |

*Figure 8 - One-Way ANOVA, Electrical EUI vs. FAC Code*

CAT Code was explored next. This usage type was regressed against electrical energy consumption, and yielded results with a decided improvement over that of the FAC Code model, as seen in Figure 9, $F(73, 2572) = 38.66$, $p<0.05$, adjusted $R^2$ = 0.5097.

**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.52322 |
| Adj Rsquare | 0.509688 |
| Root Mean Square Error | 100723 |
| Mean of Response | 99205.48 |
| Observations (or Sum Wgts) | 2646 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| CAT CODE | 73 | 2.8635e+13 | 3.923e+11 | 38.6647 | <.0001* |
| Error | 2572 | 2.6093e+13 | 1.015e+10 | | |
| C. Total | 2645 | 5.4728e+13 | | | |

*Figure 9 - One-Way ANOVA, Electrical Energy Consumption vs. CAT Code*

Once again, a similar ANOVA was run which replaced consumption with electrical EUI as the DV, allowing a one-way ANOVA to be used to find the predictive ability of CAT Code as a usage type, after normalizing for the most significant variable, building size. The results are shown in Figure 10, $F(73, 2572) = 42.55$, $p<0.05$, adjusted $R^2 = 0.5342$.

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.547025 |
| Adj Rsquare | 0.534168 |
| Root Mean Square Error | 1.115702 |
| Mean of Response | 1.60717 |
| Observations (or Sum Wgts) | 2646 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| CAT CODE | 73 | 3866.3339 | 52.9635 | 42.5481 | <.0001* |
| Error | 2572 | 3201.6007 | 1.2448 | | |
| C. Total | 2645 | 7067.9345 | | | |

*Figure 10 - One-Way ANOVA, Electrical EUI vs. CAT Code*

CAT Code appears to possess better predictive qualities than FAC Code on energy consumption and, subsequently, electrical EUI. However, it is necessary to explore further to determine if any specific CAT Codes are weakly related to electrical EUI, or require further regrouping or refinement. Figure 11 shows the actual one-way ANOVA plot, allowing for a visual inspection of the intergroup variances, means, and standard deviations.

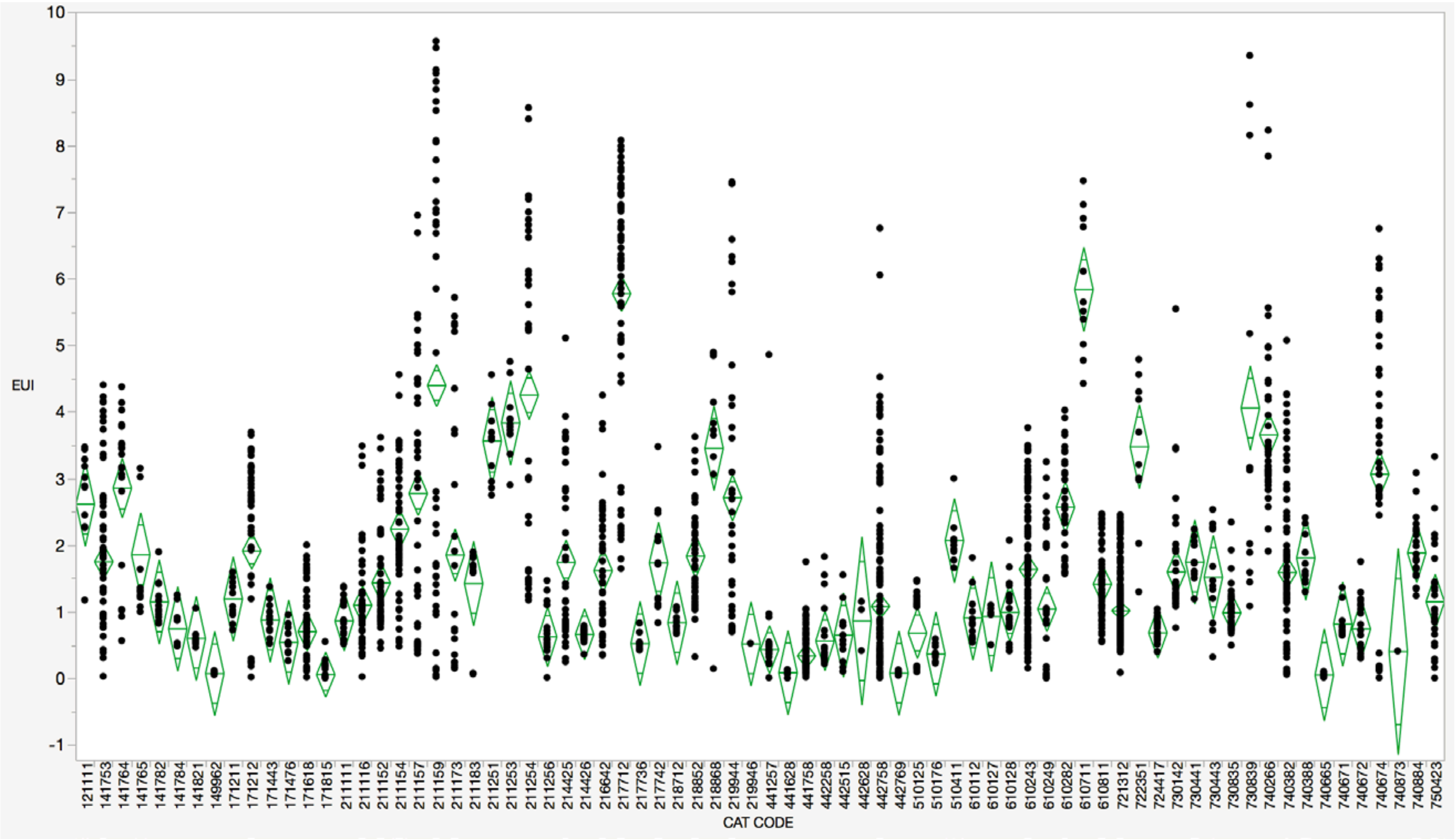


*Figure 11 - One-Way ANOVA Plot, Electrical EUI vs. CAT Code*

It is evident that certain CAT Codes have a wide range of electrical EUIs, and may not provide an accurate means to compare facilities' electrical energy use. To further delve into each CAT Code grouping, Table 8 was used to identify only those CAT Codes which provided a tight grouping of electrical EUIs, indicating energy usage peers. Those CAT Codes with an electrical EUI standard deviation less than 0.5 are highlighted in orange.

*Table 8 - Means for One-Way ANOVA, Electrical EUI vs. CAT Code*

| CAT Code | Name | Count | Mean | Std Dev | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 121111 | Petroleum Operations Building | 12 | 2.624 | **0.792** | 2.120 | 3.127 |
| 141753 | Squadron Operations | 74 | 1.758 | **1.100** | 1.503 | 2.013 |
| 141764 | Integration Support Facility | 24 | 2.863 | **1.187** | 2.362 | 3.364 |
| 141765 | Depot Quality Control Laboratory | 12 | 1.863 | **0.892** | 1.296 | 2.430 |
| 141782 | Terminal, Air Freight | 12 | 1.153 | **0.307** | 0.958 | 1.348 |
| 141784 | Air Passenger Terminal | 12 | 0.748 | **0.285** | 0.567 | 0.930 |
| 141821 | Material Processing Depot | 12 | 0.606 | **0.149** | 0.511 | 0.701 |
| 149962 | Control Tower | 12 | 0.079 | **0.020** | 0.066 | 0.092 |
| 171211 | Flight Training Classroom | 12 | 1.197 | **0.307** | 1.002 | 1.392 |
| 171212 | Flight Simulator Training | 65 | 1.920 | **1.270** | 1.605 | 2.235 |
| 171443 | Reserve Forces General Training Support | 12 | 0.884 | **0.251** | 0.724 | 1.043 |
| 171476 | Combat Arms Training Maintenance Building | 12 | 0.549 | **0.211** | 0.415 | 0.683 |
| 171618 | Field Training Facility | 57 | 0.709 | **0.576** | 0.556 | 0.862 |
| 171815 | NCO Professional Military Education Center | 42 | 0.063 | **0.108** | 0.030 | 0.097 |
| 211111 | Hangar, Maintenance | 24 | 0.868 | **0.292** | 0.744 | 0.991 |
| 211116 | Hangar, Maintenance Depot | 60 | 1.105 | **0.759** | 0.909 | 1.301 |
| 211152 | Shop, Aircraft General Purpose | 56 | 1.441 | **0.769** | 1.235 | 1.647 |
| 211154 | Shop, Aircraft Maintenance, Organizational | 56 | 2.247 | **0.938** | 1.996 | 2.499 |
| 211157 | Shop, Jet Engine Inspection And Maintenance | 44 | 2.781 | **1.957** | 2.186 | 3.377 |
| 211159 | Aircraft Corrosion Control | 48 | 4.402 | **3.547** | 3.372 | 5.432 |
| 211173 | Large Aircraft Maintenance Dock | 31 | 1.858 | **2.019** | 1.117 | 2.598 |

| CAT Code | Name | Count | Mean | Std Dev | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 211183 | Test Cell | 12 | 1.430 | **0.642** | 1.021 | 1.838 |
| 211251 | Shop, Turbine Depot | 11 | 3.572 | **0.581** | 3.181 | 3.962 |
| 211253 | Shop, Alternator Drive Overhaul And Test Depot | 12 | 3.841 | **0.489** | 3.530 | 4.152 |
| 211254 | Shop, Aircraft And Engine Access Overhaul Depot | 36 | 4.259 | **2.427** | 3.438 | 5.080 |
| 211256 | Shop, Engine Test And Storage Depot | 24 | 0.631 | **0.336** | 0.489 | 0.773 |
| 214425 | Vehicle Maintenance Shop | 43 | 1.748 | **1.241** | 1.366 | 2.130 |
| 214426 | Vehicle Operations Heated Parking | 33 | 0.668 | **0.086** | 0.638 | 0.699 |
| 216642 | Shop, Conventional Munitions | 45 | 1.624 | **0.967** | 1.333 | 1.914 |
| 217712 | Shop, Avionics | 69 | 5.782 | **1.826** | 5.344 | 6.221 |
| 217736 | Radome Overhaul & Test Depot | 12 | 0.529 | **0.122** | 0.452 | 0.607 |
| 217742 | Air Force Communications Service Maintenance Facility | 13 | 1.740 | **0.769** | 1.276 | 2.205 |
| 218712 | Aircraft Support Equipment Shop/Storage Facility | 12 | 0.841 | **0.143** | 0.750 | 0.932 |
| 218852 | Shop, Survival Equipment | 45 | 1.839 | **0.816** | 1.594 | 2.085 |
| 218868 | Precision Measurement Equipment Lab | 12 | 3.461 | **1.676** | 2.396 | 4.526 |
| 219944 | Base Engineer Maintenance Shop | 40 | 2.716 | **2.097** | 2.046 | 3.387 |
| 219946 | Base Engineer Covered Storage Facility | 12 | 0.525 | **0.000** | 0.525 | 0.525 |
| 441257 | Hazardous Storage Depot | 37 | 0.439 | **0.795** | 0.174 | 0.704 |
| 441628 | Shed Supplies And Equipment Depot | 12 | 0.092 | **0.037** | 0.069 | 0.116 |
| 441758 | Warehouse Supplies And Equipment Depot | 150 | 0.344 | **0.277** | 0.299 | 0.388 |
| 442258 | Liquid Oxygen Storage | 24 | 0.569 | **0.437** | 0.385 | 0.754 |
| 442515 | WRM | 12 | 0.656 | **0.424** | 0.387 | 0.925 |
| 442628 | Base Supply And Equipment Shed | 3 | 0.867 | **0.395** | -0.114 | 1.848 |
| 442758 | Warehouse Supply And Equipment Base | 154 | 1.089 | **1.311** | 0.880 | 1.298 |
| 442769 | Housing Supplies And Storage Facility | 12 | 0.085 | **0.029** | 0.066 | 0.104 |
| 510125 | Medical Command And Administration | 33 | 0.687 | **0.539** | 0.496 | 0.878 |
| 510176 | Environmental Health | 12 | 0.372 | **0.113** | 0.300 | 0.444 |
| 510411 | Air Force Clinic | 12 | 2.075 | **0.332** | 1.864 | 2.286 |
| 610112 | Law Center | 12 | 0.913 | **0.383** | 0.670 | 1.157 |
| 610127 | Base Engineer Administration | 7 | 0.935 | **0.197** | 0.753 | 1.117 |

| CAT Code | Name | Count | Mean | Std Dev | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 610128 | Base Personnel Office | 24 | 0.999 | **0.379** | 0.839 | 1.159 |
| 610243 | Headquarters, Group | 112 | 1.642 | **0.987** | 1.458 | 1.827 |
| 610249 | Wing Headquarters | 42 | 1.048 | **1.046** | 0.723 | 1.374 |
| 610282 | Headquarters Air Force | 33 | 2.576 | **0.760** | 2.307 | 2.846 |
| 610711 | Data Processing Installation | 12 | 5.845 | **1.009** | 5.204 | 6.486 |
| 610811 | Administrative Office, Non Air Force | 56 | 1.422 | **0.525** | 1.282 | 1.563 |
| 721312 | Dormitory Airman Permanent Party/PCS-Student | 292 | 1.022 | **0.465** | 0.968 | 1.076 |
| 722351 | Airman Dining Halls (Detached) | 12 | 3.484 | **1.077** | 2.800 | 4.169 |
| 724417 | Visiting Officer's Quarters | 33 | 0.691 | **0.152** | 0.637 | 0.745 |
| 730142 | Fire Station | 45 | 1.603 | **0.826** | 1.355 | 1.852 |
| 730441 | Education Center | 12 | 1.754 | **0.302** | 1.562 | 1.945 |
| 730443 | Post Office | 12 | 1.524 | **0.706** | 1.075 | 1.973 |
| 730835 | Security Police Operations | 61 | 0.991 | **0.305** | 0.913 | 1.070 |
| 730839 | Traffic Check House | 12 | 4.063 | **3.013** | 2.149 | 5.977 |
| 740266 | Store, Commissary | 44 | 3.664 | **1.251** | 3.283 | 4.044 |
| 740382 | Exchange Branch | 89 | 1.596 | **1.193** | 1.345 | 1.847 |
| 740388 | Exchange Sales Store | 12 | 1.813 | **0.394** | 1.562 | 2.063 |
| 740665 | Hobby Shop Automotive | 10 | 0.058 | **0.036** | 0.033 | 0.084 |
| 740671 | Bowling Center | 12 | 0.822 | **0.227** | 0.678 | 0.966 |
| 740672 | MWR Supply And NAF Central Storage | 24 | 0.747 | **0.409** | 0.575 | 0.920 |
| 740674 | Gymnasium | 43 | 3.074 | **2.154** | 2.412 | 3.737 |
| 740873 | Theater, Base | 2 | 0.410 | **0.000** | 0.410 | 0.410 |
| 740884 | Child Development Center | 24 | 1.891 | **0.452** | 1.700 | 2.082 |
| 750423 | Golf Equipment Building | 28 | 1.157 | **0.815** | 0.841 | 1.473 |

These remaining 36 CAT Codes were re-analyzed with electrical EUI, as shown in Figure 12. Tighter, less varied, clusters are evident. This is indicative of successfully categorized energy consumption peer groupings. The CAT Codes which appear to correlate highly with electrical EUI make up a diverse collection of facility types. Only a small portion of the administrative-type spaces, hangars, and laboratories showed a low variance in electrical EUI. This may be attributed to a number of factors. For the facilities whose primary usage is administrative, variables such as occupancy may be account for a large portion of the unexplained variance in electrical EUI, and should be normalized accordingly. The hangar facilities may vary significantly across air frame (i.e. C-5 vs F-15), or equipment type and usage patterns.

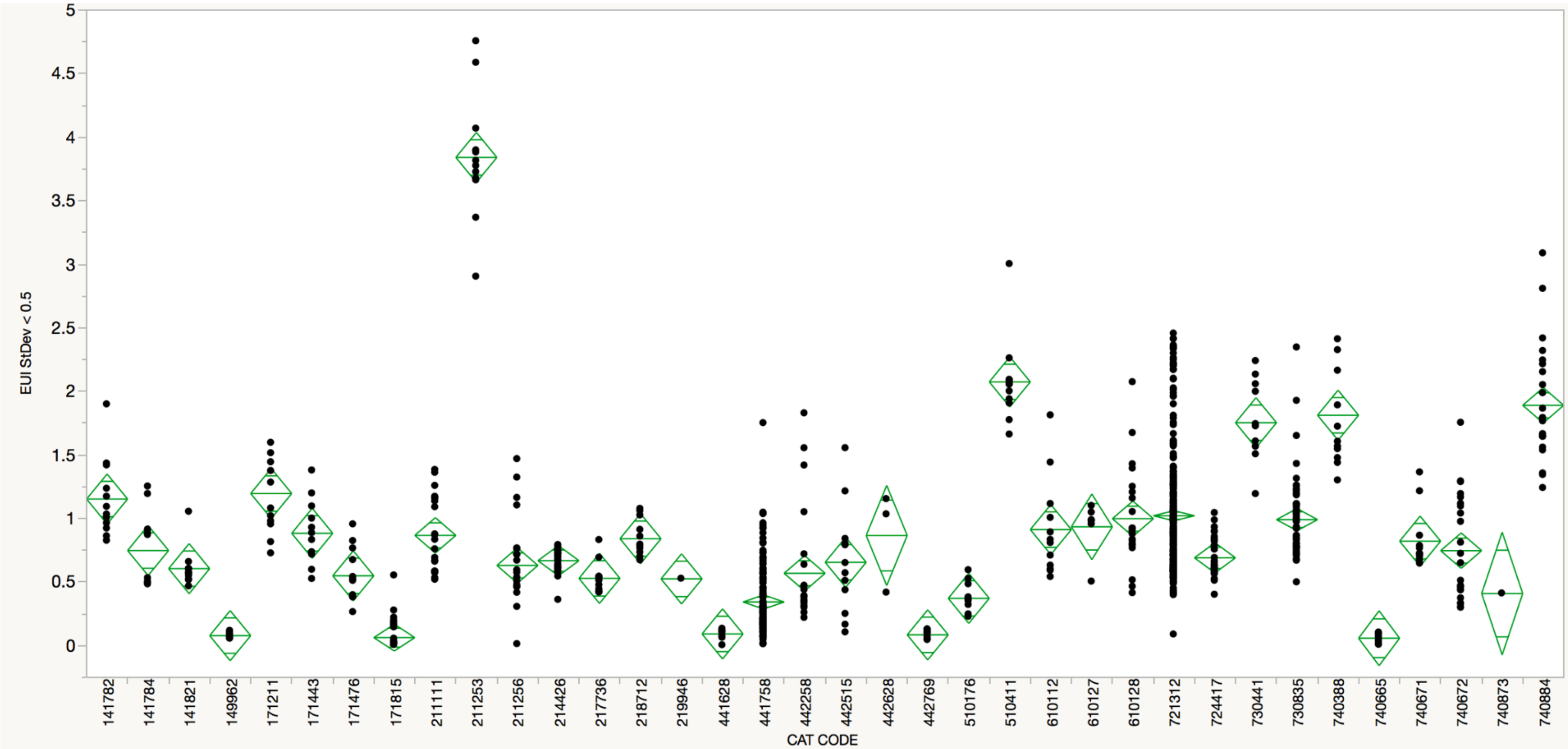


*Figure 12 - One-Way ANOVA Plot, Electrical EUI with StDev < 0.5 vs. CAT Code*

Figure 13 shows the improved model's results, demonstrating that these CAT Codes represent usage types which very accurately predict the electrical EUI of a given USAF facility; $F(35, 981) = 68.54$, $p<0.05$, adjusted $R^2 = 0.6993$.

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.709678 |
| Adj Rsquare | 0.69932 |
| Root Mean Square Error | 0.347617 |
| Mean of Response | 0.825766 |
| Observations (or Sum Wgts) | 1017 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| CAT CODE | 35 | 289.76838 | 8.27910 | 68.5144 | <.0001* |
| Error | 981 | 118.54149 | 0.12084 | | |
| C. Total | 1016 | 408.30988 | | | |

*Figure 13 - One-Way ANOVA, Electrical EUI with StDev < 0.5 vs. CAT Code*

The CAT Code groupings which had an electrical EUI standard deviation greater than 0.5 are all candidates for further refinement and adjustment.

## **Summary**

This study was conducted using 2,646 electrical energy consumption data points, collected from Tinker AFB and Ellsworth AFB. The first research question is aimed at determining the validity of both datasets. Multiple ANOVAs were used as the methodology to compare the behavior of each respective energy consumption dataset for consistency with that of the literature review. Typically, facility size is the best predictor of energy consumption, with facility usage type and climate also possessing statistically significant abilities to explain consumption variance (ENERGY STAR, 2014). The

ANOVA results demonstrated that both Ellsworth AFB and Tinker AFB's energy consumption databases showed consistency with the trend observed in the literature review. These results indicate that the collection processes at both installations are sound, the meters are functioning, and the data is of adequate quality to use for the remainder of this study.

The second and third research questions sought to determine which of the current USAF usage categories was better able to predict energy consumption, CAT Codes or FAC Codes. One-way ANOVAs were utilized to explore the relationship between each usage variable and electrical EUI. CAT Codes demonstrated a better ability to predict energy usage than FAC Code. However, after further exploration, it was determined that not all CAT Codes possessed the same predictive qualities. In fact, only 36 of the 74 observed CAT Codes had an intergroup electrical EUI standard deviation less than 0.5. These results may be linked to a multitude of factors. It is important to remember that the usage types assigned to USAF real property were not designed to account for, or relate to, energy consumption. It is also important to note the lack of natural gas consumption data included in this study. CAT Code may explain more variance of a complete EUI, with electrical and natural gas consumption. Although this research demonstrates a mixed success in utilizing CAT Codes to accurately assign facilities into energy consumption peer groups, it also points to the need for future research in order to redefine or adjust those usage types which do not adequately predict EUI. The findings and implications will be further discussed in Chapter 5.

# V. Conclusions and Recommendations

## Chapter Overview

This chapter utilizes the results from Chapter 4 to answer the research questions posed by this study.

## Problem Statement

The objective of this thesis was to use an empirical approach to determine if the data currently collected at Ellsworth AFB and Tinker AFB is valid, and follows the trends discovered in the literature review. This research also determined the most accurate categorization of facilities, based on existing USAF usage types, into electrical energy consumption peer groups.

## Research Questions

1. **Is the electrical energy consumption data collected at Ellsworth and Tinker Air Force Bases valid?**

The results show that the electrical energy consumption data collected at both Ellsworth and Tinker Air Force Bases are consistent with the trends identified in the literature review. Although the two installations did not behave identically when electrical energy consumption was analyzed against each combination of IVs, they showed similarities which indicated validity. Both datasets demonstrated facility size was a significant predictor of electrical energy consumption. These results conform to the trends observed in literature.

2. **Are Facility Analysis Category Codes significant predictors of facility electrical energy consumption?**

FAC Codes do possess a limited ability to predict facility electrical energy consumption and electrical EUI, $r(48) = 0.3824$, $p<0.01$. However, significant unexplained variance within each FAC Code group indicated that there were many FAC Codes which were largely unrelated to electrical EUI, and were not suitable energy consumption peer groups.

3. **Are Category Codes significant predictors of facility electrical energy consumption?**

CAT Codes were shown to have a limited ability to accurately predict energy consumption, $r(72) = 0.5097$, $p<0.01$. Although this is a decided improvement over the ability of FAC Code to explain the variance in electrical energy consumption, there were also instances of CAT Code groupings which did not appear related to consumption. After further analysis, it was determined that 36 CAT Codes were appropriate electrical energy usage peer groups, with the remaining 38 CAT Codes had a relatively high standard deviation (greater than 0.5), and were deemed necessary for further evaluation.

## Significance of Research

The results of this research gives AFCEC a launching point to stand up its own, branch-specific energy benchmarking program. By identifying the potential of CAT Codes as energy consumption peer groups, the groundwork is set for categorization refinement to perfect a benchmarking scheme. This research also demonstrates the quality of existing data available at the installation level. Although not all USAF bases are collecting meter data, the work conducted at Tinker and Ellsworth proves that it is possible to move forward with an energy program without the prospect of waiting for the roll-out of advanced meters.

## Limitations of Research

A major limitation of this research was the lack of natural gas data meter data. Because Tinker AFB was unable to provide natural gas consumption data at the time of this research's data call, this study moved forward with electrical energy consumption data only. Because of the typically high correlation between natural gas consumption and heating energy, this lack of data affects the ability to adequately account for both the baseline and heating loads in facilities. This also prevents a complete EUI calculation for each facility, and instead limits the analysis to electrical energy consumption. The lack of natural gas data limit's this study's ability to completely represent the energy drawn from each facility, and subsequently, attempt to explain the variance contained therein with CAT and FAC Codes.

Another limitation is introduced by the small sample size of installations which submitted datasets for use in this study. Since neither Ellsworth AFB nor Tinker AFB had every type of facility in USAF's infrastructure portfolio, there were CAT and FAC Codes which were not able to be explored. This is only overcome by collecting data from a more robust spread of installations.

**Recommendations for Action**

It is recommended that AFCEC/USAF establish a comprehensive, standardized template for electrical energy and gas consumption as a part of a large-scale data call. The data must contain, at a minimum:

1. Installation
2. Facility Number
3. Facility Size
4. Facility Age
5. CAT Code
6. FAC Code
7. Meter ID
8. Meter Type (electrical/gas)
9. Daily Consumption
10. Unit of Measure
11. Date of Reading
12. Climate Data (HDD and CDD)

In an attempt to comply with federal mandates, each USAF installation should report facility-level electrical and natural gas meter data to AFCEC. This influx of data would allow AFCEC to re-perform portions of the analysis outlined in this study, to gain better insights into energy consumption peer groups, and refine each grouping until each facility is sufficiently represented. Advanced meters are the preferred method of collecting this data, since the relevant information would be transmitted to key stakeholders instead of having to go out and manually collect the information. However, until the contract to have AMRS installed at each facility/installation is approved, it is necessary to send members of the installation energy manager's team out for the purposes of data collection. This is only feasible if manning levels permit.

## Recommendations for Future Research

Once a more robust dataset is available, namely natural gas consumption, USAF would greatly benefit from further analysis into each CAT Code grouping. An exploration into the similarities between the poorly performing CAT Codes may yield results which provide insights into the most effective way to restructure categories. Facilities with multiple or mixed uses are also excellent candidates for further investigation. It may also prove beneficial to research the feasibility and effectiveness of developing an alternative categorization taxonomy, which is independent of existing real property labels.

## Summary

This study determined that the energy consumption data being collected from utility meters at Tinker AFB and Ellsworth AFB is valid, and conforms to the trends observed in literature. This indicates the opportunity for USAF to collect this type of data from every installation, and create a robust energy benchmarking program immediately. This can be done in the interim, while a more permanent and technologically advanced data collection practice is procured. Additionally, it was determined that CAT Codes are the more effective usage type in distinguishing energy consumption peers. However, these groupings need refinement, as recommended for future research.

The findings in this research indicate the ability for USAF to move immediately towards collecting existing data, instead of waiting for a contract which would install networked meters at all installations. Although this method is much more labor intensive, it has the ability to prove USAF with invaluable insight into the energy performance of its infrastructure portfolio. This knowledge can help lead to the pinpointing of weak performers, wastefulness, and help defend funding requests for energy focused improvement projects. These actions will ultimately propel the Air Force towards their goal of energy reduction and huge financial savings.

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## Appendix A – Tinker AFB, Sample of Original Dataset

| Month | Year | Facility | Facility Name | Meter ID | Util Type | Meter Type | Rollover | Multiplier | Previous Reading | Current Reading | UOM | Reading Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 2015 | 2136 | HG, MAINT DEP | 2136TBD | EL | TBD | 0 | 0 | | | Kwh | |
| Jan | 2015 | 3001 | | 3001TBD | EL | TBD | 0 | 0 | | | Kwh | |
| Jan | 2015 | 3234 | TST CELL | 3234TBD | EL | TBD | | | | | Kwh | |
| Jan | 2015 | 3502 | UNKNOWN | 3502TBD | EL | TBD | | | | | Kwh | |
| Jan | 2015 | 3761 | SHP AVIONICS | 3761TBD | EL | TBD | 0 | 0 | | | Kwh | |
| Jan | 2015 | 9301 | HTG FCLTY BLDG | A0001 | CA | FAC_MAIN | 0 | 1 | | | | |
| Jan | 2015 | 2121 | HG, MAINT DEP | A0002 | CA | EQMT | 10000000 | 1 | | | | |
| Jan | 2015 | 3220 | INTEGR SPT FCLTY | C0001 | CH | TBD | | 1 | | | | |
| Jan | 2015 | 3220 | INTEGR SPT FCLTY | C0002 | CH | EQMT | | 1 | | | | |
| Jan | 2015 | 3220 | INTEGR SPT FCLTY | C0003 | CH | EQMT | | 1 | | | | |
| Jan | 2015 | 61019 | BLDG WTR SUP | E0001 | EL | TBD | 0 | 0 | | | Kwh | |
| Jan | 2015 | 6601 | GO CLUBHSE | E0003 | EL | FAC_MAIN | 10000 | 80 | 1,734.00 | 1,855.00 | Kwh | 2/13/2015 |
| Jan | 2015 | 6604 | GO EQUIP BLD | E0004 | EL | SUB_MAIN | 10000000 | 1 | | | Kwh | |
| Jan | 2015 | 6604 | GO EQUIP BLD | E0005 | EL | FAC_MAIN | 10000000 | 0 | 22,190.00 | 22,232.00 | Kwh | 2/13/2015 |
| Jan | 2015 | 6001 | HQ GROUP | E0007 | EL | FAC_MAIN | 10000 | 160 | 2,249.00 | 2,426.00 | Kwh | 2/13/2015 |
| Jan | 2015 | 61018 | BLDG WTR SUP | E0008 | EL | FAC_MAIN | 1000000 | 1 | | | Kwh | |
| Jan | 2015 | 5935 | GO EQUIP BLD | E0011 | EL | FAC_MAIN | 10000 | 1 | 8,035.00 | 355.00 | Kwh | 2/12/2015 |
| Jan | 2015 | 5931 | DORM AM PP/PCS-STD | E0013 | EL | FAC_MAIN | 1000000 | 400 | 22,207.00 | 22,278.00 | Kwh | 2/12/2015 |
| Jan | 2015 | 5930 | DORM AM PP/PCS-STD | E0015 | EL | FAC_MAIN | 10000 | 400 | 4,533.00 | 4,597.00 | Kwh | 2/12/2015 |
| Jan | 2015 | 5803 | TRAFFIC MGT F | E0017 | EL | TBD | 10000 | 0 | 8,378.00 | 8,387.00 | Kwh | 2/12/2015 |
| Jan | 2015 | 5800 | MED STOR | E0019 | EL | FAC_MAIN | 10000 | 10 | 7,305.00 | 7,436.00 | Kwh | 2/12/2015 |

| Month | Year | Facility | Facility Name | Meter ID | Util Type | Meter Type | Rollover | Multiplier | Previous Reading | Current Reading | UOM | Reading Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 2015 | 5801 | AF CLINIC | E0021 | EL | TBD | 10000 | 320 | | | Kwh | |
| Jan | 2015 | 5801 | AF CLINIC | E0022 | EL | TBD | 10000 | 320 | | | Kwh | |
| Jan | 2015 | 5801 | AF CLINIC | E0023 | EL | TBD | 10000 | 80 | | | Kwh | |
| Jan | 2015 | 5703 | BOWL CEN | E0027 | EL | TBD | 0 | 0 | | | Kwh | |
| Jan | 2015 | 5603 | OPEN MESS, CONSOL | E0028 | EL | FAC_MAIN | 10000 | 100 | | | Kwh | |
| Jan | 2015 | 5603 | OPEN MESS, CONSOL | E0029 | EL | SUB_MAIN | 10000 | 40 | | | Kwh | |
| Jan | 2015 | 478 | MWR SUPP/NAF | E0032 | EL | SUB_MAIN | 0 | 10 | | | Kwh | |
| Jan | 2015 | 477 | WHSE SUP EQUIP DEP | E0036 | EL | SUB_MAIN | 100000 | 1440 | | | Kwh | |
| Jan | 2015 | 420 | CREDIT UNION | E0044 | EL | FAC_MAIN | 10000 | 80 | 7,555.00 | 7,707.00 | Kwh | 2/2/2015 |
| Jan | 2015 | 830 | FLT SIMLTR TRNG | E0053 | EL | SUB_MAIN | 10000 | 6 | 5,850.00 | 6,149.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 830 | FLT SIMLTR TRNG | E0054 | EL | FAC_MAIN | 10000 | 960 | | | Kwh | |
| Jan | 2015 | 830 | FLT SIMLTR TRNG | E0055 | EL | FAC_MAIN | 10000 | 960 | 5,622.00 | 5,622.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0058 | EL | FAC_MAIN | 1000000 | 2 | 87,980.00 | 92,221.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0059 | EL | FAC_MAIN | 100000 | 1 | 5,363.00 | 16,622.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0061 | EL | FAC_MAIN | 10000 | 160 | 4,751.00 | 5,006.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0062 | EL | FAC_MAIN | 10000 | 160 | 5,342.00 | 5,630.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0064 | EL | FAC_MAIN | 10000 | 240 | 6,233.00 | 6,700.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 820 | HG, MAINT | E0065 | EL | FAC_MAIN | 10000 | 240 | 0.00 | 0.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 829 | ELEC PWR S BLD | E0067 | EL | FAC_MAIN | 10000 | 768 | 340.00 | 425.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 829 | ELEC PWR S BLD | E0068 | EL | FAC_MAIN | 10000 | 768 | 7,234.00 | 7,234.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 825 | WHSE SUP & EQUIP BSE | E0069 | EL | FAC_MAIN | 10000 | 240 | | 876.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 821 | TOTAL ENG PLT BLDG | E0073 | EL | FAC_MAIN | 10000 | 960 | 5,755.00 | 5,758.00 | Kwh | 2/4/2015 |

| Month | Year | Facility | Facility Name | Meter ID | Util Type | Meter Type | Rollover | Multiplier | Previous Reading | Current Reading | UOM | Reading Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 2015 | 821 | TOTAL ENG PLT BLDG | E0074 | EL | FAC_MAIN | 10000 | 960 | 9,498.00 | 9,755.00 | Kwh | 2/4/2015 |
| Jan | 2015 | 995 | HYDR FL BLDG | E0077 | EL | TBD | | | | | Kwh | |
| Jan | 2015 | 4012 | HQ GROUP | E0079 | EL | FAC_MAIN | 10000 | 120 | 9,002.00 | 9,138.00 | Kwh | 2/11/2015 |
| Jan | 2015 | 510 | WHSE SUP EQUIP DEP | E0083 | EL | FAC_MAIN | 10000 | 1000 | 9,443.00 | 9,456.00 | Kwh | 2/5/2015 |
| Jan | 2015 | 1050 | CAT MAINT BLDG | E0086 | EL | FAC_MAIN | 10000 | 10 | 8,953.00 | 9,201.00 | Kwh | 2/6/2015 |
| Jan | 2015 | 2280 | ACFT COR CON | E0088 | EL | FAC_MAIN | 10000 | 1 | 183,963.00 | 201,815.00 | Kwh | |

## Appendix B – Ellsworth AFB, Sample of Original Dataset

| Installation | Facility | Meter ID | Size | Date | FAC CODE | CAT CODE | Correction Factor | READ | Adjusted Reading | Corrected Adjusted Reading | FINAL READ | UOM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 23604666 | 67440 | 1-May-09 | 2141 | 214425 | 250 | 3,162.384 | 4.462 | 1115.5 | 1115.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 2-May-09 | 2141 | 214425 | 250 | 3,165.205 | 2.821 | 705.25 | 705.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 3-May-09 | 2141 | 214425 | 250 | 3,168.023 | 2.818 | 704.5 | 704.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 4-May-09 | 2141 | 214425 | 250 | 3,172.417 | 4.394 | 1098.5 | 1098.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 5-May-09 | 2141 | 214425 | 250 | 3,177.115 | 4.698 | 1174.5 | 1174.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 6-May-09 | 2141 | 214425 | 250 | 3,181.853 | 4.738 | 1184.5 | 1184.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 7-May-09 | 2141 | 214425 | 250 | 3,186.481 | 4.628 | 1157 | 1157 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 8-May-09 | 2141 | 214425 | 250 | 3,190.899 | 4.418 | 1104.5 | 1104.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 9-May-09 | 2141 | 214425 | 250 | 3,193.870 | 2.971 | 742.75 | 742.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 10-May-09 | 2141 | 214425 | 250 | 3,196.859 | 2.989 | 747.25 | 747.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 11-May-09 | 2141 | 214425 | 250 | 3,201.623 | 4.764 | 1191 | 1191 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 12-May-09 | 2141 | 214425 | 250 | 3,206.391 | 4.768 | 1192 | 1192 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 13-May-09 | 2141 | 214425 | 250 | 3,211.166 | 4.775 | 1193.75 | 1193.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 14-May-09 | 2141 | 214425 | 250 | 3,215.568 | 4.402 | 1100.5 | 1100.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 15-May-09 | 2141 | 214425 | 250 | 3,219.620 | 4.052 | 1013 | 1013 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 16-May-09 | 2141 | 214425 | 250 | 3,222.168 | 2.548 | 637 | 637 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 17-May-09 | 2141 | 214425 | 250 | 3,224.679 | 2.511 | 627.75 | 627.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 18-May-09 | 2141 | 214425 | 250 | 3,228.803 | 4.124 | 1031 | 1031 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 19-May-09 | 2141 | 214425 | 250 | 3,233.630 | 4.827 | 1206.75 | 1206.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 20-May-09 | 2141 | 214425 | 250 | 3,238.628 | 4.998 | 1249.5 | 1249.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 21-May-09 | 2141 | 214425 | 250 | 3,242.986 | 4.358 | 1089.5 | 1089.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 22-May-09 | 2141 | 214425 | 250 | 3,245.909 | 2.923 | 730.75 | 730.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 23-May-09 | 2141 | 214425 | 250 | 3,248.582 | 2.673 | 668.25 | 668.25 | kWh |

| Installation | Facility | Meter ID | Size | Date | FAC CODE | CAT CODE | Correction Factor | READ | Adjusted Reading | Corrected Adjusted Reading | FINAL READ | UOM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ellsworth AFB | 102 | 23604666 | 67440 | 24-May-09 | 2141 | 214425 | 250 | 3,251.321 | 2.739 | 684.75 | 684.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 25-May-09 | 2141 | 214425 | 250 | 3,254.175 | 2.854 | 713.5 | 713.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 26-May-09 | 2141 | 214425 | 250 | 3,258.614 | 4.439 | 1109.75 | 1109.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 27-May-09 | 2141 | 214425 | 250 | 3,263.047 | 4.433 | 1108.25 | 1108.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 28-May-09 | 2141 | 214425 | 250 | 3,268.038 | 4.991 | 1247.75 | 1247.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 29-May-09 | 2141 | 214425 | 250 | 3,272.414 | 4.376 | 1094 | 1094 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 30-May-09 | 2141 | 214425 | 250 | 3,275.041 | 2.627 | 656.75 | 656.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 31-May-09 | 2141 | 214425 | 250 | 3,277.787 | 2.746 | 686.5 | 686.5 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 1-Jun-09 | 2141 | 214425 | 250 | 3,282.074 | 4.287 | 1071.75 | 1071.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 2-Jun-09 | 2141 | 214425 | 250 | 3,286.419 | 4.345 | 1086.25 | 1086.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 3-Jun-09 | 2141 | 214425 | 250 | 3,290.826 | 4.407 | 1101.75 | 1101.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 4-Jun-09 | 2141 | 214425 | 250 | 3,295.489 | 4.663 | 1165.75 | 1165.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 5-Jun-09 | 2141 | 214425 | 250 | 3,299.498 | 4.009 | 1002.25 | 1002.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 6-Jun-09 | 2141 | 214425 | 250 | 3,302.087 | 2.589 | 647.25 | 647.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 7-Jun-09 | 2141 | 214425 | 250 | 3,304.703 | 2.616 | 654 | 654 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 8-Jun-09 | 2141 | 214425 | 250 | 3,309.058 | 4.355 | 1088.75 | 1088.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 9-Jun-09 | 2141 | 214425 | 250 | 3,313.343 | 4.285 | 1071.25 | 1071.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 10-Jun-09 | 2141 | 214425 | 250 | 3,317.783 | 4.44 | 1110 | 1110 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 11-Jun-09 | 2141 | 214425 | 250 | 3,322.191 | 4.408 | 1102 | 1102 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 12-Jun-09 | 2141 | 214425 | 250 | 3,325.748 | 3.557 | 889.25 | 889.25 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 13-Jun-09 | 2141 | 214425 | 250 | 3,328.212 | 2.464 | 616 | 616 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 14-Jun-09 | 2141 | 214425 | 250 | 3,330.684 | 2.472 | 618 | 618 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 15-Jun-09 | 2141 | 214425 | 250 | 3,334.755 | 4.071 | 1017.75 | 1017.75 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 16-Jun-09 | 2141 | 214425 | 250 | 3,338.819 | 4.064 | 1016 | 1016 | kWh |
| Ellsworth AFB | 102 | 23604666 | 67440 | 17-Jun-09 | 2141 | 214425 | 250 | 3,343.346 | 4.527 | 1131.75 | 1131.75 | kWh |

## Appendix C – Sample of Merged Dataset

| Installation | Facility | Age | Sq Ft | 2-Digit | FAC | CAT | Long Name | Date | HDD | CDD | TDD | Consumption | EUI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jan-14 | 2343 | 0 | 2343 | 26382.2864 | 3.2503 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Feb-14 | 2532.2 | 0 | 2532.2 | 26384.6310 | 3.2505 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Mar-14 | 2053.6 | 2.6 | 2056.2 | 19343.8840 | 2.3831 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Apr-14 | 1228.6 | 22.8 | 1251.4 | 12221.6631 | 1.5057 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | May-14 | 700.4 | 90.4 | 790.8 | 7112.8426 | 0.8763 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jun-14 | 322.2 | 147.2 | 469.4 | 4866.7835 | 0.5996 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jul-14 | 94.6 | 487.2 | 581.8 | 1053.8847 | 0.1298 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Aug-14 | 80 | 392.8 | 472.8 | 994.6843 | 0.1225 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Sep-14 | 490.8 | 233 | 723.8 | 4825.1273 | 0.5944 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Oct-14 | 850 | 42.6 | 892.6 | 8382.4279 | 1.0327 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Dec-14 | 2238 | 1 | 2239 | 22168.5060 | 2.7311 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jan-15 | 2261 | 3.2 | 2264.2 | 24424.4634 | 3.0091 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Feb-15 | 2049.4 | 2.2 | 2051.6 | 18709.5313 | 2.3050 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Apr-15 | 1099.2 | 21.6 | 1120.8 | 7796.6119 | 0.9605 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | May-15 | 840.6 | 27.6 | 868.2 | 6682.6710 | 0.8233 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jun-15 | 133.2 | 294.2 | 427.4 | 1436.3792 | 0.1770 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jul-15 | 57.2 | 520.4 | 577.6 | 401.5078 | 0.0495 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Aug-15 | 118.4 | 517 | 635.4 | 1044.5064 | 0.1287 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Sep-15 | 233.4 | 335.8 | 569.2 | 99.5714 | 0.0123 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Oct-15 | 827.4 | 52.6 | 880 | 39.7984 | 0.0049 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Nov-15 | 1775.2 | 2.2 | 1777.4 | 17.0400 | 0.0021 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Dec-15 | 2338.2 | 0.6 | 2338.8 | 118.0400 | 0.0145 |

| Installation | Facility | Age | Sq Ft | 2-Digit | FAC | CAT | Long Name | Date | HDD | CDD | TDD | Consumption | EUI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jan-16 | 2392.8 | 0 | 2392.8 | 87.6800 | 0.0108 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Feb-16 | 1647.4 | 2.2 | 1649.6 | 584.7200 | 0.0720 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Mar-16 | 1444.2 | 13 | 1457.2 | 427.2400 | 0.0526 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jun-16 | 99.8 | 562.2 | 662 | 290.1407 | 0.0357 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Jul-16 | 57.4 | 602.2 | 659.6 | 287.2100 | 0.0354 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Aug-16 | 107.2 | 462.4 | 569.6 | 228.6357 | 0.0282 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Sep-16 | 348.2 | 189 | 537.2 | 88.5476 | 0.0109 |
| Ellsworth AFB | 1011 | 29 | 8117 | 61 | 6100 | 610249 | CE READINESS | Oct-16 | 807.2 | 81 | 888.2 | 282.5608 | 0.0348 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jan-14 | 2343 | 0 | 2343 | 78919.8600 | 1.2921 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Feb-14 | 2532.2 | 0 | 2532.2 | 69432.2300 | 1.1367 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Mar-14 | 2053.6 | 2.6 | 2056.2 | 76847.6500 | 1.2581 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Apr-14 | 1228.6 | 22.8 | 1251.4 | 77706.2600 | 1.2722 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | May-14 | 700.4 | 90.4 | 790.8 | 86521.1400 | 1.4165 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jun-14 | 322.2 | 147.2 | 469.4 | 92797.8100 | 1.5193 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jul-14 | 94.6 | 487.2 | 581.8 | 112087.2600 | 1.8351 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Aug-14 | 80 | 392.8 | 472.8 | 107789.1700 | 1.7647 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Sep-14 | 490.8 | 233 | 723.8 | 87966.8400 | 1.4402 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Oct-14 | 850 | 42.6 | 892.6 | 82999.8600 | 1.3588 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Nov-14 | 2146 | 0 | 2146 | 73221.3200 | 1.1988 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Dec-14 | 2238 | 1 | 2239 | 75803.2600 | 1.2410 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jan-15 | 2261 | 3.2 | 2264.2 | 77286.6300 | 1.2653 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Feb-15 | 2049.4 | 2.2 | 2051.6 | 69008.7800 | 1.1298 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Apr-15 | 1099.2 | 21.6 | 1120.8 | 75840.5200 | 1.2416 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | May-15 | 840.6 | 27.6 | 868.2 | 78501.3900 | 1.2852 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jun-15 | 133.2 | 294.2 | 427.4 | 102008.3100 | 1.6700 |

| Installation | Facility | Age | Sq Ft | 2-Digit | FAC | CAT | Long Name | Date | HDD | CDD | TDD | Consumption | EUI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jul-15 | 57.2 | 520.4 | 577.6 | 113192.2800 | 1.8532 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Aug-15 | 118.4 | 517 | 635.4 | 109913.0900 | 1.7995 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Sep-15 | 233.4 | 335.8 | 569.2 | 96076.7700 | 1.5729 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Oct-15 | 827.4 | 52.6 | 880 | 81362.5300 | 1.3320 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Nov-15 | 1775.2 | 2.2 | 1777.4 | 72299.6600 | 1.1837 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Dec-15 | 2338.2 | 0.6 | 2338.8 | 73126.0400 | 1.1972 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jan-16 | 2392.8 | 0 | 2392.8 | 74166.3700 | 1.2142 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Feb-16 | 1647.4 | 2.2 | 1649.6 | 70568.3800 | 1.1553 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Mar-16 | 1444.2 | 13 | 1457.2 | 76527.6200 | 1.2529 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Apr-16 | 1091.4 | 43 | 1134.4 | 78469.9900 | 1.2847 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | May-16 | 638.8 | 74.2 | 713 | 88033.1800 | 1.4413 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jun-16 | 99.8 | 562.2 | 662 | 115139.0400 | 1.8850 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Jul-16 | 57.4 | 602.2 | 659.6 | 121761.3800 | 1.9934 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Aug-16 | 107.2 | 462.4 | 569.6 | 116990.8700 | 1.9153 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Sep-16 | 348.2 | 189 | 537.2 | 94644.7300 | 1.5495 |
| Ellsworth AFB | 4020 | 26 | 61081 | 73 | 7346 | 740382 | BASE EXCHANGE | Oct-16 | 807.2 | 81 | 888.2 | 51885.2000 | 0.8494 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Jun-15 | 403.5 | 2.5 | 406 | 20478.0000 | 0.9538 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Jul-15 | 500.9 | 0.1 | 501 | 22462.0000 | 1.0462 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Aug-15 | 424.2 | 2.9 | 427.1 | 23585.1000 | 1.0985 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Sep-15 | 355 | 6.5 | 361.5 | 10795.0000 | 0.5028 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Oct-15 | 101 | 143.9 | 244.9 | 21181.0000 | 0.9865 |
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Nov-15 | 11.6 | 407.1 | 418.7 | 21015.0000 | 0.9788 |

| Installation | Facility | Age | Sq Ft | 2-Digit | FAC | CAT | Long Name | Date | HDD | CDD | TDD | Consumption | EUI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tinker AFB | 400 | 27 | 21470 | 61 | 6100 | 610127 | BASE ENGINEER ADMINISTRATION | Dec-15 | 5.4 | 600.3 | 605.7 | 21015.0000 | 0.9788 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jan-15 | 16.4 | 1615.2 | 1631.6 | 41306.0000 | 0.7996 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Feb-15 | 11.8 | 1579.6 | 1591.4 | 40704.0000 | 0.7880 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Mar-15 | 74.6 | 868.2 | 942.8 | 45234.0000 | 0.8757 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Apr-15 | 149.6 | 345.2 | 494.8 | 43003.0000 | 0.8325 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | May-15 | 191.6 | 157.4 | 349 | 46049.0000 | 0.8915 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jun-15 | 807 | 5 | 812 | 59768.0000 | 1.1570 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jul-15 | 1001.8 | 0.2 | 1002 | 64522.0000 | 1.2491 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Aug-15 | 848.4 | 5.8 | 854.2 | 62245.0000 | 1.2050 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Sep-15 | 710 | 13 | 723 | 62245.0000 | 1.2050 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Oct-15 | 202 | 287.8 | 489.8 | 47565.0000 | 0.9208 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Nov-15 | 23.2 | 814.2 | 837.4 | 40861.0000 | 0.7910 |
| Tinker AFB | 460 | 75 | 51656 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Dec-15 | 10.8 | 1200.6 | 1211.4 | 39557.0000 | 0.7658 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Jan-15 | 8.2 | 807.6 | 815.8 | 378.0000 | 0.1049 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Feb-15 | 5.9 | 789.8 | 795.7 | 347.0000 | 0.0963 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Mar-15 | 37.3 | 434.1 | 471.4 | 303.0000 | 0.0841 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Apr-15 | 74.8 | 172.6 | 247.4 | 226.0000 | 0.0627 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | May-15 | 95.8 | 78.7 | 174.5 | 196.0000 | 0.0544 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Jun-15 | 403.5 | 2.5 | 406 | 295.0000 | 0.0819 |

| Installation | Facility | Age | Sq Ft | 2-Digit | FAC | CAT | Long Name | Date | HDD | CDD | TDD | Consumption | EUI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Jul-15 | 500.9 | 0.1 | 501 | 312.0000 | 0.0866 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Aug-15 | 424.2 | 2.9 | 427.1 | 199.0000 | 0.0552 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Sep-15 | 355 | 6.5 | 361.5 | 236.0000 | 0.0655 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Oct-15 | 101 | 143.9 | 244.9 | 217.0000 | 0.0602 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Nov-15 | 11.6 | 407.1 | 418.7 | 284.0000 | 0.0788 |
| Tinker AFB | 935 | 47 | 3604 | 14 | 1413 | 149962 | CONTROL TOWER | Dec-15 | 5.4 | 600.3 | 605.7 | 416.0000 | 0.1154 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jan-15 | 8.2 | 807.6 | 815.8 | 5780.0000 | 1.3924 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Feb-15 | 5.9 | 789.8 | 795.7 | 6940.0000 | 1.6719 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Mar-15 | 37.3 | 434.1 | 471.4 | 2130.0000 | 0.5131 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Apr-15 | 74.8 | 172.6 | 247.4 | 1710.0000 | 0.4119 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | May-15 | 95.8 | 78.7 | 174.5 | 4360.0000 | 1.0503 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jun-15 | 403.5 | 2.5 | 406 | 3820.0000 | 0.9203 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Jul-15 | 500.9 | 0.1 | 501 | 5920.0000 | 1.4262 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Aug-15 | 424.2 | 2.9 | 427.1 | 3420.0000 | 0.8239 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Sep-15 | 355 | 6.5 | 361.5 | 3440.0000 | 0.8287 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Oct-15 | 101 | 143.9 | 244.9 | 1920.0000 | 0.4625 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Nov-15 | 11.6 | 407.1 | 418.7 | 3790.0000 | 0.9130 |
| Tinker AFB | 5899 | 23 | 4151 | 61 | 6100 | 610128 | BASE PERSONNEL OFFICE | Dec-15 | 5.4 | 600.3 | 605.7 | 8600.0000 | 2.0718 |

## Appendix D – NOAA Climate Dataset

| STATION | DATE | CDSD | HDSD | TAVG | TMAX | TMIN |
|---|---|---|---|---|---|---|
| USW00003954 | 2015-01 | 0 | 2174 | 39.1 | 50.2 | 28 |
| USW00003954 | 2015-02 | 0 | 2910 | 38.7 | 50.6 | 26.9 |
| USW00003954 | 2015-03 | 7 | 3290 | 53 | 64.7 | 41.2 |
| USW00003954 | 2015-04 | 56 | 3425 | 62.1 | 72.4 | 51.9 |
| USW00003954 | 2015-05 | 165 | 3464 | 67.2 | 75.8 | 58.7 |
| USW00003954 | 2015-06 | 604 | 3464 | 80.1 | 90 | 70.3 |
| USW00003954 | 2015-07 | 1166 | 0 | 83.1 | 92.4 | 73.9 |
| USW00003954 | 2015-08 | 1662 | 0 | 81 | 91.3 | 70.7 |
| USW00003954 | 2015-09 | 2062 | 0 | 78.3 | 89.5 | 67.2 |
| USW00003954 | 2015-10 | 2136 | 104 | 64 | 75.4 | 52.7 |
| USW00003954 | 2015-11 | 2139 | 500 | 51.9 | 62.5 | 41.3 |
| USW00003954 | 2015-12 | 2139 | 1080 | 45.7 | 56.9 | 34.5 |
| USW00013967 | 2015-01 | 0 | 2087 | 40.5 | 51.3 | 29.6 |
| USW00013967 | 2015-02 | 0 | 2809 | 39.2 | 51.2 | 27.2 |
| USW00013967 | 2015-03 | 9 | 3170 | 53.7 | 65.2 | 42.2 |
| USW00013967 | 2015-04 | 58 | 3291 | 62.6 | 72.9 | 52.2 |
| USW00013967 | 2015-05 | 167 | 3325 | 67.4 | 76.1 | 58.7 |
| USW00013967 | 2015-06 | 586 | 3325 | 79 | 89.6 | 68.4 |
| USW00013967 | 2015-07 | 1101 | 0 | 81.6 | 91.9 | 71.3 |
| USW00013967 | 2015-08 | 1549 | 0 | 79.4 | 90.4 | 68.5 |
| USW00013967 | 2015-09 | 1922 | 0 | 77.4 | 89.3 | 65.6 |
| USW00013967 | 2015-10 | 1994 | 93 | 64.3 | 75.7 | 53 |
| USW00013967 | 2015-11 | 1995 | 496 | 51.6 | 62.7 | 40.5 |
| USW00013967 | 2015-12 | 1995 | 1107 | 45.3 | 56.8 | 33.8 |
| USC00342825 | 2015-01 | 0 | 2464 | 36.5 | 48.8 | 24.1 |
| USC00342825 | 2015-02 | 0 | 3265 | 36.4 | 49.3 | 23.5 |
| USC00342825 | 2015-03 | 2 | 3716 | 50.5 | 63.8 | 37.2 |
| USC00342825 | 2015-04 | 41 | 3905 | 60 | 71.5 | 48.5 |
| USC00342825 | 2015-05 | 101 | 3980 | 64.5 | 74.1 | 54.9 |
| USC00342825 | 2015-06 | 472 | 3980 | 77.4 | 88.6 | 66.2 |
| USC00342825 | 2015-07 | 952 | 0 | 80.5 | 90.9 | 70 |
| USC00342825 | 2015-08 | 1336 | 3 | 77.3 | 89 | 65.6 |
| USC00342825 | 2015-09 | 1647 | 3 | 75.4 | 88.1 | 62.6 |
| USC00342825 | 2015-10 | 1699 | 162 | 61.6 | 74.9 | 48.2 |

| STATION | DATE | CDSD | HDSD | TAVG | TMAX | TMIN |
|---|---|---|---|---|---|---|
| USC00342825 | 2015-11 | 1700 | 636 | 49.2 | 61.7 | 36.7 |
| USC00342825 | 2015-12 | 1700 | 1328 | 42.7 | 54.9 | 30.5 |
| USC00346382 | 2015-01 | 0 | 2183 | 39 | 50.2 | 27.9 |
| USC00346382 | 2015-02 | 0 | 2932 | 38.2 | 49.9 | 26.6 |
| USC00346382 | 2015-03 | 6 | 3324 | 52.5 | 63.4 | 41.7 |
| USC00346382 | 2015-04 | 48 | 3465 | 61.7 | 71.8 | 51.6 |
| USC00346382 | 2015-05 | 132 | 3506 | 66.4 | 74.5 | 58.2 |
| USC00346382 | 2015-06 | 557 | 3506 | 79.2 | 89 | 69.3 |
| USC00346382 | 2015-07 | 1080 | 0 | 81.9 | 90.9 | 72.8 |
| USC00346382 | 2015-08 | 1533 | 0 | 79.6 | 89.8 | 69.4 |
| USC00346382 | 2015-09 | 1898 | 0 | 77.2 | 88.1 | 66.2 |
| USC00346382 | 2015-10 | 1967 | 108 | 63.7 | 75.4 | 52 |
| USC00346382 | 2015-11 | 1967 | 492 | 51.3 | 62.5 | 40.1 |

# Appendix E – USAF Real Property DD Form 1354

**TRANSFER AND ACCEPTANCE OF DoD REAL PROPERTY**

*Form Approved*
*OMB No. 0704-0188*

PAGE OF PAGES

The public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Washington Headquarters Services, Executive Services Directorate, Information Management Division, 4800 Mark Center Drive, Alexandria,VA 22350-3100 (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if itdoes not display a currently valid OMB control number.

**PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ORGANIZATION.**

**1. FROM** *(Organization Name)*

**2. DATE PREPARED** *(YYYYMMDD)*

**3. PROJECT/JOB NUMBER**

**4. SERIAL NUMBER**

**5. TO** *(Organization - Installation Code and Name)*

**6. RPSUID/SITENAME/ INSTCODE/INSTNAME**

**7. CONTRACT NUMBER(S)**

**7a. PLACED-IN-SERVICE DATE** *(YYYYMMDD)*

**8. TRANSACTION DETAILS**

**a. METHOD** *(X all that apply)*
- ACQUISITION BY CONSTRUCTION
- TRANSFER BETWEEN SERVICES
- CAPITAL IMPROVEMENT
- INVENTORY ADJUSTMENT

**b. WHEN/EVENT** *(X one)*
- TOTAL ASSET PLACED-IN-SERVICE
- PARTIAL ASSET PLACED-IN-SERVICE

**c. TYPE** *(X one)*
- DRAFT
- FINAL
- INTERIM

| 9. ITEM NO. | 10a. FACILITY NO. | 10b. RPUID | 11. CATEGORY CODE | 12. CATCODE DESCRIPTION | 13. TYPE CODE | 14. SUST. CODE | AREA | | OTHER | | 19. COST | 20. FUND SOURCE | 21. FUND ORG | 22. INTER-EST CODE | 23. ITEM REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 15. PRIMARY UM | 16. PRIMARY UM QUANTITY | 17. SECONDARY UM | 18. SECONDARY UM QUANTITY | | | | | |
| | | | | | | | | | | | | | | | |

**24. STATEMENT OF COMPLETION.** The facilities listed hereon are in accordance with maps, drawings, and specifications and change orders approved by the authorized representative of the using agency except for the deficiencies listed on the reverse side.

**a. TRANSFERRED BY** *(Typed Name and Signature)*

**b. DATE SIGNED** *(YYYYMMDD)*

**c. TITLE** *(Area Engr./Base Engr./DPW/Construction Agent)*

**25a. ACCEPTED BY** *(Typed Name and Signature)*

**b. DATE SIGNED** *(YYYYMMDD)*

**c. TITLE** *(DPW/RPAO)*

**26. PROPERTY VOUCHER NUMBER**

**DD FORM 1354, AUG 2013** PREVIOUS EDITION MAY BE USED. Adobe Designer 9.0

| 27. CONSTRUCTION DEFICIENCIES *(Attach blank sheet for continuations)* | 28. PROJECT REMARKS *(Attach blank sheet for continuations)* |
|---|---|
| | |

**INSTRUCTIONS**

**GENERAL.** This form has been designed and issued for use in connection with the transfer of military real property between the military departments and to or from other government agencies. It supersedes ENG Forms 290 and 290B (formerly used by the Army and Air Force) and NAVDOCKS Form 2317 (formerly used by the Navy).

Existing instructions issued by the military departments relative to the preparation of DD Form 1354 are applicable to this revised form to the extent that the various items and columns on the superseded forms have been retained. The military departments may promulgate additional instructions, as appropriate.

For detailed instructions on how to fill out this form, please refer to Unified Facilities Criteria (UFC) 1-300-08, dated 16 April 2009 or later.

**SPECIFIC DATA ITEMS.**

**1. From.** Name of the transferring agency.

**2. Date Prepared.** Date of actual preparation. Enter all dates in YYYYMMDD format (Example: March 31, 2010 = 20100331).

**3. Project/Job Number.** Project number on a DD Form 1391 or Individual Job Order Number.

**4. Serial Number.** Sequential serial number assigned by the preparing organization (e.g., 2010-0001).

**5. To.** Name and address of the receiving installation, activity, and Service of the Real Property Accountable Officer (RPAO).

**6. RPSUID/SITENAME/INSTCODE/INSTNAME.** Site Unique Identifier and name or installation code and name where the constructed facility is located.

**7. Contract Number(s).** Contract number(s) for this project.

**7a. Placed-In-Service Date.** RPA Placed In Service Date. This is the date the asset is actually placed-in-service.

**8. Transaction Details.**
a. Method of Transaction. Mark (X) as many boxes as apply.
b. When/Event. When or event causing preparation of DD Form 1354. X only one box.
c. Type. Draft, interim, or final DD Form 1354. X only one box.

**9. Item Number.** Use a separate item number for each facility, no item number for additional usages.

**10a. Facility Number.** Assigned in accordance with the Installation/Base Master Numbering Plan.

**10b. RPUID.** Identified in Real Property Inventory.

**11. Category Code.** The category code describes the facility usage.

**12. Catcode Description.** The category code name which describes the facility usage.

**13. Type.** Type of construction: P for Permanent; S for Semi- permanent; T for Temporary.

**14. Sustainability Code.** Reports whether or not an asset meets the sustainability guidelines set forth in Section 2(g) of Executive Order 13514. Valid values are: 1 (asset meets the guidelines); 2 (asset does not meet the guidelines); 3 (asset not evaluated); 4 (asset not subject to guidelines).

**15. Area: UM 1.** Area unit of measure; use the unit of measure associated with the category code selected in 11.

**16. Total Quantity UM 1.** The total area for the measure identified in Item 15. Use negative numbers for demolition.

**17. Other: UM 2.** Unit of Measure 2 is the capacity or other measurement unit (e.g., LF, MB, EA, etc.).

**18. Total Quantity UM 2.** The total capacity/other for the measure identified in Item 17.

**19. Cost.** Cost for each facility; for capital improvements to existing facilities, show amount of increase only. If there is no increase for the capital improvement, enter N/A.

**20. Fund Source.** Enter the Fund Source Code for this item.

**21. Funding Organization.** Enter the code for the organization responsible for acquiring this facility.

**22. Interest Code.** Enter the code that reflects government interest or ownership in the facility.

**23. Item Remarks.** Remarks pertaining only to the item number identified in Item 9; show cost sharing.

**24. Statement of Completion.** Typed name, signature, title, and date of signature by the responsible transferring individual or agent.

**25. Accepted By.** Typed name, signature, title, and date of signature by the RPAO or accepting official.

**26. Property Voucher Number.** Next sequential number assigned by the RPAO in voucher register.

**27. Construction Deficiencies.** List construction deficiencies in project during contractor turnover inspection.

**28. Project Remarks.** Project level remarks and continuation of blocks.

**DD FORM 1354 (BACK), AUG 2013**

## Appendix F – Detailed ANOVA Results

This appendix provides detailed information on the creation and use of each model used to determine whether CAT or FAC Codes were more influential on building energy consumption.

Each model was created using the following steps:

1. Create linear regression model
    a. A stepwise function is utilized to develop a working representation of the linear regression model.
2. Perform ANOVA
    a. Complete F-Test to determine the level of influence CAT and FAC Codes have on energy consumption. The level of significance, $\alpha$, is associated with the amount of risk of encountering a Type I error, where the null hypothesis is rejected when in fact, it is true. For this test, a p-value less than $\alpha=0.05$ will be considered statistically significant.

       $H_o$: NONE of the factors explain variability

       $H_a$: AT LEAST ONE of the factors explains variability
    b. Complete Interaction Effect Test to see if combination of variables causes the effect. This ensures the model is not skewed by multicollinearity.
3. Test for Outliers
    a. The studentized residuals are displayed on a histogram for a visual test to determine if any data points are outliers.
4. Test for Overly Influential Points
    a. Cook's Distance values are derived from the linear regression model and displayed on an overlay plot to determine all data points are valid and not over 0.5, and therefore overly influential.

| REPORT DOCUMENTATION PAGE | *Form Approved OMB No. 0704-0188* |
|---|---|



| 1. REPORT DATE *(DD-MM-YYYY)* | 2. REPORT TYPE | 3. DATES COVERED *(From - To)* |
|---|---|---|
| 23-03-2017 | Master's Thesis | Sept 2015 - Mar 2017 |

**4. TITLE AND SUBTITLE**
An Energy Benchmarking Categorization Scheme and Consumption Data Validation for Air Force Facilities

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Olive, Mary C, Capt

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way
Wright-Patterson AFB OH 45433-7765

**8. PERFORMING ORGANIZATION REPORT NUMBER**
AFIT-ENV- MS -17-M-207

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
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**10. SPONSOR/MONITOR'S ACRONYM(S)**
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**14. ABSTRACT**
The purpose of this research was to provide a proof of concept for an Air Force facility energy benchmarking program which utilizes the meter data currently available at installations. It also sought to explore the effectiveness of utilizing real property category labels as energy consumption peer groupings. Specifically, this thesis strove to answer three research questions regarding energy consumption data validity, and the ability Facility Analysis Codes and Category Codes possess in predicting facility energy consumption. These research questions were answered through an empirical approach, which included the statistical technique of analysis of variance. The results of this study demonstrated the validity of the energy consumption information currently available at Air Force installations, and its ability to form the basis a robust benchmarking program. It also revealed the limited effectiveness of applying real property labels as facility usage type categories. The culmination of this research effort was the identification of the category codes which do or do not accurately represent facility usage types as they relate to energy consumption.

**15. SUBJECT TERMS**
^Energy benchmarking; facility usage types: energy consumption peer groups

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | Dr. Brent T. Langhals, AFIT/ENV |
| | | | | | 19b. TELEPHONE NUMBER *(Include area code)* |
| U | U | U | UU | 84 | (937) 255-3636 x7402 brent. langhals@afit.edu |

Reset

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