Electronic Auditing Tool with Geometry Capture

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14. ABSTRACT
This ESTCP project was a joint effort between energy simulation and auditing experts at the National Renewable Energy Laboratory (NREL) and software developers from commercialization partner concept3D. This team integrated NREL's formal auditing methodology and open source modeling tools with existing concept3D software technologies to create and demonstrate a tablet computer-based tool called simuwatt™ Energy Auditor™, which is now offered as a commercial product by concept3D. The goal of this project was to demonstrate that simuwatt™ could enable an energy auditor to perform ASHRAE level II audits while achieving a 35% cost reduction compared to audits typically procured by DoD without sacrificing audit quality. Results of the field demonstration show that simuwatt™ successfully met the goal for audit cost reduction. However, audit reports generated by simuwatt™ in this demonstration fell short of the success criteria for audit quality based on reviews by DoD personnel and an unbiased auditing expert. Many of these deficiencies are expected to be addressed in future versions of the product.

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LIST OF ACRONYMS

AHU	Air Handling Unit
API	Application Program Interface
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BCL	Building Component Library
BIM	Building Information Modeling
CAD	Computer-Aided Design
CAV	Constant Air Volume
CRAC	Computer Room Air Conditioner
DDC	Direct Digital Control
DHW	Domestic Hot Water
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
ECM	Energy Conservation Measure
EE	Energy Efficiency
EEAP	Energy Efficiency Analysis Program
EISA	Energy Independence and Security Act
ESTCP	Environmental Security Technology Certification Program
EUI	Energy Use Intensity
FY	Fiscal Year
HVAC	Heating, Ventilating, and Air Conditioning
IFC	Industry Foundation Classes
LEED	Leadership in Energy and Environmental Design
NAVFAC SE	Naval Facilities Engineering Command Southeast
NREL	National Renewable Energy Laboratory
NSAM	Naval Support Activity, Monterey
RTU	Rooftop Unit
VAV	Variable Air Volume

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EXECUTIVE SUMMARY

This Environmental Security Technology Certification Program (ESTCP) project was a joint effort between energy simulation and energy auditing experts at the National Renewable Energy Laboratory (NREL) and software developers from commercialization partner concept3D. This team integrated NREL's formal auditing methodology with existing concept3D software technologies to create a single, tablet-based tool called simuwatt™ Energy Auditor, which concept3D now offers as a commercial product. The goal of this project was to demonstrate that simuwatt™ could enable an energy auditor to perform ASHRAE level II audits and achieve a 35% cost reduction compared to audits typically procured by the U.S. Department of Defense (DoD) without sacrificing audit quality. The Energy Independence and Security Act (EISA) of 2007 requires DoD to audit 25% of its 1.9 billion ft^2 of covered facilities each year, and simuwatt™ Energy Auditor has the potential to significantly reduce the cost of these audits.

The software integration goal of this project was achieved. Project team members demonstrated simuwatt™ Energy Auditor at 11 buildings across four DoD sites, and a third-party energy auditor with minimal training also used the tool to audit 2 buildings at a fifth DoD site. Connections between simuwatt™ Energy Auditor and the Building Component Library (BCL) were also successful, allowing access to high-quality, standardized energy modeling components. The EnergyPlus simulation engine was used to transfer data collected during the simuwatt™ audit to OpenStudio for detailed energy analysis. Standardized energy efficiency measures from the BCL were used to perform life cycle calculations. Data from this process were presented in an automatically generated, standardized report.

The demonstration occurred in two phases. During the first phase, NREL auditing experts performed energy audits using simuwatt™ at 11 DoD buildings across four DoD sites. NREL auditors recorded the time required to perform a range of audit tasks, estimated audit costs by applying reasonable energy auditor rates to those times, and compared the results to the cost of audits previously procured by DoD. This phase tested simuwatt™'s flexibility to be used across a range of sites and provided data on the cost and quality of simuwatt™ audit reports. The second phase provided a direct head-to-head comparison of the simuwatt™ audit approach with a traditional audit process. In this phase, two teams of auditors with similar qualifications from the same third-party auditing firm audited the same two buildings at Naval Support Activity Monterey. One team used simuwatt™ and the other team used a standard audit process. Neither team was aware of the other's activities. In both phases, the audits were scored on cost of the audit, the quality and usefulness of the audit report from the perspective of a DoD facility/energy manager, and the comprehensiveness and completeness of the audit report from the perspective of an unbiased energy auditing expert.

Phase 1 demonstrations achieved an average cost savings of 53% compared to past DoD audits, exceeding the project's cost reduction goal of 35%. However, the DoD reviewers gave the reports an average score of 49.9/80 and the third-party energy auditing expert gave the reports an average score of 40.5/80. Review comments by DoD and third-party reviewers indicated that the Phase 1 reports were not as comprehensive as desired, specifically with regard to documenting underlying analysis assumptions. Because the simuwatt™ audit report generation is semi-automated, its content might be improved based on data already collected by simuwatt™.

However, there was little time between Phase 1 and Phase 2, and the team was unable to address these issues before Phase 2 started.

In Phase 2, the third-party auditing team used simuwatt™ to successfully complete audits of two buildings and achieved a time savings of 28% compared to the traditional auditing team. This time savings is slightly less than the 35% time savings goal. However, this was the third-party auditor team's first time using the simuwatt™ Energy Auditor. This team's members reported that they believe that their audit, analysis, and reporting times would improve with subsequent use of the tool. The DoD reviewers gave the reports produced by both the simuwatt™ and the traditional auditing teams identical scores of 71/80 in terms of quality and usefulness, which was an improvement from the average score of 49.9/80 given during Phase 1. However, the third-party energy auditing expert gave the Phase 2 reports an average score of 45/80 in terms of completeness and comprehensiveness, similar to the average score of 40.5/80 in Phase 1. As in Phase 1, these scores are expected to increase as improvements are made to the simuwatt™ audit report generation.

Based on Phase 1 and Phase 2 results, simuwatt™ reduces the time to complete an audit for DoD. The time savings for a first-time user were 28% in the Phase 2 head-to-head test and 53% for experienced auditors with previous simuwatt™ experience in Phase 1. However, the performance goals for report quality were not met during this demonstration. During a reviewer debriefing, the development team explained how calculations are performed and what assumptions are used, improving the reviewers' opinions of the analysis results; however, this information was not clearly communicated in the reports. Improvements to quality as well as clarification of calculation methods and assumptions in the generated report are anticipated in future versions of simuwatt™.

Based on the demonstration results, and the expectation that report quality issues are addressed by future software releases, simuwatt™ Energy Auditor shows potential for significant energy audit cost savings. If simuwatt™ is used to audit all DoD buildings over a 4-year period, the estimated DoD-wide savings is approximately $171 million, or an average of $43 million annually. This savings level is substantially larger than the estimated software cost of approximately $1 million annually, and indicates that DoD could recognize significant energy audit savings through the use of simuwatt™.

Although the first-time audit cost and the audit report quality were the main focuses of this demonstration, simuwatt would provide additional benefits, including:

- The data collection process is standardized and DoD owns and controls the resulting data. This means that future energy audits, such as those performed every 4 years to comply with the EISA 2007 mandate, would have a significant head start in collecting data. The recurring audits would simply be updates rather than entirely new investigations. Reusing previous simuwatt™ audit data would reduce the amount of time needed to complete a future audit by an estimated 50%. A 25-year estimate of DoD-wide auditing costs shows that the life cycle cost savings have a net present value of approximately $1.3 billion. This estimate does not include further savings associated with reduced audit review costs resulting from the standardized report format and calculation methods.

- DoD can compare a portfolio of buildings to find opportunities and economies of scale that may currently go unnoticed.

- The data can be leveraged for other uses. For example, energy auditors commonly record detailed inventories of equipment, space usage, and building condition. This information could be tied to facility maintenance systems and used to develop operations and maintenance plans.

- The building energy models could be used to support automated fault detection and diagnostics and used to support model-based control strategies.

1.0 INTRODUCTION

The objective of this project was to demonstrate a tablet-based software tool that significantly lowers the cost of energy audits for the U.S. Department of Defense (DoD), improves the quality of these audits, and preserves the data in a standardized format to facilitate portfolio-wide tracking, reporting, decision-making, and data reuse.

The cost of conducting an energy audit is influenced by several factors, including the use of tedious, non-standardized, and error-prone processes. Highly trained personnel spend a significant amount of time transcribing data, gathering equipment information, sorting through utility bills, and developing customized calculations for each audit. A tablet-based software tool that can automate these processes has the potential to significantly reduce the time required to complete an audit, thereby reducing audit expenses incurred by DoD.

This project was a joint effort between energy simulation and energy auditing experts from the National Renewable Energy Laboratory (NREL) and software developers from commercialization partner concept3D. The team initiated the project by integrating a formal auditing methodology with several existing software technologies to create a single, tablet-based tool called simuwatt™ Energy Auditor. Next, simuwatt™ Energy Auditor was used to conduct a total of 13 energy audits across five DoD sites. The resulting audits were judged based on cost, quality and usefulness of the audit report from the perspective of a DoD facility/energy manager, and comprehensiveness and completeness of the audit report from the perspective of an energy auditing expert.

1.1 BACKGROUND

Energy audits provide valuable insight into key opportunities for site-specific energy conservation measures (ECMs). As part of the overall goal of reducing energy consumption in federal buildings, the Energy Independence and Security Act (EISA) of 2007 (govtrack 2007) requires that federal agencies audit 25% of their 1.9 billion ft^2 of covered facilities each year (Brown and Dirks; Lisell 2011). These are typically level I or II audits. During the course of this project, the U.S. Army Corps of Engineers shared cost data from the 2012 Energy Efficiency Analysis Program (EEAP) energy auditing initiative with the NREL team (Lissell 2012). Review of these data revealed the average cost for DoD audits to be \$0.20/ ft^2. The data included one of the demonstration sites for this project, Fort Bliss, which had a higher than average audit cost of \$0.33/ft^2.

Much of the cost for an energy audit is due to tedious, non-standardized, error-prone processes in which pen and paper methods are used to collect data and ad-hoc calculation tools are used to conduct analyses. Highly trained personnel spend significant time performing data transcription, gathering data on equipment, sorting utility bills, and developing customized calculations for each audit. This non-standardized process also makes management, quality control, and results reporting difficult and time consuming.

After an energy audit is complete, auditors deliver the summarized results in a non-standardized report. The detailed building information that was collected during the audit is lost. Future audits of the building have no data as a starting point, so auditors must recollect all data, even though

much of the building remains unchanged between audits. Additionally, facility and installation operators and managers lose data that would be valuable in other efforts, such as equipment tracking, energy planning, and installation-wide asset management and capital expenditure planning. With the approach proposed in the auditing software tool, the audit project information could be stored in a database to provide future auditors a baseline. This would greatly reduce the costs of future audits. It would also benefit facility managers, who could access this information as needed.

Currently, DoD is performing level I and level II audits. Higher quality level III energy audits performed previously at federal facilities throughout the country show recommendations that would reduce energy consumption of the building by approximately 30% while maintaining a positive net present value (Brown and Dirks 2001). The motivation for developing simuwatt™ Energy Auditor was to provide an electronic auditing workflow that leverages tablet computers for data collection onsite, uses a standard data format, and can be accessed with a desktop computer is expected to provide high-quality audits at or above level II at a cost lower than that of the level I and level II audits that DoD is currently performing.

Initial development of simuwatt™ Energy Auditor for this demonstration project targeted an ASHRAE level III audit. However, feedback from the Environmental Security Technology Certification Program (ESTCP) committee indicated that level III audits exceeded DoD's needs. The committee stated that level I or II audits would cost effectively meet DoD's needs, and the project team subsequently focused the simuwatt™ development on level I or II audits. The project team only added features in excess of a level II audit when those features would not further increase the audit cost.

Tables 1 and 2 provide a comparison of the required tasks to qualify for an ASHRAE level I, II, or III energy audit along with the capabilities of the simuwatt™ Energy Auditor tool. Some planned features of simuwatt™ Energy Auditor were not completed in time to be demonstrated in this study; these features are marked with an asterisk (*) in Tables 1 and 2. Implementation of these features would be expected to improve the simuwatt™ Energy Auditor report quality and comprehensiveness relative to the version used in this demonstration. These features would be implemented by concept3D during their commercialization of simuwatt™ Energy Auditor after the conclusion of this ESTCP project.

Table 1. ASHRAE Energy Audit Required Process Tasks (ASHRAE 2004)

Process	Level I Audit	Level II Audit	Level III Audit	simuwatt™ Energy Auditor
Conduct preliminary energy analysis	X	X	X	X*
Conduct walk through survey	X	X	X	X
Identify low-cost/no-cost recommendations	X	X	X	X
Identify capital improvements	X	X	X	X
Review mechanical and electrical design and condition and operations and maintenance practices		X	X	X
Measure key parameters		X	X	X
Analyze capital measures (savings and costs, including interactions)		X	X	X
Meet with owner/operators to review recommendations		X	X	X
Conduct additional testing/monitoring			X	X*
Perform detailed system modeling			X	X
Provide schematic layouts for recommendations			X	

*Planned features of simuwatt™ Energy Auditor not completed for demonstration

Table 2. ASHRAE Energy Audit Required Reporting Tasks (ASHRAE 2004)

Report	Level I Audit	Level II Audit	Level III Audit	simuwatt™ Energy Audit
Estimate savings from utility rate change	X	X	X	X*
Compare energy use intensity (EUI) to EUIs of similar sites	X	X	X	X*
Summarize utility data	X	X	X	X
Estimate savings if EUI were to meet target	X	X	X	X
Estimate low-cost/no-cost savings		X	X	X
Calculate detailed end-use breakdown		X	X	X
Estimate capital project costs and savings		X	X	X
Complete building description and equipment inventory		X	X	X
Document general description of considered measures		X	X	X
Recommend measurement and verification method		X	X	X*
Perform financial analysis of recommended ECMs		X	X	X
Write detailed description of recommended measures			X	X
Compile detailed ECM cost estimates			X	X

*Planned features of simuwatt™ Energy Auditor not completed for demonstration

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective was to demonstrate a tablet-based software tool that lowers the cost of energy audits for DoD by increasing speed, reducing errors, and facilitating the management of audits across a broad portfolio of buildings. This objective was accomplished by combining a proven auditing methodology, building geometry capture software, and established energy analysis software in a single tool. Application of the software-guided workflow at the first 4 DoD sites was designed to demonstrate tool outcomes across climate zones and building types for multiple service branches. A study at the final site, Naval Support Activity Monterey (NSAM), was designed to compare the tool's time and cost savings compared with a traditional audit process. Demonstrations at the first 4 sites are referred to as Phase 1 and the comparison demonstration at the final site is referred to as Phase 2. A total of 13 buildings were evaluated; 11 in Phase 1 and two in Phase 2.

Estimates based on the results of this project show that simuwatt™ can be used by DoD to achieve high-quality audits with the feature set denoted in Table 1 and achieve a cost savings of 35% relative to the level I or level II audits that are currently being performed. With 475 million ft^2 (25% of 1.9 billion ft^2) audited each year, the direct cost savings could be $43 million annually. Further, a standardized auditing process and data collection format will ensure consistency, continuity, and compatibility across DoD assets that use a diverse pool of contractors to perform energy audits. This will also allow audit data to be used for additional purposes and will lead to additional savings as buildings are re-audited in future years.

1.3 REGULATORY DRIVERS

EISA 2007 requires that DoD audit 475 million ft^2 (25% of 1.9 billion ft^2) of its facilities each year as part of a plan to reduce energy consumption of all federal buildings.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

NREL and concept3D partnered to produce simuwatt™ Energy Auditor, an innovative cloud-based software solution. It lowers the time and cost of providing high-quality, investment-grade commercial building energy audits and preserve the data to facilitate portfolio-wide tracking, reporting, decision-making, and reuse. simuwatt™ Energy Auditor leverages an integrated community-driven library of energy simulation data, advanced 3D building geometry capture tools, and NREL's OpenStudio whole-building energy software platform to create a comprehensive building model (Weaver et al. 2012). An extensible set of ECMs can be applied to the baseline model to determine retrofit actions based on energy performance, cost, and return on investment of each design alternative. An initial report is automatically generated from the data collection and analysis; this initial report is then manually completed. The technologies integrated by simuwatt™ are shown in Figure 1.

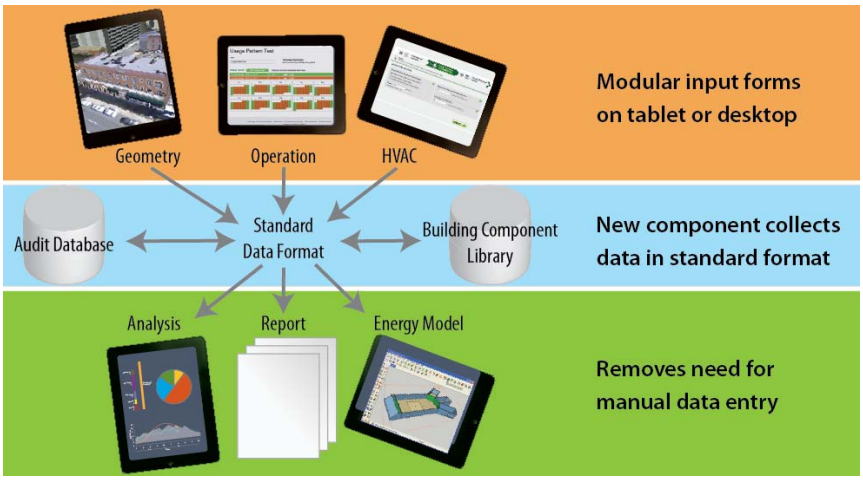

Figure 1. simuwatt™ Energy Auditor Concept

The simuwatt™ tool provides a software-guided workflow for audit data collection based on an easy-to-use geometry capture capability. Satellite imagery is combined with floor plans or other images to define the building shape and the spaces inside. These spaces provide the framework for gathering relevant data within the building, including construction, lighting; plug loads; windows; schedules; heating, ventilating, and air conditioning (HVAC); zoning information; water fixtures; and more using specially designed forms on the tablet. A few representative screenshots of the application are shown in Figure 2.

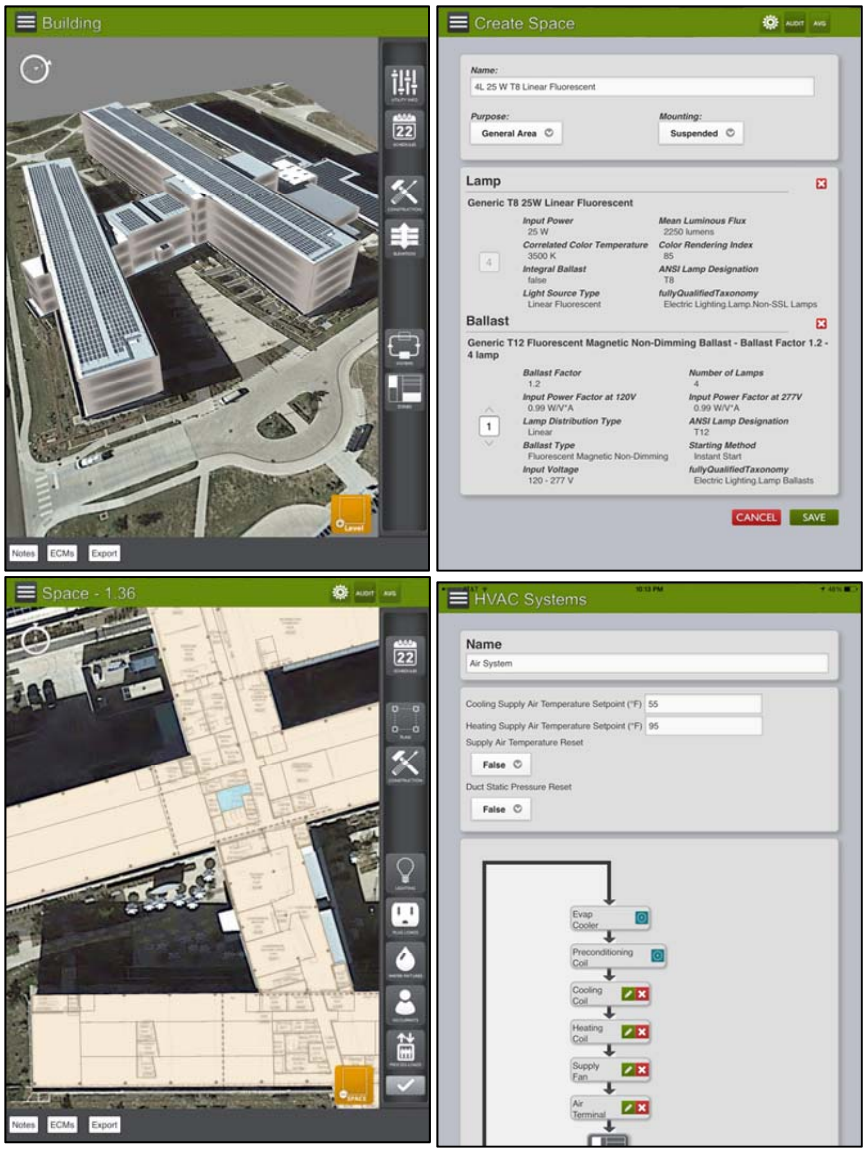

Figure 2. Sample simuwatt™ Energy Auditor Screenshots Illustrating Geometry, Lighting, and HVAC System Data Collection

Once collected, these data are automatically converted into an OpenStudio whole-building energy model, ready for analysis with the U.S. Department of Energy's (DOE) EnergyPlus simulation engine (Drury et al. 2001). Figure 3 illustrates one example of the geometry capture and model conversion process.

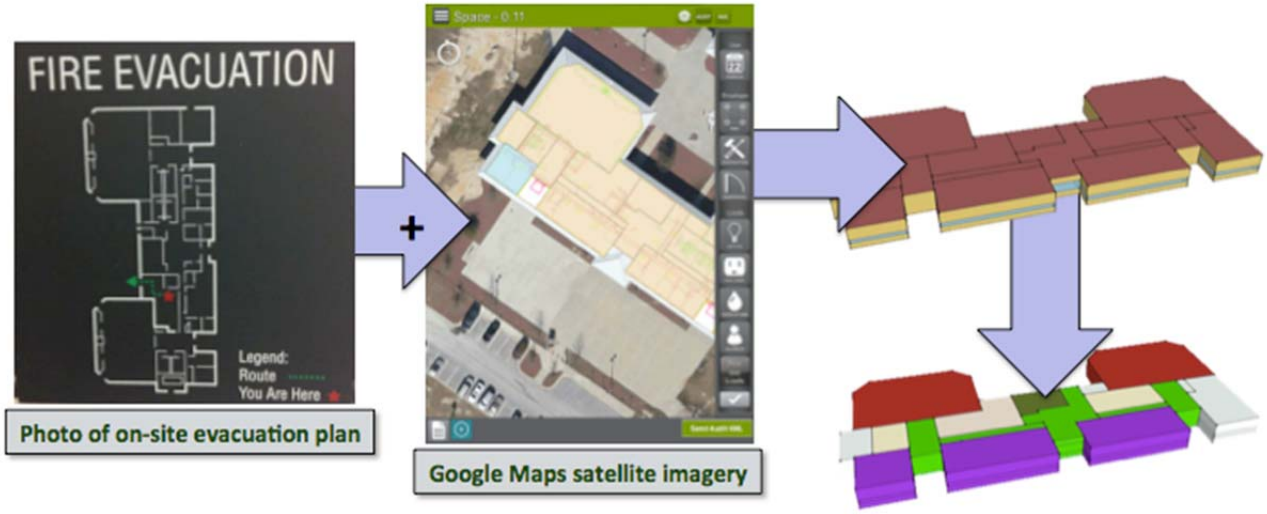

Figure 3. simuwatt™ Energy Auditor Geometry Capture for Building 10400 at Fort Jackson

The detailed building component attributes required to produce a detailed energy model are obtained from a library of building component data (BCL) (Fleming et al. 2012)). This decreases audit costs and increases quality by standardizing modeling and analysis inputs for each audit. Figure 4 shows some of the details associated with another simuwatt™ example model.

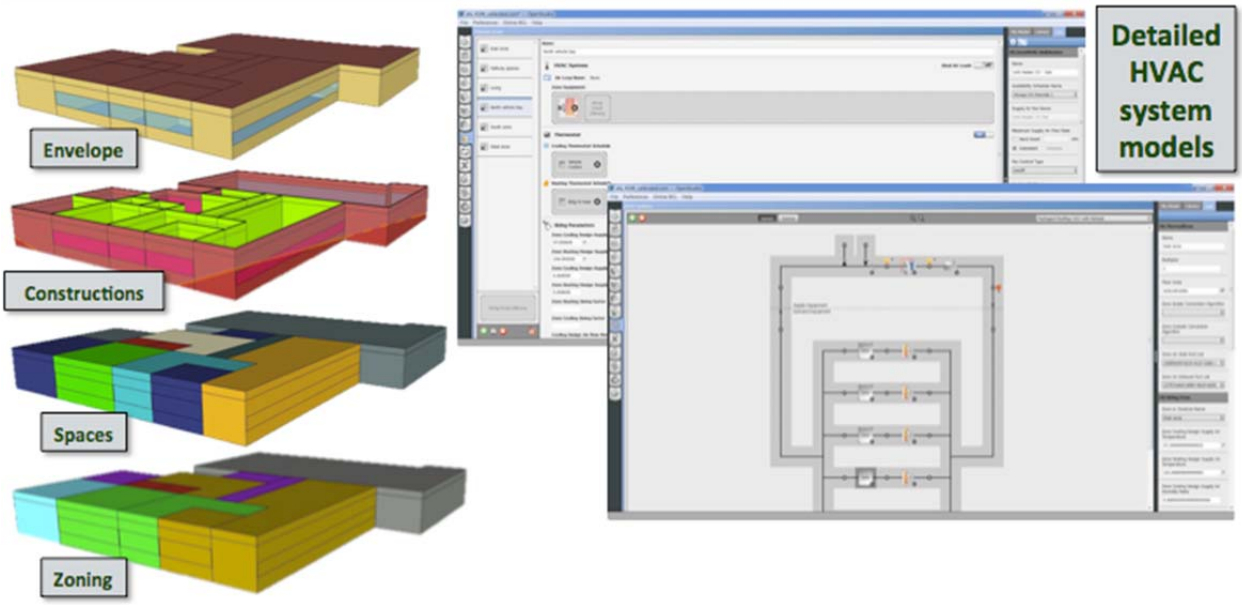

Figure 4. Detailed Model Contents Based on simuwatt™
Energy Auditor Input for Building 4198 at Air Force Academy

Baseline energy models are calibrated against actual monthly energy use to within the error tolerance laid out in ASHRAE Guideline 14 (ASHRAE 2002). The calibration process involved the auditors identifying parameters that they were least certain of and then adjusting these parameters to increase the goodness of fit between the simulation and billed data. In the future,

calibration could be automated. A typical comparison of monthly and modeled electricity and gas consumption after calibration is shown in Figure 5.

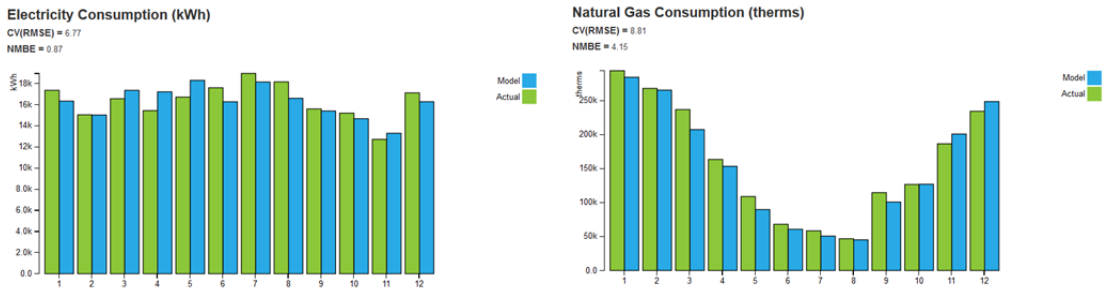

Figure 5. Comparison of Measured and Modeled Electricity and Natural Gas Consumption Following Calibration for Building 4198 at Air Force Academy

ECMs obtained from the BCL are then applied to the calibrated baseline model using OpenStudio's "drag-and-drop" parametric analysis capability. Once energy analyses are complete, an electronic report is automatically generated. The report includes information from both the simuwatt™ Energy Auditor software and the OpenStudio energy analysis, including utility data, calibration summaries, ECM energy savings and cost metrics, background information on building systems, inventory data, and climate data. This saves the auditor significant time and improves the consistency of reports delivered to the building owner. Figure 6 shows how ECMs are applied to the baseline model to produce a detailed life cycle analysis and audit report.

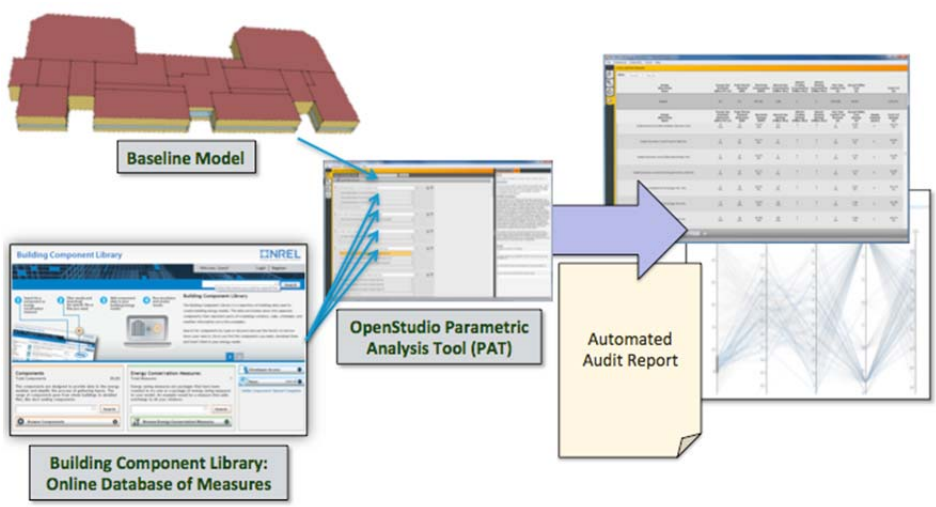

Figure 6. ECMs Are Applied to the Calibrated Model for Life Cycle Analysis and Reporting

This entire process, from initial data collection to report generation, is streamlined with seamless data passes and quality checks during each step. The process uses consistent data throughout, eliminating the potential for transcription error. Further, the approach includes detailed models of HVAC systems, heat transfer, occupancy schedules, etc. Combinations of ECMs are modeled together in the same model, which accounts for the interactive effects between different ECMs.

This differs significantly from spreadsheet-based analyses that typically leave out interactive effects of ECMs entirely.

2.2 TECHNOLOGY DEVELOPMENT

As explained in the project proposal, software development during the ESTCP period of performance focused on integrating four previously developed tools and methodologies into a single software package and workflow. The four components and their purposes are described below.

Energy audit software tool – NREL previously developed an energy audit methodology that was adapted to DoD needs. Over the course of many energy audits, this methodology was refined to capture the information needed to successfully identify significant energy savings opportunities. To support this methodology, NREL developed a suite of Excel-based calculations to identify and analyze some of the most common ECMs based on the audit data. The audit methodology and the calculations were incorporated into a prototype Excel macro (Visual Basic for Applications)-based auditing tool, which was tested on 20 buildings. The audit methodology, calculations, and experience with the Excel prototype provided the foundation for the simuwatt™ tool demonstrated in this project.

Geometry capture software – NREL and concept3D Inc. previously developed geometry capture software for tablets and smart phones that helped users quickly extract building dimensions from photographs taken during the audit, 2-D floor plans available before the audit, or fire escape plans available during the site visit. Building dimensions are critical to accurately analyze many ECMs, but manually cataloging this information during an audit is time consuming. The geometry capture capability was integrated directly into the audit tool as part of the simuwatt™ workflow.

OpenStudio – NREL is the lead developer for OpenStudio, DOE's platform for whole-building energy modeling and analysis. Whole-building energy simulation is preferred for calculating the impacts of ECMs on a building's energy consumption because it captures complex interactions within a building. However, creating a detailed energy model by hand is time consuming. simuwatt™ Energy Auditor used the OpenStudio application programming interface (API) to automatically turn the information collected during the audit into a whole-building energy model, enabling auditors to accurately analyze potential ECMs without the time commitment typically associated with model development.

Building Component Library – NREL and concept3D developed and launched the BCL, an online repository of building component and ECM information. This database was linked directly to simuwatt™ to allow auditors to select components from a list, rather than spend hours hunting through manufacturer catalogs to find component information. In addition to accelerating data collection, the BCL supports quality control of reusable component information used for analysis.

The combination of these technologies is shown in Figure 7. The data collection workflow developed by NREL was implemented as a tablet application. This application allowed auditors to pull standard building component data from the BCL. The software mechanism to create an OpenStudio energy model from the collected data was developed as part of the demonstration project. ECM analysis was performed using OpenStudio's Parametric Analysis Tool (Parker et al. 2014), which was developed during the period of performance utilizing cost-share from DOE and Xcel Energy.

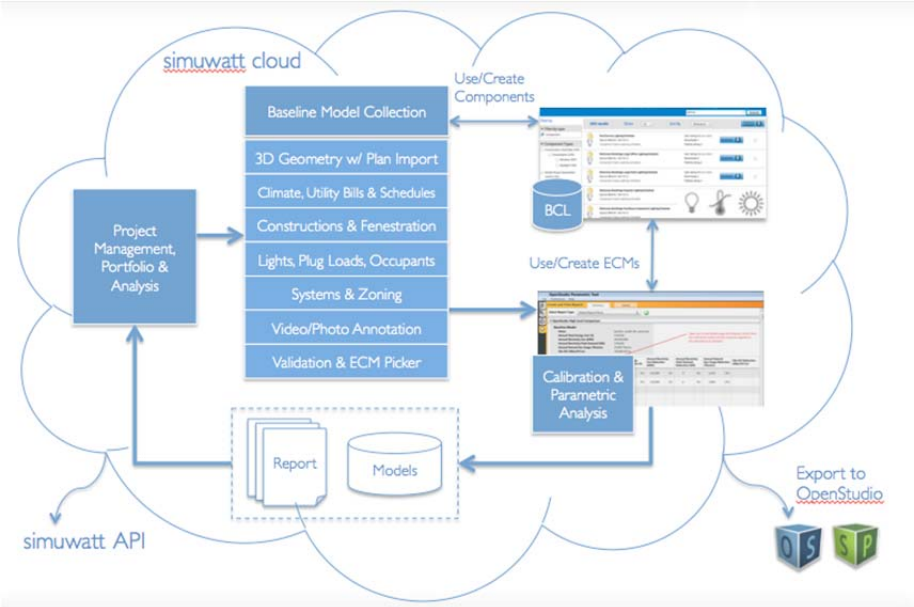

Figure 7. simuwatt™ Energy Auditor's Integrated Architecture

The overall development and demonstration effort is shown chronologically in Figure 8. Software integration activities took place between Q2 2012 and Q2 2013 with usability and functional testing and refinement of the system occurring in Q3/Q4 of 2013.

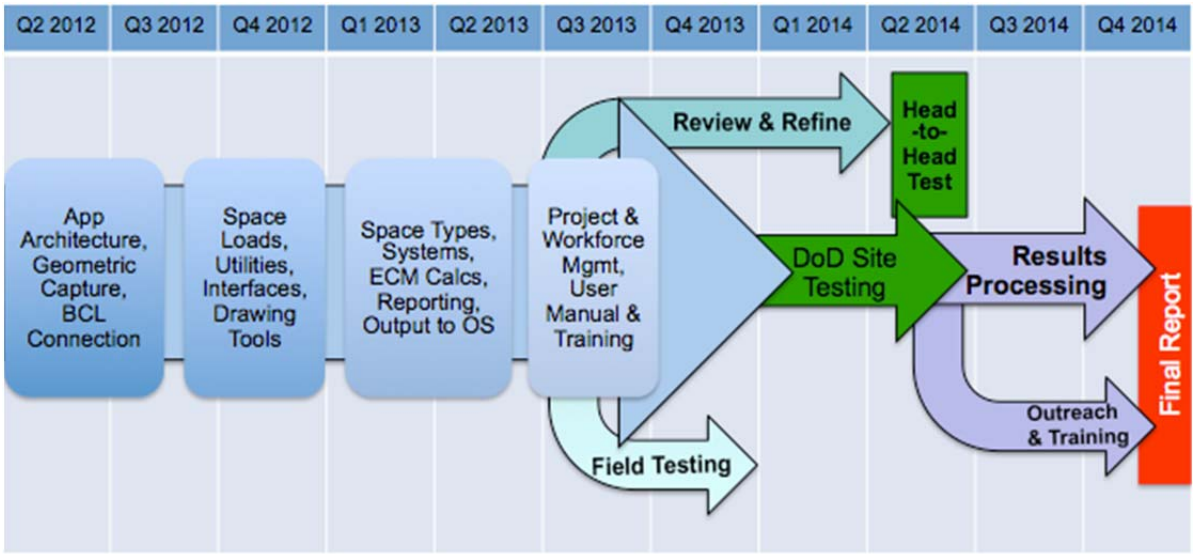

Figure 8. ESTCP Development and Demonstration Chronology

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

A number of software innovations aimed at reducing the cost of energy audits have emerged in the marketplace over the past several years. These are compared and contrasted with the advantages and limitations of simuwatt™.

2.3.1 Whole-Building Energy Modeling Versus Spreadsheet-Based Analysis

For this ESTCP demonstration, simuwatt™ focused on using whole-building energy modeling for several reasons. First, the simulation of the building and its systems are fundamental, physics-based models that have been tested extensively and are used in a wide variety of energy efficiency programs across the country (8,9). The inner workings of the simulation engines are also extensively documented. This means that auditors can focus on getting the model inputs correct rather than focusing on developing and maintaining their own simulation method in addition to performing the analysis. Although some companies have created their own internal standard analysis methods, they typically consider these methods trade secrets and will not provide reviewers (DoD facility managers, energy managers, etc.) access to the calculations. Thus, facility managers must trust that auditors' assumptions are reasonable, that they did not make mistakes, and that they are not intentionally biasing the results. This is a genuine concern in situations such as energy savings performance contracts where investments are tied to analysis results.

NREL reviewed many energy audit reports for DoD and other federal agencies and found that questionable audit results are frequently delivered to clients (savings that exceed 100% of the building energy consumption, savings of a fuel not impacted by an ECM, etc.). Without access to the simulation method, it is difficult for reviewers to evaluate the credibility of recommendations. This leaves DoD employees in the unenviable position of accepting the results and proceeding with a project based on suspect savings, or questioning the results and risking having the energy savings performance contract fall through.

Skeptics of whole-building energy modeling claim that it doesn't work because they have seen unreasonable results of whole-building energy analysis. In NREL's experience, this in most often the result of incorrect model inputs, and is not a fundamental issue with the simulation engine. Knowing this, simuwatt™ strives to mitigate the entry of incorrect inputs by:

- Pulling building component data from a standard library (BCL), which is populated using well-established sources of high-quality information.
- Automating the creation of the energy model based on the information collected by the auditor to avoid transcription/translation errors, and automatically incorporating modeling best practice.
- Standardizing ECM analysis methodology by limiting the user to a few easily understood inputs rather than exposing all the details of the complete energy model.
- Showing the calibration between the model and the actual utility bills to help ensure that the starting point for the analysis is sound.

Skeptics also sometimes claim that they don't trust the results of whole-building energy analysis because they don't understand the simulation engine. Documents such as ASHRAE Standard 140 (ASHRAE 2014) seek to codify simulation engine validation activities. Adherence to Standard 140 coupled with intrinsic engine documentation describing underlying engineering approaches and assumptions is generally sufficient to assuage concerns; however, this body of documentation is technically rigorous and intimidating to reviewers. To mitigate the impact of this valid concern, the simuwatt™ team believes that it is necessary to standardize ECM analysis methodology such that the initial and final states of the model are clearly communicated to auditors and reviewers along with a brief summary of the modeling approach. This avoids exposing all the underlying complexity of a rigorous analysis, yet provides the reviewer sufficient information to understand what has occurred in creating a specific retrofit design alternative.

Assuming that the key issues outlined above are mitigated, NREL and the simuwatt™ team believe that whole-building energy modeling is the most rigorous and transparent analysis tool to achieve the deep savings that are available once simple ECMs such as lighting replacement have been completed. Further, it is the only credible analysis method that can identify the energy and cost savings potential associated with interactive effects.

2.3.2 Alternate Approach – *Zero-Touch Audits*

Prominently represented in recent trade media are so-called "zero-touch" audit solutions from companies such as Retroficiency and First Fuel. Both companies are based on a Software As A Service business model that consumes high-level building information along with billing/meter data to disaggregate energy usage. This disaggregation is typically performed using statistical analysis of meter data in the context of a population of buildings and/or simulated results for archetypal buildings. Disaggregated energy consumption is compared with typical and exemplary values for each end-use category, and lists of recommended ECMs associated with the categories are presented for the building.

Advantages

- Zero-touch methodologies excel at identifying poor performers within a population of buildings, and classifying the general improvements that might be made to these buildings.
- Benchmarking and ECM recommendations are continually refreshed as additional metered data flow into the system.
- They do not require that personnel walk through the building to collect data or perform an analysis.
- They do not require the user to perform an energy analysis. Collecting data with simuwatt™ can be performed by anyone with building knowledge (facility managers, building managers, energy managers, etc.); however, energy analysis requires a user with training and expertise in energy engineering.

Disadvantages

- They do not meet the EISA 2007 requirements for an audit: "The format of the required audit report is based on the ESPC Preliminary Analysis (PA) level audits. A PA-level audit contains the documented findings of a walk-through

survey…". Acceptable audits must describe the "Locations affected" and provide a "detailed description of existing energy consuming equipment and systems." Zero-touch audits cannot meet these criteria because they have no knowledge of the building contents.

- Statistically based modeling approaches work with limited data, and the resulting "black box" models are not physically based. This limits the types of ECM recommendations that can be made, as opposed to fundamental approaches, which model the actual systems present in the building, the costs and benefits of very specific retrofit actions, and the interactive effects between proposed ECMs.
- General opportunities can be identified, but the specifics will not be known. For example, it may be possible to identify an HVAC opportunity, but not to the level of identifying fixing a broken economizer in the north zone air handling unit (AHU) as a cost-effective solution. This means that a site visit must typically be performed before an ECM can truly be identified and implemented.
- Modeling methodologies and resulting models are proprietary, and are not made available for inspection or alternate uses.
- The process requires metered "interval" data (sub hourly consumption data requiring a smart meter or advanced utility meter). The diagnostic process identifies trends in the data that can be used to inform end-use disaggregation and ECM recommendation. Interval data must be granular to the building level or at least the building type, so meters with entire bases or different building type groupings cannot be analyzed. Although the DoD has an advanced metering initiative, it has been NREL's experience that many of the installed meters are improperly commissioned or that interval data are not readily available. This is expected to improve over time.

2.3.3 Direct Competitors – Tablet-Based Audit Tools

Tablet-based audit tools produced by kWhOURS and Efficient Mobile Audit Technology (EMAT) contain software-guided workflows for gathering the type of information required in conducting a rigorous energy audit. However, there are some key differences between these tools and simuwatt™.

kWhOURS-kW-Field

As of August 25, 2014, the kWhOURS website is offline, and simuwatt™ has confirmed that the kWhOURS offerings have been discontinued. For historical purposes, this product offered a mobile software application for performing energy audits. Their software and services were tailored exclusively to commercial energy auditors, facility managers, Leadership in Energy & Environmental Design (LEED) approved professionals and other energy efficiency professionals. The product was designed to eliminate repetitive manual tasks involved in recording and managing building data. Building data were collected through a series of interfaces and output to a spreadsheet for use in user-prescribed analysis.

Advantages

- Spreadsheet output was a desirable feature for auditors accustomed to performing spreadsheet-based analysis. For the ESTCP demonstration, simuwatt™ focused on

generating a whole-building energy model for analysis in OpenStudio, and did not provide a spreadsheet output alternative. This limited users who wanted to perform spreadsheet-based analysis. In response to this frequently requested feature, simuwatt™ intends to add a spreadsheet output option to its offering.

Disadvantages

- kW-Field lacked integral analysis capability, and relied on the user to manipulate the exported spreadsheet to identify cost-effective ECMs. simuwatt™ explicitly generates a whole-building energy model that can be used in conjunction with extensible, community-driven library measures to perform simple payback or life cycle analysis of design alternatives.
- kW-Field lacked building geometry drawing tools. Building geometry, and the locations of rooms and thermal zones within it, have significant impacts on ECM recommendations. simuwatt™ provides tools for the user to specify geometry directly in the application. This geometry provides context for subsequent data collection, and is included in the energy model export to OpenStudio.

Efficient Mobile Audit Technology

EMAT is a cloud-based tablet and Web product designed to help auditors move quickly through the entire auditing process, including site visit preparation, data collection, data organization and analysis, and report development. The solution provides a Microsoft Windows tablet interface for data collection, and a Web interface for analyzing and creating reports.

Advantages

- EMAT is available for Microsoft Windows tablet devices. simuwatt™ was developed for iOS tablet devices. In response to requests from demonstration sites and companies serving the Federal market, simuwatt™ has included support for Microsoft Windows tablets to its roadmap beyond the ESTCP project period.
- EMAT provides integrated spreadsheet analysis calculations. For the ESTCP demonstration, simuwatt™ focused on generating a whole-building energy model for analysis in OpenStudio, and did not provide a spreadsheet analysis alternative. This limited users who wanted to perform spreadsheet-based analysis. In response to this frequently requested feature, simuwatt™ intends to add spreadsheet analysis capability to its offering.
- EMAT data can be exported to ENERGY STAR® Portfolio Manager for use in building life cycle tracking and ENERGY STAR scoring. simuwatt™ has received feedback from the demonstration sites and industry that connecting with Portfolio Manager is a highly desirable feature. simuwatt™ has added roadmap features to export project data and leverage ENERGY STAR's API for integrated scoring in the simuwatt™ product.
- Customizable reports can be created using the application. In-product report generation contributes significantly to time and cost savings. Today, simuwatt™ uses the OpenStudio software platform as its primary source of analysis, and generates a report from the results using its cloud service. The auto-generated report is in Microsoft Word format, and can be further customized by auditors to add their own

narratives and supporting material. Because reporting represents such a significant opportunity for time and cost savings, simuwatt™ continues to expand its reporting capability and intends to add company-specific reporting capability for more automated customization.

Disadvantages

- EMAT does not offer iOS tablet support. Apple holds the largest market share of the tablet manufacturer market – 32.5% (IDC, April 2014), and holds the second largest market share in mobile operating systems: Android – 61.9%, iOS – 36.0%, Windows – 2.1% (Gartner, February 2014). simuwatt™ was developed with initial support for iPad devices in mind, and will be expanded to support the additional markets to provide an agnostic solution.
- EMAT cannot perform the whole-building energy analysis required to identify interactive effects and opportunities. simuwatt™ explicitly generates a whole-building energy model that can be used in conjunction with extensible, community-driven library measures to perform simple payback or life cycle analysis of design alternatives.
- EMAT lacks building geometry drawing tools. Building geometry, and the locations of rooms and thermal zones within it, have significant impacts on ECM recommendations. simuwatt™ provides tools for the user to specify geometry directly in the application. This geometry provides context for subsequent data collection, and is included in the energy model export to OpenStudio.

3.0 PERFORMANCE OBJECTIVES

3.1 SUMMARY OF PERFORMANCE OBJECTIVES

The three performance metrics tracked for this demonstration were the cost of the audit; the comprehensiveness, completeness, and technical merit of the audit report from the perspective of an energy auditing expert; and the clarity, quality, and usefulness of the audit report from the perspective of a DoD facility/energy manager.

For federal organizations working to comply with the EISA 2007 mandate, the audit cost objective, which encapsulates audit cost savings, is perhaps of greatest importance. Comprehensiveness and clarity objectives are necessary to ensure that the quality of the audit product that DoD receives meets or exceeds that of traditional level I and level II audits.

3.2 PERFORMANCE OBJECTIVE DESCRIPTIONS

Audit Costs – The cost for each audit was calculated based on the time spent and the cost of labor required for each task. The time and cost savings objective is defined as follows:

- Purpose: This objective allows the cost of the new audit method to be compared with that of the traditional audit method.
- Metric: The metric used to quantify this objective was cost intensity ($/ft^2). This is a standard measure of audit cost, used to price out projects and analyze quotes.
- Data: The data required to analyze the objective included auditor man-hours, auditor bill out rates, auditor qualifications, and EISA 432 reporting requirements. These data allowed project costs to be fully generated.
- Analytical Methodology: The analytical methodology was straightforward, requiring only comparison of cost intensities of traditional and simuwatt™ audit processes. To ensure a fair comparison, labor rates for each labor category were held constant between the two test groups.
- Success Criteria: The simuwatt™ team seeks an aggressive cost intensity target reduction of 35% compared to baseline level I and level II audits (see Section 5.2 for baseline cost assumptions). Although a lower reduction would still indicate a significant improvement in the auditing industry, the success criteria for the demonstration will be a 35% cost intensity reduction compared to traditional audit methods.

Audit Comprehensiveness, Completeness, and Technical Merit – Audit reports from both teams were examined by an independent auditing expert to determine:

- Purpose: This objective evaluation was performed by an independent auditing expert and was intended to gauge the quality of the audit report. The results were used to quantify the difference in comprehensiveness between a level II audit performed using a traditional auditing method and an audit performed with simuwatt™.
- Metric: The metric used to qualify this objective was contained in a score sheet that was evaluated by an independent auditing expert. It will be completed for both audit reports. The score sheet (see Appendix D) consisted of nine questions that were designed to identify the most common weaknesses in audits as reported by ASHRAE.

- Data: The data used to qualify this objective were in a score sheet evaluation obtained from an independent auditing expert. The score sheet was used to evaluate the audit report and the underlying energy calculation methodology.
- Analytical Methodology: The analytical methodology used to compare both audit approaches was a comparison of both sets of scores.
- Success Criteria: The success criterion set for simuwatt™ was to have a neutral or positive impact on audit quality compared to traditional approaches.

Audit Report Clarity, Quality, and Usefulness to DoD Personnel – Audit reports from both teams were examined by the responsible DoD staff at each base to determine:

- Purpose: DoD demonstration site facility and energy managers performed this objective evaluation, which was designed to gauge the clarity and usefulness of the audit report. The results were used to quantify the difference in clarity between traditional and simuwatt™ auditing methods.
- Metric: The metric used to qualify this objective was a score sheet (see Appendix D), evaluated by DoD personnel, which was completed for all audit reports. The score sheet consisted of eight questions that were designed to identify clarity and communication effectiveness of the audits.
- Analytical Methodology: The analytical methodology used to compare both audit approaches was a comparison of both sets of scores.
- Success Criteria: The success criterion set for simuwatt™ was to have a neutral or positive impact on audit quality as compared to traditional approaches.
- The three key performance objectives for the demonstration are called out in Table 3.

Table 3. Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Audit Costs	Cost Intensity ($/ft^2)	Auditor man hours, auditor bill out rate, required audit staff qualifications, EISA 432 reporting requirement	35% reduction compared to baseline audit costs	*Success* Phase 1: Average cost of $0.11/ft^2 is a 53% reduction in cost relative to historical DoD audit costs Phase 2: Third party achieved 28% time savings first time using simuwatt™ Energy Auditor

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Qualitative Performance Objectives				
Expert Energy Auditor Review for Comprehensiveness, Completeness, and Technical Merit	Technical audit review	Energy models and/or other audit calculations, audit report/audit data	Favorable audit report review (auditing expert)	*Needs Improvement* Reviews found that simuwatt™ reports were not comprehensive enough Phase 1: Auditing Expert Average score 40.5/80 Phase 2: Auditing Expert Average Score simuwatt™ 45/80 traditional 71/80
DoD Personnel Review for Audit Report Clarity, Quality, and Usefulness	DoD review	Audit report	Favorable audit report review (DoD personnel)	*Mixed* Unfavorable reviews by first two sites but favorable reviews by second two sites Phase 1: DoD Personnel Average Score 49.9/80 Phase 2: DoD Personnel simuwatt™ 71/80 traditional 71/80

4.0 FACILITY/SITE DESCRIPTION

Audits were performed in 12 buildings across five DoD installations. In Phase 1 the NREL team performed audits at 10 buildings across four installations. The initial demonstration plan also called for two to three buildings at Naval Facilities Engineering Command Southeast (NAVFAC SE) in Panama City, FL. However, staffing issues at this location during the demonstration period left them unable to participate. The following section describes the specific buildings audited in Phase 1.

4.1 PHASE 1 – NREL-PERFORMED simuwatt™ ENERGY AUDITORS

- Air Force Academy in Colorado Springs, CO
    - Building 8116/20 – This single-story building was essentially two buildings that were connected by a hallway. One side was primarily low and high bay workshops; the second side was primarily office space with break rooms, restrooms, and conference rooms. The building had separate HVAC systems to serve the two sides. The 8116 side was served by rooftop units (RTUs); the 8120 side was served by a central AHU. The heat was natural gas fueled.
    - Building 4198 – This building contained living spaces, office spaces, and vehicle bays. The facility was served by a central variable air volume (VAV) HVAC system. The spaces were occupied 24/7, as the facility was an operating fire station.
    - Building 6202 – This building was nearly identical in use and function to building 4198.
- Fort Bliss in El Paso, TX
    - Building 20107 – This facility was primarily a high bay vehicle workshop, with some offices and other miscellaneous spaces on the second floor. The systems were all VAV RTUs with direct digital controls (DDCs). The building contained hot and cold spots throughout its spaces. The climate was cooling dominated, so heating was a small part of the building energy usage.
    - Building 20105 – This facility was a battle readiness building, and contained office space, conference space, and two large high bay equipment storage and preparation spaces. The systems were all VAV RTUs with DDCs, except for the high bay spaces, which were served by evaporative coolers.
    - Building 20355 – This was a barracks facility at nearly full occupancy. The building had laundry facilities shared by all occupants, and each double-room suite had a shared kitchen. Each two-room suite was served by a dedicated air source heat pump unit. The rooms included occupancy sensors, which were tied to HVAC schedules.
- Fort Jackson in Columbia, SC (performed in collaboration with a separate Honeywell ESTCP project)
    - Building 9810 – This facility was a counseling center. Most of the spaces were conference rooms, offices, and storage areas. The systems in these buildings were antiquated constant air volume (CAV) central AHUs and had many failed components and operational issues. The pneumatic controls had leaks, and

appeared to be failing in many locations. This building represented a modeling challenge to adequately represent the failed components.
    - Building 10400 – This facility was primarily a classroom building with some office space, locker rooms, and an atrium. This building was only a few years old with efficient CAV HVAC systems. The systems were standard configuration and seemed to be operating appropriately. There were energy recovery units and variable frequency drives on most motors.
- Tyndall AFB in Panama City, FL
    - Building 1060 – This building was a two- story temporary lodging facility containing rooms similar to what would be found in a hotel. The HVAC system was a central CAV AHU with bypass terminals in the spaces. Major loads included lighting and DHW.
    - Building 662 – This was a large two story building which had a variety of space types including office, conference, clinic, storage, and an atrium. This building was all electric, with old pneumatic control systems and constant volume air delivery. The air cooled chiller appeared to be at the end of its useful life.

In Phase 2, two teams of auditors from the same organization each audited the same two buildings, one using their normal auditing process and the other using simuwatt™. The Phase 2 buildings audited at Naval Support Activity Monterey (NSAM) are described here.

4.2 PHASE 2 – HEAD TO HEAD COMPARISON BUILDING DESCRIPTIONS

- NSAM in Monterey, CA
    - Building 259 – This was a very simple building in terms of systems and operation. The building included office and conference space, with most of the spaces broken up into small personal or two person offices. Heating was provided via hot water baseboards. The hot water system was energized from steam off the central plant. There was no cooling system or ventilation system, and all fresh air was introduced via operable windows. The building was formerly a barracks building, constructed in the mid-1900s.
    - Building 330 – This 3 story building was very complex, with a data center, classrooms, offices, break rooms, and storage areas. The systems in the building were very complex, and had been built up over the years as loads had been added to spaces. These included three CRAC units, a water cooled chiller, an air cooled chiller, a cooling tower, fan coils, and baseboards. The building was served steam from the central steam plant for heating.

4.3 FACILITY/SITE LOCATION AND OPERATIONS

Air Force Academy in Colorado Springs, CO – October 4-6, 2013

The first day the simuwatt™ team audited building 8116/20, which was essentially two buildings connected by a hallway. One side was primarily low and high bay workshops, while the second side was primarily office space with break rooms, restrooms, and conference rooms. The building had separate HVAC systems to serve the two different sides. The second day the team audited building 4198, a fire station. This building contained living spaces, office spaces, and vehicle bays. The third day was used to audit building 6202, a building nearly identical to 4198.

Building 8116/20 Building 4198 Building 6202

Fort Bliss in El Paso, TX – November 19-21, 2013

On the first day the simuwatt™ team audited building 20107, which was primarily a high bay vehicle workshop, with some offices and other miscellaneous spaces on the second floor. The second day the team audited building 20105, which was a battle readiness building. This facility was primarily office space, conference space, and two large high bay equipment storage and preparation spaces. The third day the simuwatt™ team audited building 20355, which was a barracks facility at nearly full occupancy. The building had laundry facilities, and shared kitchens for each double room suite.

Building 20105 Building 20107 Building 20355

Fort Jackson in Columbia, SC – December 9-11, 2013

On the first day the team audited building 9810, which was a counseling center. Most of the spaces were conference rooms, offices, and storage areas. The second day the simuwatt™ team audited building 10400, which was primarily a classroom building with some office space, locker rooms, and atrium. The third day the simuwatt™ team audited building 2450, which was a high bay vehicle workshop that was used as a training area for students of the mechanic program. Most of the spaces had heating, but no cooling beyond portable evaporative cooling units. There were some interior spaces which were primarily offices, classrooms, and break rooms all conditioned by RTUs.

Building 2450

Building 10400

Building 9810

Tyndall AFB in Panama City, FL – January 21-23, 2014

Two buildings were audited at the site. The first, building 1060, was a temporary lodging facility that was two stories tall and had rooms similar to what would be found in a hotel. The second building was a large two-story building that had a variety of space types, primarily office, conference, clinic, storage, and atrium. This building was all electric, with old pneumatic control systems and constant volume air delivery.

Building 662

Building 1060

NSAM in Monterey, CA – February 19-21, 2014

NSAM audits were part of the Phase 2 demonstration, and were conducted by two separate teams from an independent auditing firm. Building 259 was primarily office and conference space, most of which were small personal or two person offices. Heating was provided via hot water baseboards. The hot water system was energized from steam off the central plant. There was no cooling system or ventilation system; all fresh air was introduced from the operable windows. The building was formerly a barracks building, constructed in the mid-1900s. Building 330 has three stories and was very complex, with a data center, classrooms, offices, break rooms, and storage areas. There were CRAC units (3), a water cooled chiller (1), an air cooled chiller (1), a cooling tower (1), fan coils, and baseboards.

Building 259 Building 330

4.4 FACILITY/SITE CONDITIONS

The demonstration sites were selected to demonstrate flexibility of the tool to work across multiple system types (old and new), climate zones, and construction types. As discussed below, the sites varied widely in these categories.

Air Force Academy in Colorado Springs, CO – October 4-6, 2013
The buildings at AFA were found to be in good operating condition; however, some of the systems were nearing the end of useful life. 8116 in particular was starting to experience operational issues indicative of replacement age equipment. This location was in climate zone 5B.

Fort Bliss in El Paso, TX – November 19-21, 2013
These buildings were in relatively good operating shape with well-designed and efficient systems. The buildings were constructed 8 years ago, an indication that the systems should be relatively efficient, although in need of retro-commissioning and general maintenance. This location was in climate zone 3B.

Fort Jackson in Columbia, SC – December 9-11, 2013
The systems in building 9810 were antiquated and had many failed components and operational issues. The pneumatic controls had leaks, and appeared to be failing in many locations. Building 10400 was only a few years old with efficient systems. The systems in Building 2450 were standard configuration and seemed to be operating appropriately. This location was in climate zone 3A.

Tyndall AFB in Panama City, FL – January 21-23, 2014
The buildings at Tyndall were equipped with old HVAC systems, all of which were reaching the end of useful life. The technologies are inefficient and are not typically implemented on new construction. This location was in climate zone 2A.

NSAM in Monterey, CA – February 19-21, 2014
Building 259 was a very simple building in terms of systems and operation. Building 330 was very complex, and systems had been built up over the years as loads had been added to the spaces. The variety of systems and vintages created challenges for the controls and operations of the building. This location was in climate zone 3C.

5.0 TEST DESIGN

This energy audit demonstration project included a total 13 buildings at five different DoD sites. Work was completed in two phases as described in the following sections. Phase 1 energy audits were performed by project team members at 11 buildings across four different DoD sites. Phase 2 energy audits were performed by professional energy auditors from a large, well-known energy service company. Phase 2 compared audits of the same two buildings at the Naval Support Activity Monterey site by one team trained to use the simuwatt tool against another team using their traditional auditing process. The sites and buildings selected for Phase 1 and Phase 2 did not overlap.

5.1 PHASE 1 – COMPARISON AGAINST PREVIOUS DoD AUDITS

The goal of the first phase was to test whether the costs of audits performed using simuwatt™ Energy Auditor are lower than those of the typical level I and level II audits performed by DoD. For this phase, the NREL auditing team performed energy audits on 11 buildings at four military installations in several climate zones. The team members recorded the time they spend on each auditing task (outlined in Table 6 in Section 6.1), and then applied a reasonable hourly rate for an energy auditor to determine the costs of the audit when using simuwatt™ Energy Auditor. A reasonable hourly rate of $120/hr for an energy auditor was determined by examining invoices from a set of audits previously performed for DoD. The U.S. Army Corps of Engineers shared cost data from the 2012 EEAP energy auditing initiative with the NREL team, who used these data as a baseline to compare the costs of the simuwatt™ audits with historical costs for DoD audits. DoD representatives from each site were asked to complete a qualitative analysis of the quality and clarity of the Audit Tool report and analysis. This phase allowed the tool to be demonstrated at a wide range of facilities without incurring the expense of auditing each facility twice, which was not possible within the budget.

NREL auditors performed audits on the 11 buildings spanning multiple climate zones at the following locations:

- Air Force – three buildings at the Air Force Academy in Colorado Springs, CO
- Army – three buildings at Fort Bliss, TX
- Army – three buildings at Fort Jackson, SC, where collaboration between the NREL and Honeywell ESTCP projects also occurred
- Air Force – two buildings at Tyndall AFB in Panama City, FL.

The initial demonstration plan also called for three buildings at NAVFAC SE in Panama City, FL. However, staffing issues at this location during the demonstration period prevented their participation.

An additional goal of the Fort Jackson site demonstration involved collaboration with a Honeywell ESTCP project involving a new approach to building control and fault detection. The Honeywell tool requires CAD input, which is not always available for existing buildings. The collaboration used simuwatt™'s geometry capture capability coupled with OpenStudio's ability

to export a gbXML file (building geometry description) for their tool to read. This file was successfully delivered to the Honeywell team in February 2014.

Each site visit was an opportunity to identify and improve upon usability and performance issues associated with simuwatt™. These necessary refinements required additional testing and bug fixes not in the original plan. Although the site visit and data collection at Fort Jackson were performed, complete model calibration, energy analysis, and reporting were not completed for this site because of budgeting constraints. Once the gbXML was delivered to the Honeywell team, the team began to analyze the primary sites. This precluded the Fort Jackson buildings from being included in the analysis of the results later in the report.

5.2 PHASE 2 – HEAD-TO-HEAD COMPARISON

The goal of the second phase was to compare the quality and cost of simuwatt™ audits relative to a traditional process to represent the outcome if simuwatt™ Energy Auditor were used by energy auditors who typically perform audits for DoD. This comparison was executed by two teams of professional energy auditors from a large, well-known energy service company. Both teams had comparable experience performing level II audits. One team used the energy service company's current auditing methodology; the other team was trained to use simuwatt™. Each team independently audited the same facilities at NSAM to the same standard and scope of work. Both teams were requested to use whole-building energy modeling as part of their analyses. The teams were not informed that two sets of audits had been procured and were to be compared. Times to complete key audit tasks are reported in Table 9 (in Section 6.1).

For both phases of the demonstration, a team of representatives from the DoD partner facility and an NREL auditing expert (who routinely performs energy audits of DoD facilities) evaluated the performance objective categories. The audit expert was not connected to simuwatt™'s development, and was asked to provide an independent assessment of the audit reports and recommendations. Audits were judged according to the following criteria: cost, comprehensiveness (as defined by the auditing expert scorecard), and report clarity (as defined by the DoD partner scorecard).

5.3 CONCEPTUAL TEST DESIGN

Unlike equipment demonstrations, the Audit Tool demonstration had no test fixtures, but instead consisted of two teams of auditors, each going through the same building and keeping track of man hours and engineering staff qualifications.

- Independent variable: The variable that changed was the auditing methodology. The experimental group was the team with the simuwatt™ Energy Auditor.
- Dependent variables: The variables that were affected by the independent variable were the man hours required to perform the audit and the quality and comprehensiveness of the audit report. These variables were measured and ultimately used to calculate audit cost intensity ($\$/ft^2$) and audit quality.
- Control variables: The buildings being audited and the scope of work were the control variables. The audit teams (simuwatt™ and traditional) went through the same buildings, collected the same types of information, ran calculations, and had reports reviewed by the

same manager. This helped ensure that the only variable significantly affecting the results was the auditing methodology.

- Hypothesis: The simuwatt™ process will reduce the auditing cost intensity ($/ft^2) by 35% with a neutral or positive effect on audit quality compared to the level I and level II audits currently being performed by DoD.
- Test Design: The test design is described in Section 5.0. Its objective was to determine audit cost savings ($/ft^2) and quality/clarity implications.
- Test Phases: The test design for this project had two phases. Phase 1 was a comparison of the simuwatt™ Energy Auditor with energy audits that have been done previously by DoD. Phase 2 was a head-to-head comparison between simuwatt™ and a traditional auditing process.

5.4 BASELINE CHARACTERIZATION

This project is evaluating a process rather than a physical system; thus, the baseline characterization differs slightly from traditional demonstrations, which rely on metering of performance before and after a technology is applied.

The baseline for cost reduction in Phase 1 was the cost of energy audits that were previously performed at each site. If costs of previous audits for the site were not available, an average cost intensity of $0.20/ft^2 was used. This was derived from cost data for audits procured by DoD in a 2012 EEAP. After an analysis of the EEAP audit costs, NREL found that the initial baseline estimate of $0.10 to $0.15 $/ft^2 for the baseline cost of level I and level II audits performed by DoD was too low. A reasonable total hourly rate of $120/hr for an energy auditor was determined by examining invoices from a set of audits previously performed for DoD. This hourly rate was used to compare audit times in Phase 1 to historical DoD audit costs. Baseline audit costs for Phase 1 are shown in Table 4.

Table 4. Phase 1 Baseline Audit Costs

Building	Area (ft^2)	Cost Intensity of Past Audit ($/ft^2)	Baseline Cost ($)
USAFA 8116 and 8120	52,820	$0.20*	$10,564
USAFA 6202	8,611	$0.20*	$1,722
USAFA 4198	9,784	$0.20*	$1,957
Fort Bliss 20105	48,675	$0.33	$16,063
Fort Bliss 20107	31,751	$0.33	$10,478
Fort Bliss 20355	51,592	$0.33	$17,025
Fort Jackson 2450	94,075	$0.20*	$18,815
Fort Jackson 9810	40,966	$0.20*	$8,193
Fort Jackson 10400	23,041	$0.20*	$4,608
Tyndall AFB 662	81,402	$0.20*	$16,280
Tyndall AFB 1060	34,000	$0.20*	$6,800

*No past audit cost data were available from these sites. An average cost intensity of $0.20/ ft2 from EEAP studies performed in 2012 was used.

The baseline for cost reduction in the Phase 2 audits at NSAM was the time recorded by the audit team using the traditional energy auditing method. This time was compared to the time recorded by the simuwatt™ Energy Auditor team. Assuming both teams have approximately equal hourly rates, savings in time directly relate to savings in audit cost.

5.5 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

The first part of this demonstration project was the combination of four previously developed components to create simuwatt™ (see Section 2.1). Because this project demonstrates a combination of software and process, the description of the layout is simple: a team of energy auditors went to the site with tablets that had simuwatt™ Energy Auditor installed. These auditors conducted an in-brief meeting with the relevant facility managers and key site personnel, walked through the facilities gathering information, conducted an out-brief meeting, and left the site. Model calibration and ECM analysis were performed offsite using OpenStudio; reports were automatically generated by uploading key OpenStudio results to a simuwatt™ cloud service.

5.6 OPERATIONAL TESTING

For each demonstration site during both phases, the test procedure was as follows:

Onsite Activities

1. Conduct in-brief meeting for key site personnel.
2. Conduct walk-through audits of the buildings to collect data.
3. Conduct out-brief meeting for key site personnel.

Offsite Activities

1. Calibrate building energy model to monthly utility data.
2. Perform analysis of ECMs.
3. Generate template audit report.
4. Elaborate on template audit report and send to site.

For each building audited, the time for each step was collected. After the audit reports were finished, they were reviewed for clarity by the DoD site representative and for quality by the independent auditing expert.

Table 5. Operational Testing Dates

Location	Date
Air Force Academy – Colorado Springs, CO	11/4/2013
Fort Bliss – El Paso, TX	11/19/2013
Fort Jackson – Columbia, SC	12/9/2013
Tyndall AFB – Panama City, FL	1/21/2014
NSAM – Monterey, CA	2/19/2014

5.7 SAMPLING PROTOCOL

As described in the demonstration plan, the sampling protocol for this project consisted of traveling to the demonstration sites (see Figure 9), performing audits in multiple buildings, and

comparing the results with the appropriate baseline. The demonstration sample was designed to incorporate different building types, climate zones, system types, and building controls. The objective of this sample was to demonstrate simuwatt™'s flexibility and adaptability under typical use conditions.

Figure 9. Map of Sampling Locations

5.8 SAMPLING RESULTS

Two sites in the initial demonstration plan were not able to participate in this project. The U.S. Military Academy in West Point, New York was not able to participate because staff were unavailable. To substitute for loss of this site, a demonstration was added at the Fort Bliss in El Paso, Texas. The NAVFAC SE demonstration site was also unable to participate in the study because staff were unavailable. This did not present a significant impact to the project, as Tyndall Air Force Base was located in the same vicinity, providing comparable climate zone, system type, and construction type coverage. Thus, the NAVFAC SE demonstration site was removed from the study.

6.0 PERFORMANCE ASSESSMENT

The three performance metrics for this project were life cycle audit cost, report clarity, and comprehensiveness. These metrics were determined for both Phase 1 and Phase 2. Phase 1 results show that the overall average cost savings was 53% relative to historical DoD audit costs. Phase 2 results show a 28% reduction in time for the team using simuwatt™ versus the traditional approach. When recording time, only productive analysis hours were recorded. Time spent identifying and fixing software issues during the course of the demonstration was so that a more accurate picture of how the market-ready tool will perform could be presented. Details about tasks excluded in time reporting are detailed in the following section.

6.1 PHASE 1. COMPARISON AGAINST PREVIOUS DoD AUDITS

This project involved first integrating several existing software technologies into a new software tool for energy auditing, and then demonstrating this new tool in real buildings. One of the unique challenges of software development is anticipating and planning for the complexity of all situations likely to be encountered in normal operation. This was particularly true when producing a tool to handle all the variability and conditions found in buildings. One of the unique differences between the demonstration of software and the demonstration of equipment that software can be changed quickly in response to new situations. Although testing was performed prior to Phase 1, the realities of field testing uncovered scenarios that had not been considered during initial design. The following narrative describes how the team addressed these issues at each demonstration site.

Air Force Academy in Colorado Springs, CO – October 4-6, 2013
This was the first DoD site visit, and presented the team with its first issue, a lack of Internet connectivity. Although the tool was designed for offline use, the first step—downloading aerial imagery of the building—still requires a network connection. The team determined that downloading the imagery at the office prior to the site visit was the surest way to avoid this issue. The team also noted that the tablet with a built-in cellular connection sidestepped this issue. For the remaining site visits, a quick call to the site contact could usually determine cellular coverage at the facility, letting the team know which approach to rely on. A second issue involved the shortcomings in simuwatt™'s geometry capture capability and translation to energy model geometry. The team also encountered HVAC systems and control strategies that had not been anticipated, minor issues with the note-taking capability, and other minor software problems. During this visit, the team also recognized that tablet battery life, portability, and durability were important considerations when working in mechanical rooms, on roofs, etc. A heavy-duty case with a shoulder strap addressed all these issues in subsequent visits. The battery of the iPad tablets lasted all day, and was easily recharged for work the following day.

Issues with building geometry and HVAC systems required manual correction of the resulting energy models before analysis could begin. The time required for these corrections was not included in the reported time because they were subsequently addressed by software improvements.

The analysis of ECMs using OpenStudio requires that the modeling strategy, list of assumptions, and cost inputs be defined in a small, self-contained script known as an *OpenStudio Measure*.

Because this was the first analysis, the ECMs that the team wanted to analyze had not yet been written and added to the BCL for easy access. Creating these ECM scripts required additional effort that was not included in the reported time, as future simuwatt™ audits are anticipated to draw from a prepopulated library of OpenStudio Measures.

Lastly, the automatic report generator during this early demonstration was nascent, and produced a document that fell far short of the team's expectations. The idea behind simuwatt™ is that the report generator automatically creates a report that is 80% complete, and that the user spends only a few hours adding a custom narrative. The team elected to spend this intended budget (4 hours) making the report as complete as possible. The state of the report generator at this early stage is reflected in the comprehensiveness and clarity metrics shown in Tables 7 and 8 (in Section 6.1).

Fort Bliss in El Paso, TX – November 19-21, 2013

The second site visit reflected significant improvement in the software's performance and usability. Most of the geometry issues from the first site visit were corrected, enabling the buildings to be modeled rapidly with the HVAC systems accurately represented. A major issue during this site visit was data loss between the tablet and simuwatt™ server. In the process of syncing the project data, a significant subset of the collected data was lost or corrupted. Data about HVAC systems, lighting, plug loads, schedules, and occupancy were partially or fully affected. After the site visit, but before discovering the data issue, software updates on the tablets erased the only complete datasets, leaving only partial datasets on the server available. Such data loss would be a critical failure in production software, and the simuwatt™ team placed immediate software and process controls in place to prevent further incident. Aside from this, only a few minor issues with note taking, HVAC system zoning, and automated model generation were identified during this visit.

After identifying the nature and extent of the data loss issue, the team manually re-entered lost data so that the rest of the analysis could be completed for this site. Time for data re-entry was not included in the reported time because software and process solutions to the data loss problem were identified and implemented for future audits.

Because some of the ECMs the team wanted to analyze overlapped with the first site, the process was faster; however, a few additional Measures needed to be created. As in the first site audits, this time was not reported because the team assumed that a rich library of measures will be available in the BCL for rapid access by auditors.

Due to the effort required to address the data loss issue, few improvements in the automated report generator had been implemented since the previous site audits. This is reflected in the comprehensiveness and clarity metrics shown in Tables 7 and 8.

Fort Jackson in Columbia, SC – December, 9-11, 2013

The third site visit happened in close succession to the second site visit, with many of the same issues and problems. Data loss issues had been resolved, but issues with note taking, HVAC system zoning, and automated model generation quality remained. One of the buildings presented a new challenge in automatically modeling failed HVAC components.

The analysis of this site did not begin immediately because outstanding software issues had to be addressed before the next demonstration, and the remaining work and budget needed to be assessed. The team then determined that the analysis and report results could not be completed for this site. This was due to overall project financial constraints, not software limitations. Consequently, although the site visits were performed and models were generated and exported for Honeywell's ESTCP project, analysis for these buildings was not performed and audit reports were not produced. As a result, Fort Jackson results are not reported in Tables 4, 7, and 8.

Collaboration with Honeywell Building Information Modeling Builder ESTCP Project

ESTCP identified a related research program awarded to Honeywell. The goal of the Honeywell Building Information Modeling (BIM) Builder project is to create 3-D BIM representations of buildings from 2-D drawings in DWG format. The Honeywell project took place at Fort Jackson, which is one reason the simuwatt™ team chose this site. The simuwatt™ tool was particularly attractive in cases where BIM Builder had no suitable as-built CAD model to use as input. We explored the potential of integrating simuwatt™ and BIM Builder to improve the ability to generate spatial reference models for buildings without existing documentation of the architecture and assets. Each team shared data from their processes and tools, and explored the merits and challenges of combining the different approaches.

simuwatt™ stores building geometry data in a custom 2-D representation. The simuwatt™ representation of spaces defined during an audit is translated to a full 3D OpenStudio representation for energy analysis. The 3-D OpenStudio representation can then be exported to several formats including gbXML, which is a common interchange format for 3-D spatial information related to energy models. BIM Builder currently requires 2-D drawings (.DWG) as its native input in order to begin constructing a model of the facility. Therefore, the gbXML data exported by OpenStudio required a translation into a readable .DWG file. The Honeywell team tested three software packages, DDS-CAD Viewer version 8.0 (Data-Design-System-Computer-Aided Design) and Autodesk AutoCAD (2013 and 2014 releases) and Revit (2013 release) for their ability to read in gbXML data and save the information in a DWG format.

DDS-CAD Viewer was able to read in the gbXML file and provided functionality to export the project as a .DWG. The resulting .DWG was used as the source drawing for a new building model in BIM Builder, which was successfully read by BIM Builder during the import stage, but with significant loss of information. Exterior and interior walls were displayed well enough to portray the correct shape of the facility, but when attempting to use the imported drawing data, the required vector primitives could not be found by the Honeywell software. It was determined that the DWG data retained the 3-D information during translation, and these 3-D faces and surfaces could not be discovered and extracted by the current version of BIM Builder. Similar results occurred when using the Autodesk software tools.

A few options could be explored that would enable these tools to exchange data more effectively:

- **Create a gbXML import plug-in for BIM Builder:** The plug-in would read gbXML and translate it directly to the required dataset(s) so that the basic Industry Foundation Classes (IFC) model can be constructed.
- **Create an IFC plug-in for BIM Builder:** An IFC plug-in could be used in the case where gbXML data are first translated into IFC format from another software tool, and that IFC is then read by BIM Builder.
- **Create an IFC import plug-in for simuwatt™:** If simuwatt™ is the preferred tool for energy performance analysis, significant time could be saved in the field by preloading simuwatt™ with an existing model of the facility. It might be helpful for simuwatt™ to accept IFC input as there are other sources of IFC data. The simuwatt™ team would need to add this feature.
- **Create a 2D DWG export from simuwatt™:** This export would be more natural from simuwatt™ than OpenStudio because simuwatt™ already stores geometrical data in a 2-D representation. These 2-D DWG files could be imported into BIM Builder.

Both tools produce suitable lightweight models for energy analysis and asset management. Although simuwatt™ is useful in the absence of CAD, BIM Builder is most useful when a reasonably consistent as-built model can be obtained. If DoD specifies the form in which it wants to manage building geometry data in the long term, software vendors will more readily be able to justify the expense of creating or improving data exchange paths between their applications.

Tyndall AFB in Panama City, FL – January 21-23, 2014

This site visit was dual purpose. It was a combination of an audit demonstration site, and training activity for the auditors from the third-party auditing firm who would be the key performers in Phase 2. The training activity was broken into three modules, each presented on a different day. Day 1 focused on the overarching architecture of simuwatt™ and workflow, day 2 was a hands-on field trial of simuwatt™, and day 3 was an explanation of the analysis procedure and interactions with the OpenStudio software suite. Many of the issues that had been encountered at the previous site visits were fixed prior to this site visit. The only issues encountered at this site were minor workflow disruptions.

During the analysis for this site, many of the ECMs that needed analysis overlapped with the first sites, meaning that even fewer Measures needed to be created anew for this analysis. At this point, it became clear that future audit analysis time and cost will be reduced as a rich library of ECMs is made available online. The team's response to software issues continued to take precedence over improvement of the report generator.

Phase 1 Analysis

The time to complete auditing tasks was recorded during each site visit in the Phase 1 tests. These times are presented in

Table **6**. When recording time, only productive analysis hours were recorded. Time spent identifying and fixing software issues during the course of the demonstration was not included in order to present a more accurate picture of how the market-ready tool will perform.

Table 6. Phase 1 Audit Time and Costs

Task	Site 1			Site 2			Site 3	
	AFA 8116 / 8120	AFA 6202	AFA 4198	Fort Bliss 20105	Fort Bliss 20107	Fort Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662
Site Visit (hrs)	12	6	6	8	8	8	8	8
Make Energy Model (hrs)	8	8	8	7	10	7	8	6
Calibrate Energy Model (hrs)	10	10	8	4	4	4	32	8
Run ECMs (hrs)	10	10	10	10	10	10	8	8
Write Audit Report (hrs)	4	4	4	4	4	4	6	6
Total (hrs)	44	38	36	33	36	33	62	36
Total Cost ($) At $120/hr	$5,280	$4,560	$4,320	$3,960	$4,320	$3,960	$7,440	$4,320
Baseline Cost ($/ft^2)	$0.20	$0.20	$0.20	$0.33	$0.33	$0.33	$0.20	$0.20
Building Area (ft^2)	52,820	8,611	9,784	48,675	31,751	51,592	34,000	81,402
Baseline Cost ($)	$10,564	$1,722	$1,957	$16,063	$10,478	$17,025	$6,800	$16,280
Total Cost ($) at $120/hr	$38,160							
Total Baseline Cost ($)	$80,889							
Cost Savings (%)	53%							

*Does not include results for Fort Jackson because analysis and audit reports were not completed at that site

DoD is unique in that the EISA mandate requires that buildings to be audited once every 4 years. For that reason, audits must be redone frequently. Currently, if the auditing firm changes or if the previous audit data cannot be found, the entire data collection process must be repeated. One advantage of simuwatt™ Energy Auditor is that in the future, previous audits could be retrieved from the simuwatt™ database and serve as a starting point for the future audit. The cost-savings potential of such a workflow is estimated below.

The Phase 1 audit times were averaged across all the Phase 1 sites in Table 7. Based on experiences during the Phase 1 audits, times to complete each of the tasks in future years assuming a previous simuwatt™ audit were also estimated in Table 7. The time to complete the site visit was reduced considerably, assuming that the building's geometry and basic inventory have not changed substantially, only minor updates are required. Multiple buildings are assumed to stand on each site to audit, so the amount of fixed travel time per building is not significant. Once the site visit is complete, simuwatt™ generates an initial energy model that the auditor needs to verify and complete. The time to finalize this energy model could be reduced considerably if these steps were performed by simuwatt™. However, simuwatt™ currently has no facilities to reduce the manual time required to complete and verify the energy model.

Therefore, at this time no cost savings were assumed here. Calibrating the energy model is assumed to be faster in future years because the previous calibration measures can be used without modification. Similarly, the process of running the ECMs should be reduced because many previous ECMs have already been defined; only price and performance inputs need be updated. Finally, writing the audit report is assumed to take less time because sections written manually for the previous audit may be reused. With all these assumptions, a future simuwatt™ audit would presumably take ~50% less time than the first simuwatt™ audit. This improvement is on top of the improvements of the first simuwatt™ audit over the traditional approach. This estimate also does not consider future improvements to simuwatt™ Energy Auditor.

Table 7. Phase 1 Audit Time and Subsequent Audit Estimate

Task	Phase 1 Average (hrs)	Subsequent Audit Estimate (hrs)
Site Visit	8.0	2.0
Make Energy Model	7.8	8.0
Calibrate Energy Model	10.0	4.0
Run ECMs	9.5	4.0
Write Audit Report	4.5	2.0
Total (hrs)	39.8	20.0
Time Savings (%)	50%	

Each audit report was reviewed by a DoD facility or energy manager at the relevant site. The goal of this assessment was to qualify the quality of the reports by the ultimate customer of the product. Table 7 summarizes this feedback. For each item, the possible score was 10/10. The actual review forms are attached in Appendix X of the final report because some of the forms also include valuable written feedback about the reports. The Tyndall reports were reviewed by two DoD personnel; their scores are averaged in Table 7.

Each audit report was also reviewed by an independent expert in energy auditing who has personally performed many DoD audits. This reviewer was involved in the project in this capacity only, and was uninvolved in the design or development of simuwatt™. The goal of this review was to evaluate the comprehensiveness and technical merit of the report, specifically the analysis methodology supporting it. Table 8 summarizes the reviews. For each item, the possible score was 10/10. The actual review forms are attached in the appendix.

Table 8. Phase 1 Audit Report Clarity Review by DoD Site Personnel

Criteria (out of 10)	Site 1			Site 2			Site 3		
	AFA 8116 / 8120	AFA 6202	AFA 4198	Ft Bliss 20105	Ft Bliss 20107	Ft Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662	Average
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc.	8	9	9	5	5	5	10	10	7.6
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing.	8	8	8	1	1	1	9	9	5.6
Report is concise, easy to read, and easy to navigate.	9	9	9	8	8	8	9.5	9.5	8.8
Existing conditions are explained well, and recommendations are detailed and clear.	5	6	6	4	4	4	10	10	6.1
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included.	5	5	5	0	0	0	9.5	9.5	4.3
Report does not include recommendations that were eliminated by the site staff during the site visit.	10	10	10	7	7	7	10	10	8.9
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources.	5	5	5	2	2	2	10	10	5.1
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating.	2	2	2	1	1	1	9.5	9.5	3.5
Total (maximum of 80)	52	54	54	28	28	28	77.5	77.5	49.9

*Does not include results for Fort Jackson because analysis and audit reports were not completed at that site

Table 9. Phase 1 Technical Audit Comprehensiveness Review by Auditing Expert

Criteria (out of 10)	Site 1			Site 2			Site 3		
	AFA 8116 /8120	AFA 6202	AFA 4198	Ft Bliss 20105	Ft Bliss 20107	Ft Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662	Average
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc.	7	7	7	7	7	6	7	7	6.9
Energy savings calculations are valid and assumptions are reasonable. Issues such as invalid calculation methods, poor assumptions, and neglecting interactive effects should be noted.	3	3	3	3	3	3	8	8	4.3
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, and dialogue surrounding anomalies.	5	5	5	5	6	6	8	8	6.0
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc.).	2	2	2	2	3	2	3	3	2.4
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation.	2	2	2	2	2	2	8	8	3.5
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities.	5	5	5	5	5	4	6	6	5.1
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life.	3	3	3	3	3	3	3	3	3.0

Criteria (out of 10)	Site 1			Site 2			Site 3		
	AFA 8116 /8120	**AFA 6202**	**AFA 4198**	**Ft Bliss 20105**	**Ft Bliss 20107**	**Ft Bliss 20355**	**Tyndall AFB 1060**	**Tyndall AFB 662**	**Average**
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement.	3	3	3	3	3	3	7	7	4.0
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types	5	5	5	5	5	4	7	7	5.4
Total (maximum of 80)	35	35	35	35	37	33	57	57	40.5

*Does not include results for Fort Jackson because analysis and audit reports were not completed at that site

6.2 PHASE 2. HEAD-TO-HEAD TEST

NSAM in Monterey, CA – February 19-21, 2014

The two audits performed at this site – Buildings 259 and 330 – served as the primary demonstrations for this ESTCP project. In contrast to the prior audits performed by the project staff, a third-party auditing firm provided two teams to participate in a blind study. The team trained on the simuwatt™ workflow at Tyndall AFB would use simuwatt™, and an additional team would serve as the control, performing the same audits using traditional methods. Both teams were given the same general project requirements and a requirement to develop energy models as a part of the effort. The team trained on the simuwatt™ workflow leveraged OpenStudio and the control team used eQuest.

Because limited training was provided with a new software workflow, the project team joined the auditor to provide support for any software- or workflow-specific questions. No direction was provided in identifying opportunities for improvement in the facility.

Improvements were made after the earlier demonstrations; thus, very few software-related issues arose during this site visit. Building 259 was a relatively simple facility, while Building 330 had more complex mechanical systems. The auditor using simuwatt™ successfully specified the attributes of the building and encountered no software issues.

Even though this audit went smoothly, the simuwatt™ developers listened to the comments of the third-party auditors as they used the tool. It was clear from their comments that one of the biggest time-saving features, the audit space type binning tool, was not presented clearly in the user interface, and was therefore used less than it could have been. However, the overarching feedback provided by the third-party auditing firm was positive. The primary points of improvement identified by the party were:

- Enable additional audit application outputs (e.g., spreadsheet) to support a variety of analysis methodologies.
- Provide support for multi-auditor site visits and data sharing.
- Provide Web browser, Microsoft Windows, and Android tablet support for the application.

The value proposition of the simuwatt™ workflow was clear to the auditor. However, a transition from using spreadsheets to using energy modeling for all analysis efforts presented the biggest perceived adoption barrier. The team trained to use simuwatt™ held expertise in HVAC auditing and primarily performed analysis via spreadsheet. The data collection requirements of an audit that will feed into a spreadsheet analysis workflow vary substantially from one that will use energy modeling. With this in mind, the simuwatt™ auditor would have benefited from additional time to master the new tool and workflow. Also, translating common data collection methods into a software survey interface changes the paradigm for how information is recorded. The typical approach often includes handwritten notes, photographs, sketched floor plans, and documents from the building owner. The notes feature, which enabled input of text information, photographs, and videos, lends itself the most to traditional methods. The team trained on the simuwatt™ workflow tended to fall back on the familiar process, so in some cases there was an

overreliance on the notes feature to record data. In these cases, the auditor transcribed these notes daily into the appropriate inputs in the application. The simuwatt™ team anticipates that these practices will change as auditors become more familiar with the tool and workflow.

As in Phase 1, the reports were reviewed by site DoD personnel. In this case, the reports from the traditional team (baseline) and the simuwatt™ team were reviewed simultaneously. The goal of this side-by-side comparison was to see whether the simuwatt™ Energy Auditor produced a report that was on par with that created by the traditional team.

As in Phase 1, each audit report was also reviewed by an expert in energy auditing who has personally performed many DoD audits. This expert reviewer was not involved in the project in any other way. The goal of this review was to evaluate the technical merit of the report, specifically the analysis methodology supporting it. Table 10 through Table 12 summarize the review. For each item, the possible score was 10/10. The actual review forms are attached in the appendix.

Table 10. Phase 2 Audit Time and Costs

Task	Traditional Team	simuwatt™ Team
	NSAM 259 and 330	NSAM 259 and 330
Site Time (hrs)	16	16
Analysis Time (hrs)	75	64
Report Time (hrs)	50	21
Total (hrs)	141	101
Total Cost ($) at 120 $/hr	$16,920	$12,120
Cost Savings (%)	28%	

Table 11. Phase 2 Audit Report Clarity Review by DoD Site Personnel

Criteria (out of 10)	Traditional Team		simuwatt™ Team	
	NSAM 259	NSAM 330	NSAM 259	NSAM 330
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc.	9	9	8	8
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing.	8	8	8	8
Report is concise, easy to read, and easy to navigate.	10	10	9	9
Existing conditions are explained well, and recommendations are detailed and clear.	10	10	10	10
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included.	8	8	8	8
Report does not include recommendations that were eliminated by the site staff during the site visit.	10	10	10	10
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources.	7	7	8	8
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating.	9	9	10	10
Total (maximum of 80)	71	71	71	71

Table 12. Phase 2 Technical Audit Comprehensiveness Review by Auditing Expert

Criteria (out of 10)	Traditional Team		simuwatt™ Team	
	NSAM 259	NSAM 330	NSAM 259	NSAM 330
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc.	9	9	8	8
Energy savings calculations are valid and assumptions are reasonable. Issues such as invalid calculation methods, poor assumptions, and neglecting interactive effects should be noted.	8	8	5	5
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, and dialogue surrounding anomalies.	9	9	4	4
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc.).	10	10	5	5
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation.	9	9	5	5
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities.	9	9	5	5
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life.	0	0	3	3
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement.	8	8	5	5
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types	9	9	5	5
Total (maximum of 80)	71	71	45	45

7.0 COST ASSESSMENT

7.1 COST MODEL

Cost to perform an energy audit was one of the key performance metrics of this demonstration. As described in detail in Section 3.0, the average cost of an audit using simuwatt™ was $0.11/ft^2. Historical DoD audit costs for comparable audits were $0.20/ft^2. As described in Table 7, subsequent audits performed using simuwatt™ are expected to be 50% less expensive than the initial simuwatt™ audit.

NREL was involved in the development and demonstration of simuwatt™ Energy Auditor for the purposes of this ESTCP demonstration. The version of the software used during the demonstration is owned by concept3D. Moving forward, simuwatt™ Energy Auditor is being commercialized and offered by concept3D as a Software as a Service with a monthly fee and pricing for total square footage of space audited using the software. Base pricing for simuwatt™ Energy Auditor is $399/month for a single user account/license. This license fee includes access to the service, maintenance, guaranteed availability, minor feature enhancements, and a limited amount of building square footage audited, and storage of photos and videos. As shown by the data in Tables 6 and 7, the average simuwatt™ audit time is around 40 hours per building. With this assumption, an auditor could be expected to perform around four audits per month. Amortizing the monthly simuwatt™ cost across these four audits, the simuwatt™ cost is around $100 per building. Taking this additional cost under consideration does not significantly change any of the cost savings metrics reported in this study.

7.2 COST ANALYSIS AND COMPARISON

The DoD-wide cost estimates in this section assume that the report quality issues identified in the previous sections can be addressed by future software development, and that addressing these issues will not significantly impact the time required to perform an audit with simuwatt™ Energy Auditor. Based on the size of the DoD portfolio, there is an enormous cost savings potential in using simuwatt™. Based on the need to audit the DoD building stock every 4 years, Table 13 below shows the potential direct energy audit cost savings over 25 years.

Table 13. Direct Audit Cost Savings Across DoD Portfolio over 25 Years

	Traditional		simuwatt™		
	$/ft^2	DoD* (Million $)	$/ft^2	DoD* (Million $)	DoD Savings (Million $)
Initial Audit	$0.20	$380	$0.11	$209	$171
Yr 4 Recurring Audit	$0.20	$380	$0.05	$95	$285
Yr 8 Recurring Audit	$0.20	$380	$0.05	$95	$285
Yr 12 Recurring Audit	$0.20	$380	$0.05	$95	$285
Yr 16 Recurring Audit	$0.20	$380	$0.05	$95	$285
Yr 20 Recurring Audit	$0.20	$380	$0.05	$95	$285
Yr 24 Recurring Audit	$0.20	$380	$0.05	$95	$285
Net Present Value of Total DoD Portfolio Audit Cost Savings at 3% discount rate					$1286 million
Annual Savings over 25 years					$51 million

*Based on DoD footprint of 1.9 billion ft^2

On average, energy audits find about 30% energy savings opportunities in buildings. Assuming that audits performed with simuwatt™ find a similar amount of savings potential in each building, and assuming that 10% of the identified measures are implemented, Table 14 shows the potential annual energy and energy cost savings that could result from energy audits DoD-wide.

Table 14. Indirect Annual Energy and Energy Cost Savings from Energy Audits

	Building Area (ft^2)	Annual Energy Cost ($)	Annual Site Energy Use (Billion Btu)
EISA 2007 covered facilities	1,900,000,000	$ 3,700,000,000	207,000
Audit 25%/yr	475,000,000	$ 925,000,000	51,750
Identify 30% savings per facility		$ 277,500,000	15,525
Implement 10% of savings identified		$ 27,750,000	1,553
Annual savings enabled by auditing 25% of covered facilities		$28 million	1,553 Billion Btu

Using the $399/auditor-month license fee given by concept3D, Table 15 gives an estimate of the annual license fee that would be required to cover the DoD portfolio. This estimate does not factor in bulk-pricing discounts, which may lower costs, or the implementation issues identified in Section 8, which may increase costs. This estimate should only be interpreted as the starting point for a discussion.

Table 15. Estimate of Annual Software Cost to Cover DoD Portfolio

EISA 2007 covered facilities	1,900,000,000	ft^2
Audit 25%/yr	475,000,000	ft^2
Area per Auditor per Month	200,000	ft^2/auditor-month
Annual Labor	2,375	auditor-months
Software Cost	$ 399	$/auditor-month
Annual Software Cost Estimate	$ 947,625	

Based on the $50 million in annual savings potential from direct energy audit cost savings alone, the $1 million annual software license would provide a simple payback of less than 1 week for DoD. Even if the savings estimates are 100% too high and the cost estimates are 100% too low, the simple payback would be well under a year.

Finally, additional savings are expected in reduced audit review costs due to the standardized report format and calculation methods. The current cost to DoD to review energy audit reports is unknown, so these cost savings are not included in Table 15.

7.3 COST DRIVERS

The analysis in Sections 7.0 and 7.1 show that the software costs for simuwatt™ are minimal compared to the cost savings from automating the analysis and reporting portions of an energy audit. These cost savings should be sufficient to allow third-party auditors to incorporate simuwatt™ into their practices and still pass along substantial cost savings to DoD. However, to encourage adoption of simuwatt™ by third-party auditors, DoD must consider additional issues, which are described in Section 8. Depending on how these issues are addressed, there may be additional cost to DoD.

8.0 IMPLEMENTATION ISSUES

Based on the results of this demonstration it appears that, once improvements to the report generator are completed, simuwatt™ has the potential to help DoD achieve lower cost, consistent, high-quality energy audits. The most likely pathway for DoD to achieve these savings would be to require or encourage third-party contractors to use simuwatt™ Energy Auditor for performing energy audits. However, certain DoD installations might choose to purchase and use simuwatt™ directly. The issues that are important to address in a DoD-wide implementation follow.

8.1 DATA SECURITY

The most common concern that the team heard during the course of the project was data security. The simuwatt™ team understands that many DoD energy audits are performed by third-party contractors, and although these contractors are not allowed to share audit data freely, security requirements for protecting this information are limited. Further, their computers are not subject to the same rigorous software and network security policies that DoD-owned computers are. The fact that these data come in many formats and are dispersed across many computers owned by many third-party contractors would appear to set few standards for current DoD audit data security. It would be important for DoD to engage the simuwatt™ development team in defining and implementing sufficient data security strategies. This may be limited to minor security improvements to the private sector cloud solution or expanded to a DoD-specific cloud solution leveraging Amazon Web Services Government Cloud Computing that adheres to U.S. International Traffic in Arms regulations as well as the Federal Risk and Authorization Management Program requirements.

8.2 DATA OWNERSHIP

If DoD required third-party contractors to use simuwatt™, it would be important to address the issue of data ownership. Currently, third-party auditors collect data, perform analysis, and then submit the analysis results to DoD. To achieve the long-term portfolio-wide benefits of using simuwatt™, DoD would need to negotiate with the third-party energy auditors to secure ownership of the analysis results and of the collected building data. This would ensure that if auditor A performed the initial audit and DoD contracted auditor B to perform the recurring audit, auditor B would be able to start where auditor A ended, rather than starting over. Third-party contractors are able to export data from simuwatt™ for delivery to DoD via an XML file type as well as OpenStudio file type. DoD might also require third-party contractors to destroy their copies of the audit data for security purposes.

8.3 TRAINING

Any procurement discussion must involve the cost of training auditors to use simuwatt™ Energy Auditor. If third-party contractors were to procure and use the software, they may need to bear this burden. If DoD were to mandate the software, the third-party contractors might expect DoD to pay for this training. Training videos and product information will be made available on both simuwatt™ and OpenStudio websites, and simuwatt™ and OpenStudio certified trainers will

provide custom trainings at a fee. Based on the limited experience of training one team of energy auditors to use simuwatt™ Energy Auditor during this demonstration, auditors should require no more than a few days to learn the software.

A Standard Library of Measures

In its current state, simuwatt™ uses the DOE's OpenStudio energy modeling platform to analyze ECMs. If DoD wants consistency and transparency in the way that a particular ECM was analyzed by a wide variety of contractors, DoD should consider identifying a standard library of OpenStudio Measures, small, self-contained scripts that contain the energy modeling logic, assumptions, and cost input fields to represent a specific ECM. OpenStudio and BCL can enable this level of control via tagging of preferred content. Understanding the underlying assumptions would give DoD greater confidence that it could realize the savings predictions provided by its contractors. Many national laboratories, utilities, and private sector energy modelers are now publishing measure content in the BCL. Additionally, DoD could work with the simuwatt™ development team or other contractors to define and tag DoD-approved OpenStudio Measures.

Availability on the General Services Administration Schedule

For DoD to most readily procure simuwatt™ Energy Auditor directly, the software needs to be listed on the General Services Administration Schedule. concept3D has begun the process of getting on contract with Information Technology Schedule 70 and expects to be awarded by mid-2015.

Use of simuwatt™ and OpenStudio on DoD Tablets and Computers

Currently, simuwatt™ and OpenStudio have not gone through the Department of Defense Information Assurance Certification and Accreditation Process to vet their use on DoD tablets and computers. This would need to be addressed if DoD were interested in having its own auditors use simuwatt™ or OpenStudio themselves. However, most audits are currently performed by third-party contractors, where this is not an issue.

Maintenance and Upgrades

If DoD procures a version of the software independently of the private sector offering, but does not want to procure further updates, regular support and maintenance of the version procured will require negotiations with simuwatt™ that may result in additional fees.

9.0 CONCLUSIONS

The goal of this ESTCP project was to integrate several existing auditing and software technologies into a single, tablet-based software tool for energy auditing that could be used at DoD facilities, and demonstrate that the tool could help an energy auditor perform an ASHRAE level II audit and achieve a 35% cost reduction compared to audits typically procured by DoD without sacrificing quality.

The software integration goal of this project was achieved. Project team members demonstrated simuwatt™ Energy Auditor in 11 buildings across 4 DoD sites, and a third-party energy auditor with minimal training used it successfully in 2 buildings at the final site. Additionally, connections between simuwatt™ Energy Auditor and the BCL were successful, allowing access to high-quality, standardized energy modeling components. Data collected during the simuwatt™ audit were successfully transferred to OpenStudio for detailed energy analysis using the EnergyPlus simulation engine. Standardized energy efficiency measures from the BCL were used to perform life cycle calculations. Data from this process were presented in an automatically generated, standardized report.

The Phase 1 demonstrations achieved an average cost savings of 53% compared to past DoD audits, more than meeting the cost savings target. However, DoD and expert third-party review of the audit reports produced during this phase indicated that the quality of the automatically generated audit reports was not sufficient for DoD's needs. Reviewer comments indicated that the content missing from the reports is in fact captured during the simuwatt™ audit. Therefore, this content could be added to the automatically generated audit reports and would be expected to improve the quality of these documents. The Phase 2 head-to-head demonstrations led to similar conclusions. A 28% time reduction was found for the team using simuwatt™ Energy Auditor over the traditional approach, and the DoD review of the simuwatt™ team's audit report found that it was of similar quality to the traditional team's report. However, the expert auditor review found that the simuwatt™ team's report was less comprehensiveness than the traditional team's report.

After reviewing all comments, it is clear to the development team that more effort must be spent to improve automated report generation. When the simuwatt™ calculation methodology was explained during review debriefs, the reviewers had a much higher opinion of the analysis results. The main issue was that this information was simply not presented in the reports. Improvements to quality as well as clarification of calculation methods and assumptions in the generated report are anticipated in future versions of simuwatt™.

Based on the demonstration results, assuming the aforementioned report quality issues can be addressed by future software development without significantly impacting the time required to perform an audit, simuwatt™ Energy Auditor shows enormous potential for direct energy audit cost savings to DoD. In the 4-year period of auditing all DoD buildings with simuwatt™ initially, the projected DoD-wide savings is estimated at $171 million ($43 million annually). This savings level is substantially larger than the estimated software cost of approximately $1 million annually, and indicates that DoD could recognize significant energy audit savings through the use of simuwatt™.

Although the first-time audit cost and the audit report quality were the main focus of this demonstration, there are additional benefits that simuwatt™ would provide to DoD, including:

- The data collection process is standardized and the resulting data are owned and controlled by DoD. This means that future energy audits, such as those performed every 4 years to comply with the EISA 2007 mandate, would have a significant head start in collecting data. The recurring audits would simply be updates rather than entirely new investigations. The team estimated that reusing previous simuwatt™ audit data would reduce the time needed to complete a future audit by an estimated 50%. A 25-year estimate of DoD-wide auditing costs shows that the life cycle cost savings have a net present value of approximately $1.3 billion. This estimate does not include further savings associated with reduced audit review costs resulting from the standardized report format and calculation methods. DoD would be able to compare buildings portfolio wide to find opportunities and economies of scale that may currently go unnoticed.

- DoD can compare a portfolio of buildings to find opportunities and economies of scale that may currently go unnoticed.

- The data can be leveraged for other uses. For example, energy auditors commonly record detailed inventories of equipment, space usage, and building condition. This information could be tied to facility maintenance systems and used to develop operations and maintenance plans.

- The building energy models could be used to support automated fault detection and diagnostics and used to support model-based control strategies.

concept3D has identified software improvement opportunities through additional site visit activities with NREL, DoD partners, and third-party companies that serve the public and private sectors. concept3D has incorporated this feedback into its simuwatt™ product roadmap, expanding its capabilities to serve a broader market of energy auditing use cases and maintain a standardized data gathering and energy modeling approach. These improvements are expected to improve the quality of simuwatt™ reports and spur simuwatt™ adoption in the energy auditing community. Key areas of future development for simuwatt™ include:

- A lighter weight application to support a broader range of iOS, Android, Windows, and Web devices including full size tablets, mini tablets, laptops, desktop computers and more.

- A centralized project data source for multiple contributors to share project data, perform team audits of the same facility or campus, track revision history, and easily reuse project data for future audits or other applications.

- Support level I to level III energy audits by offering export options to spreadsheet analysis while continuing to export to energy modeling platforms such as OpenStudio.

- Connect to other related technologies such as ENERGY STAR Portfolio Manager to allow for reuse of data and further streamlining of the energy audit process.

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Appendix A: Points of Contact

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Appendix B: Audit Report Summary

A total of 8 audits were completed during the demonstration of the simuwatt Energy Auditor software. This section summarizes the results of the audits and the savings that were analyzed from the 69 energy conservation measures that were identified. Full reports from the audits can be found in Appendix C.

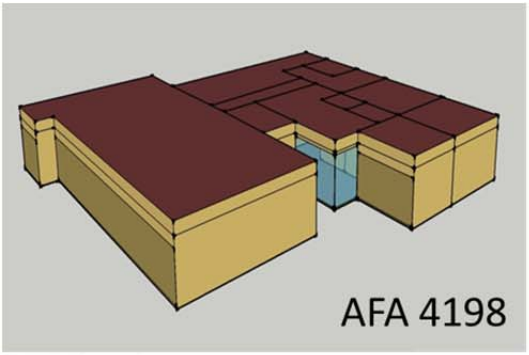
The table below shows the bundled savings from all ECMs identified for each of the demonstration sites. Ft. Bliss was found to have the most economically feasible opportunities. The annual electrical savings were found to represent approximately a 26% reduction compared to the baseline electricity consumption. The annual natural gas savings were found to represent approximately an 11% reduction compared to the baseline natural gas consumption.

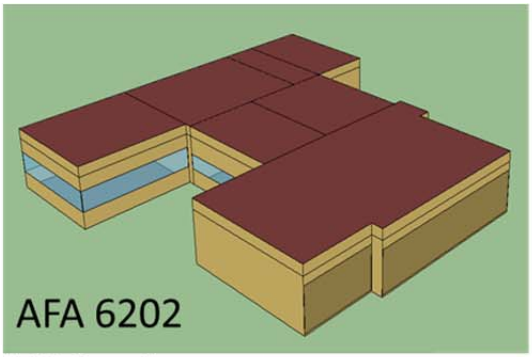
	Quantity of Measures Identified	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Annual Cost Savings ($/yr)	Installation Cost ($)	Simple Payback Period (yrs)
Tyndall 1060	9	103,369 (21%)	131 (13%)	$8,744	$450,360	52
Tyndall 662	10	218,450 (34%)	0 (0%)	$16,014	$794,348	50
Bliss 20355	5	32,611 (9%)	0 (0%)	$2,763	$53,566	19
Bliss 20107	10	44,580 (15%)	(-1.06) (-1%)	$3,182	$43,608	14
Bliss 20105	7	103,733 (31%)	33 (4%)	$10,578	$48,746	5
AFA 8116/8120	14	299,786 (35.9%)	2,445 (60.5%)	$25,665	$935,529	36
AFA 6202	7	61,033 (34.5%)	38 (4.0%)	$3,783	$114,214	30
AFA 4198	7	60,783 (31.2%)	183 (9.7%)	$4,222	$114,214	27

The table below shows the cumulative savings from all ECMs identified by building energy system type. HVAC was found to have the largest quantity of ECMs identified (25) and plug loads was found to have the second largest quantity, with 22 ECMs identified during the demonstrations. However, lighting ECMs were found to be the most economically viable with a payback period of 10 years. Domestic hot water and envelope ECMs were found to have the longest payback periods and lowest quantity of ECMs identified.

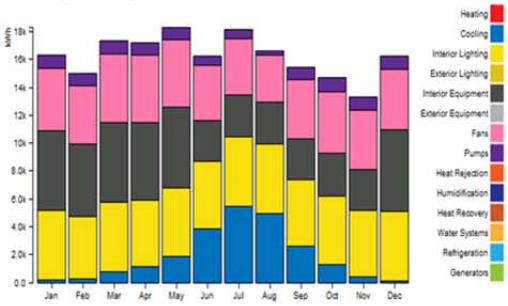
	Quantity of Measures Identified	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Annual Cost Savings ($/yr)	Installation Cost ($)	Simple Payback Period (yrs)
Lighting	16	243,155	-243	$16,442	$159,517	10
HVAC	25	382,708	1,023	$33,225	$931,972	28
Plug Loads	22	256,320	-135	$16,813	$696,440	41
Envelope	5	82,820	1,111	$8,488	$767,318	90
Domestic Hot Water	1	0	7	$62	$8,000	129

The simuwatt data was translated into OpenStudio energy models, which were used for the analysis of energy conservation measures. The figures below show the 3-D rendering of the building, the electrical and natural gas (if applicable) consumption by end uses, and the calibration graphs for modeled versus utility data.

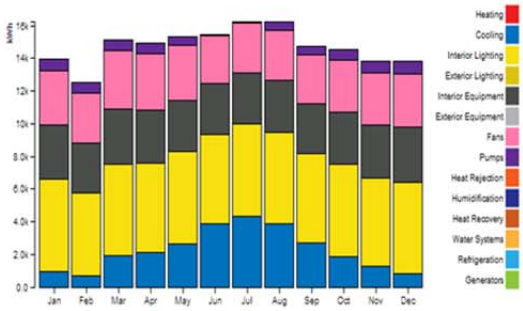




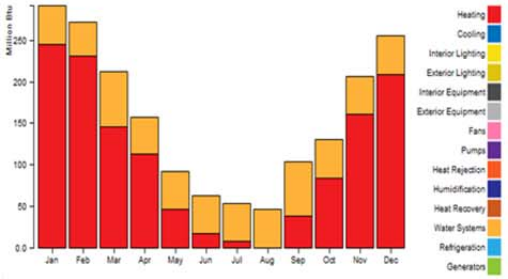
Electricity Consumption



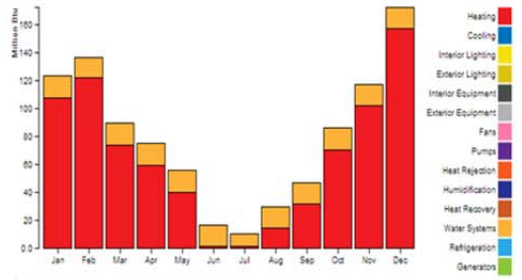
Electricity Consumption



Natural Gas Consumption



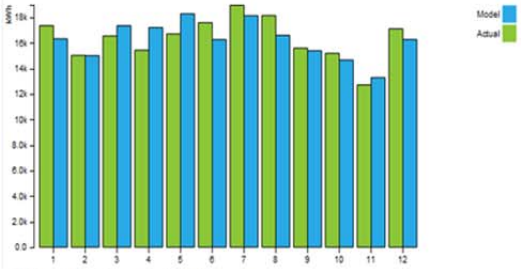
Natural Gas Consumption



Electricity Consumption (kWh)

CV(RMSE) = 6.77

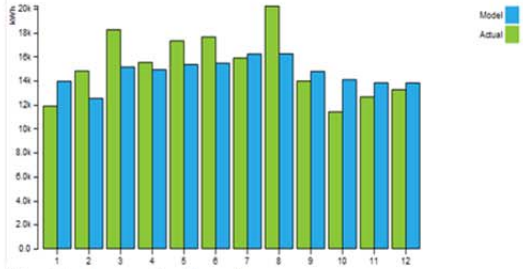
NMBE = 0.87



Electricity Consumption (kWh)

CV(RMSE) = 14.49

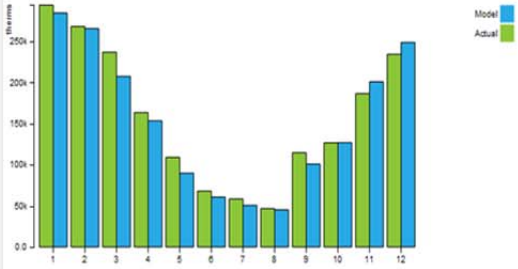
NMBE = 3.88



Natural Gas Consumption (therms)

CV(RMSE) = 8.81

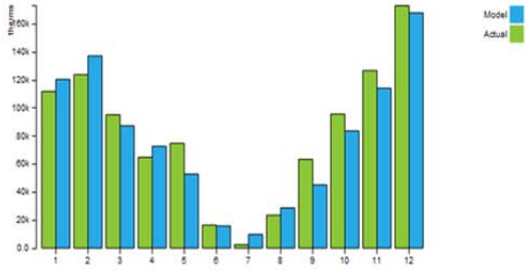
NMBE = 4.15

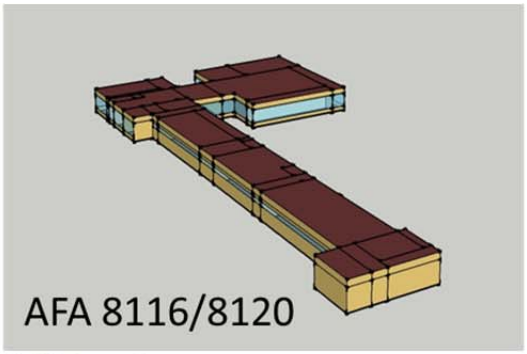


Natural Gas Consumption (therms)

CV(RMSE) = 14.89

NMBE = 4.05

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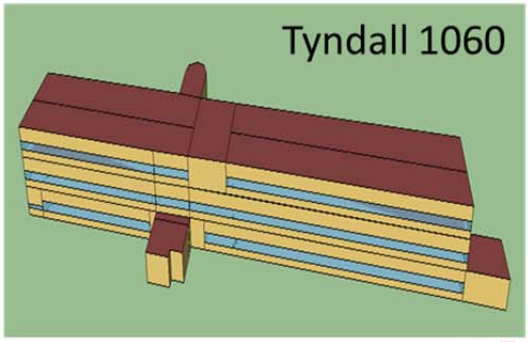
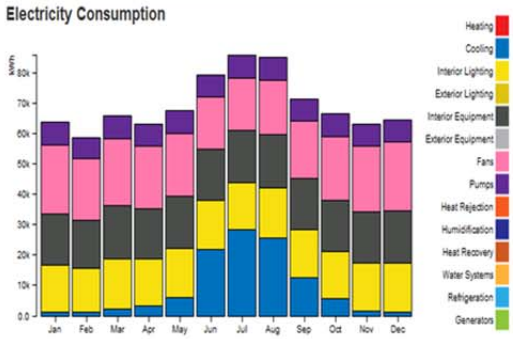
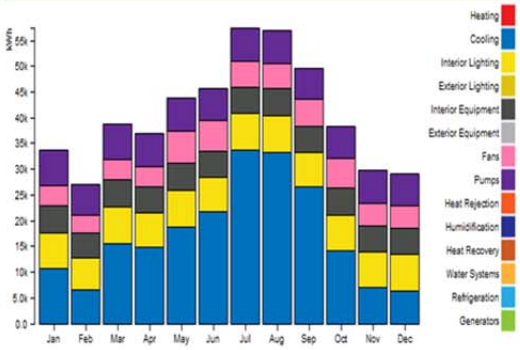

Tyndall 1060


Electricity Consumption
kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
Heat Rejection
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
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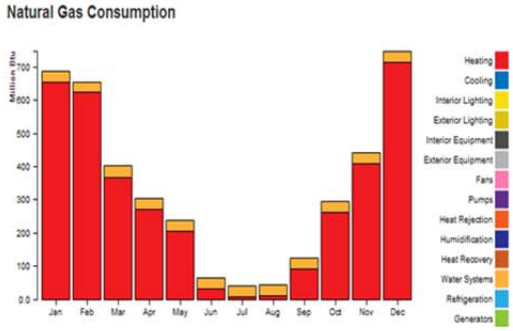
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


Natural Gas Consumption
Million Btu
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
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Pumps
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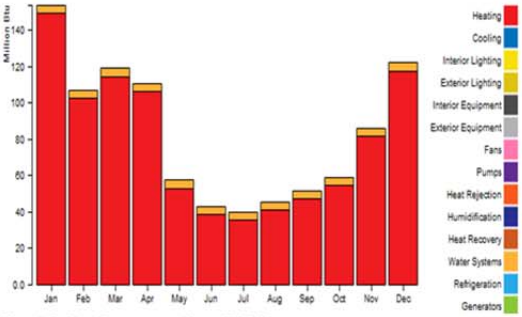
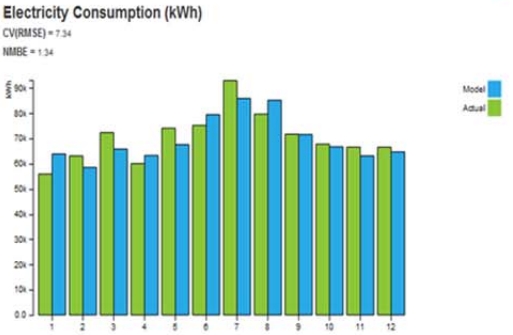
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


Million Btu
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
Heat Rejection
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators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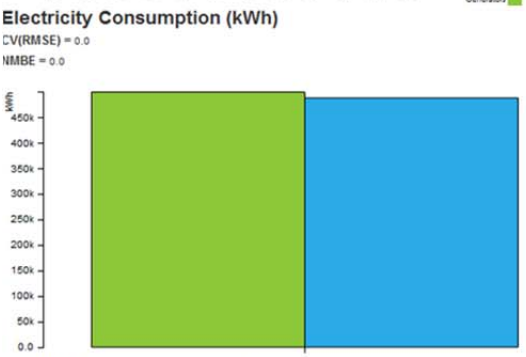
NMBE = 1.34
kWh
Model
Actual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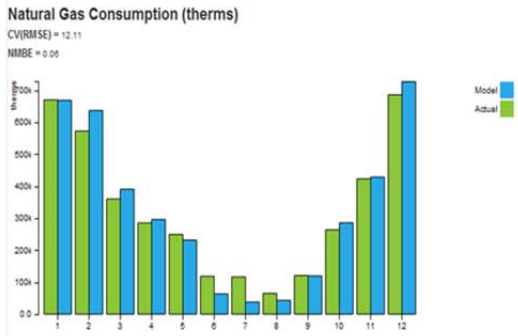
NMBE = 0.0
kWh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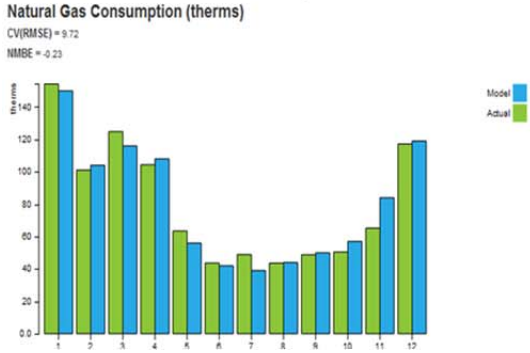
NMBE = 0.06
therms
Model
Actual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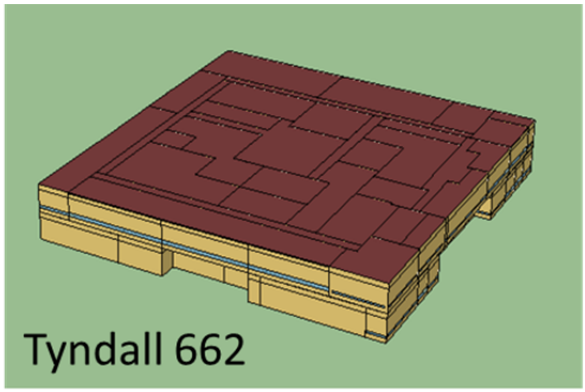
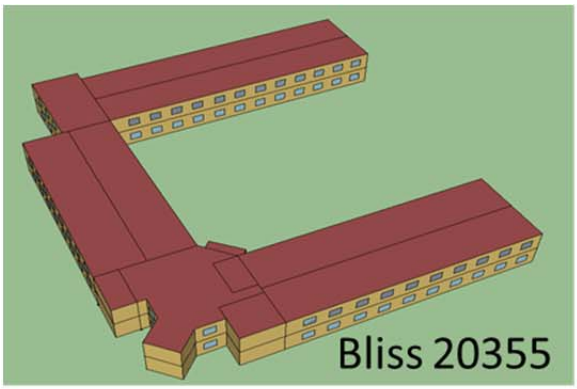
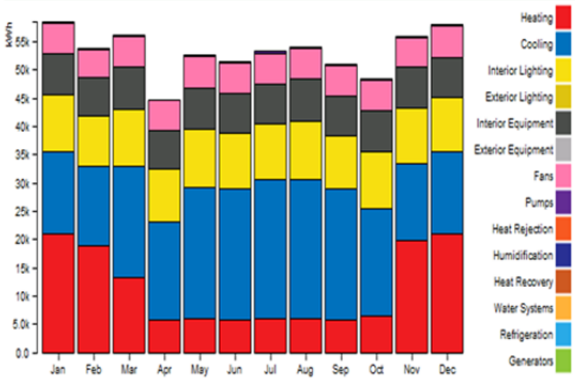
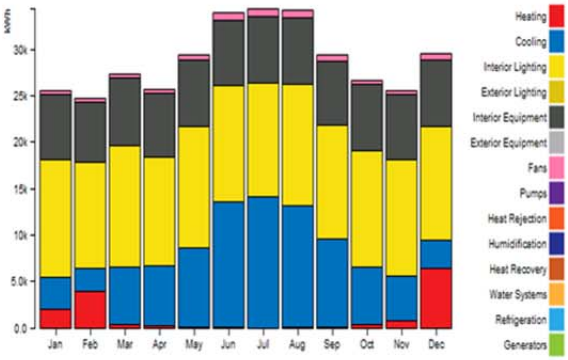
therms
Model
Actual


Tyndall 662


Bliss 20355


kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
Heat Rejection
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
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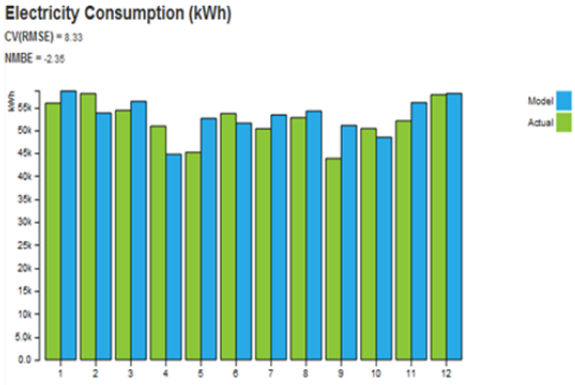
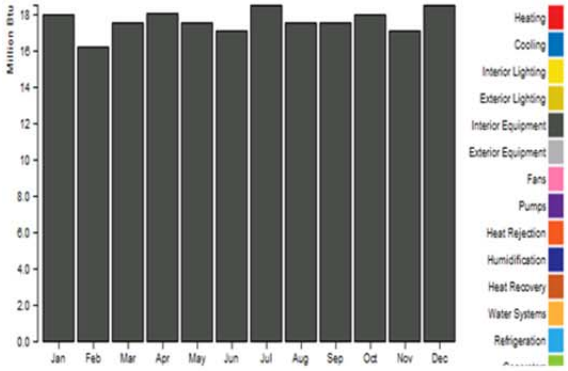
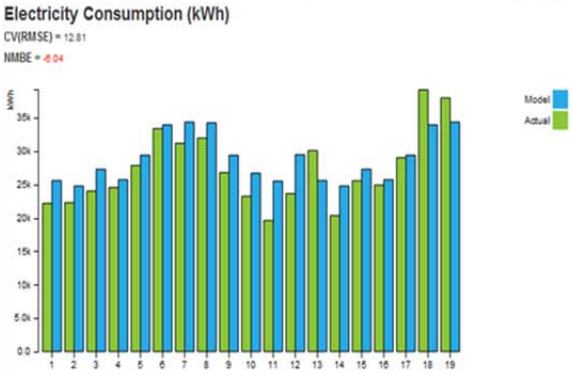
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


Electricity Consumption (kWh)
CV(RMSE) = 8.33
NMBE = -2.35
kWh
Model
Actual


Million Btu
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
Heat Rejection
Humidification
Heat Recovery
Water Systems
Refrigeration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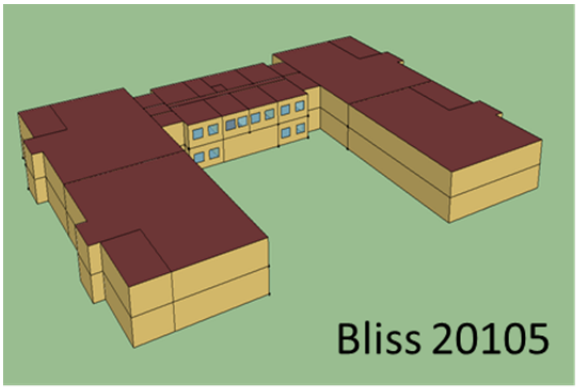
CV(RMSE) = 12.81
NMBE = -6.04
kWh
Model
Actual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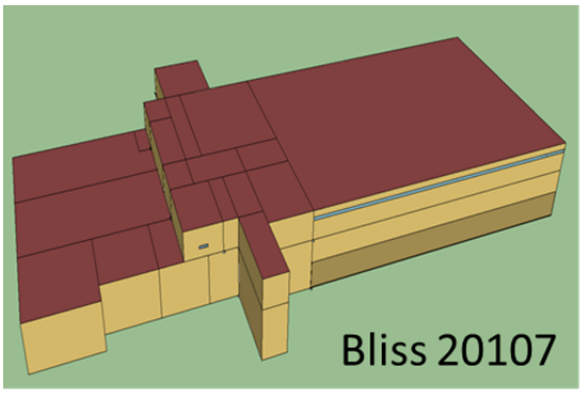
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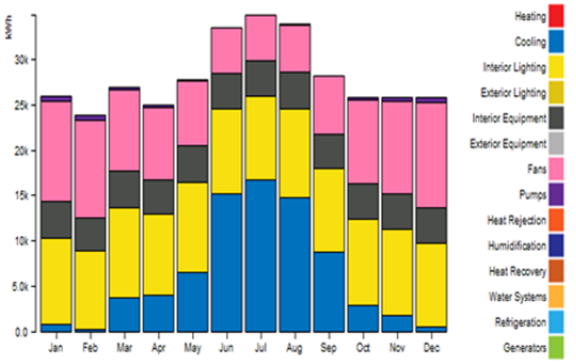
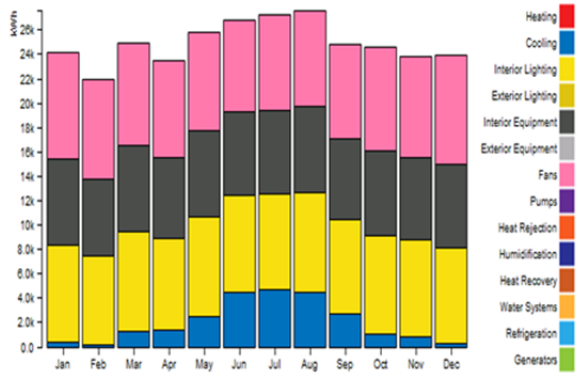

kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
Heat Rejection
Humidification
Heat Recovery
Water Systems
Refrigeration
Generators


kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
Exterior Equipment
Fans
Pumps
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Heat Recovery
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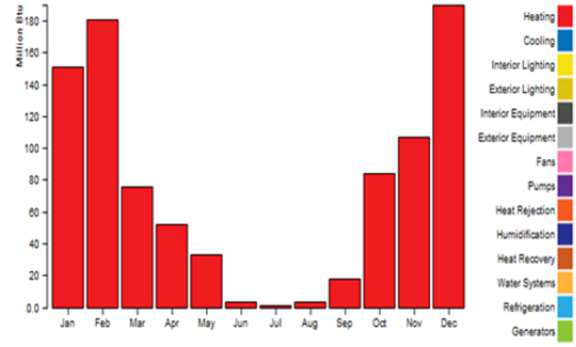
Refrigeration
Generators


Million Btu
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
Exterior Lighting
Interior Equipment
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Fans
Pumps
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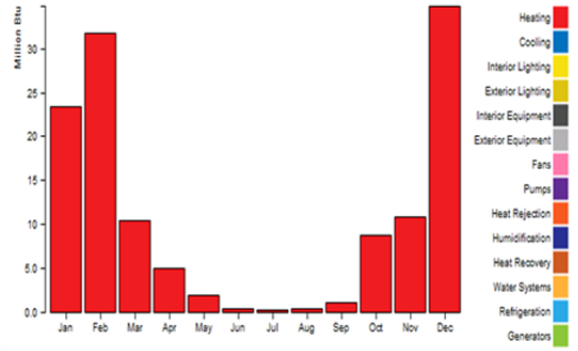
Heat Recovery
Water Systems
Refrigeration
Generators


Million Btu
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Heating
Cooling
Interior Lighting
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Interior Equipment
Exterior Equipment
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Heat Rejection
Humidification
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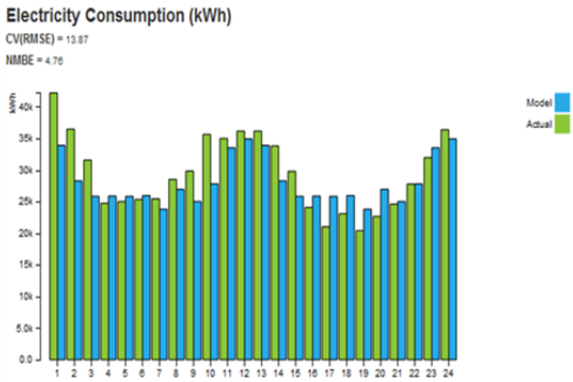
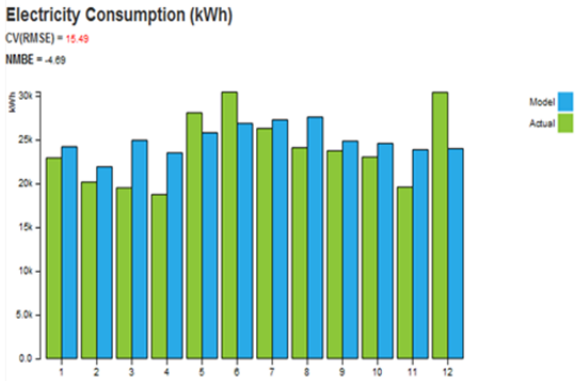
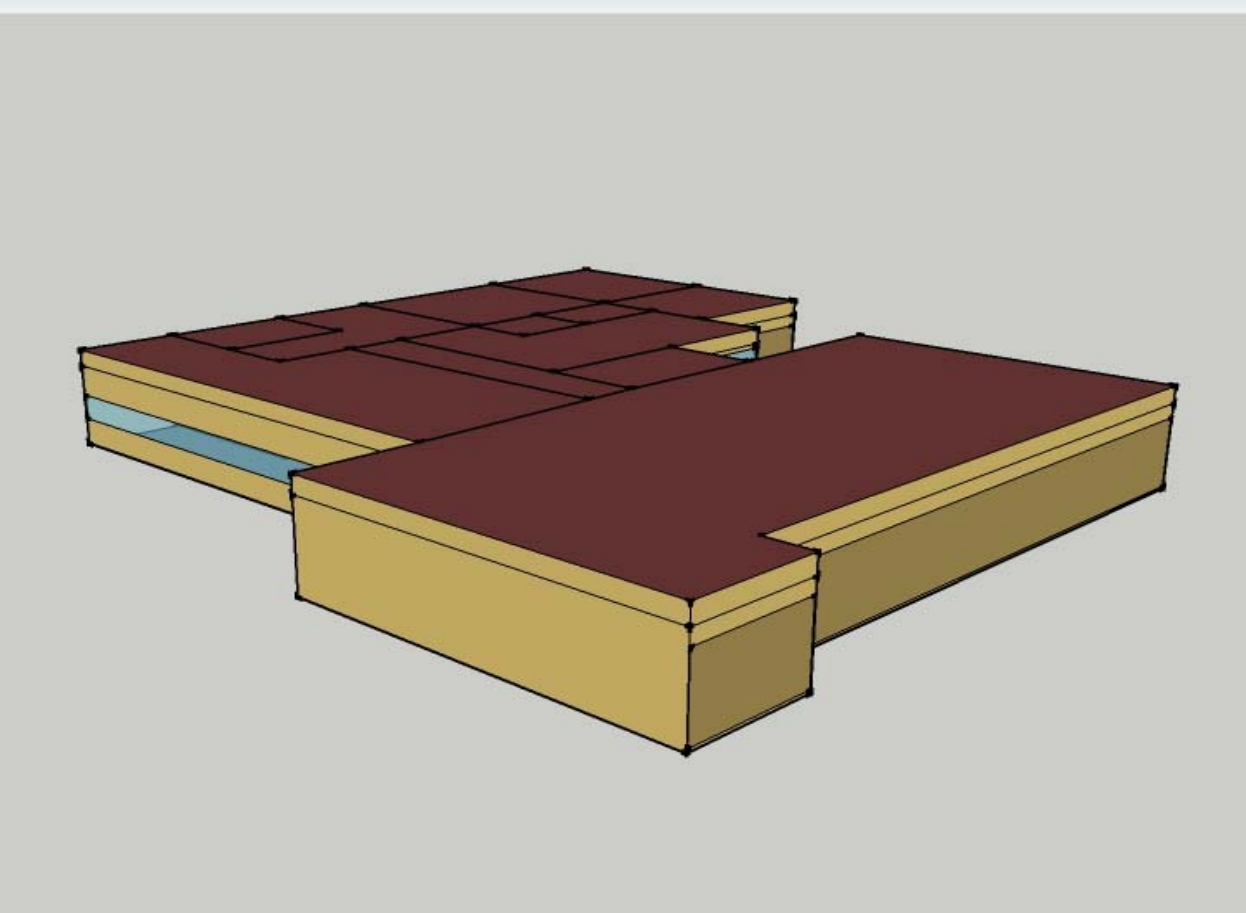

Electricity Consumption (kWh)
CV(RMSE) = 13.87
NMBE = 4.76
kWh
Model
Actual


Electricity Consumption (kWh)
CV(RMSE) = 15.49
NMBE = -4.69
kWh
Model
Actual

Appendix C: Full Audit Reports

AFA 4198
Energy Audit Report

3116 Academy Drive, Air Force Academy, CO 80840, USA



Wednesday, May 28, 2014

Prepared By: simuwatt Energy Auditor

EXECUTIVE SUMMARY

The following report summarizes the results from the AFA 4198 Energy Efficiency and Renewable Energy Site Assessment of the AFA 4198 building in 3116 Academy Drive, Air Force Academy, CO 80840, USA. During the site visit, the team identified 7 energy conservation, water conservation, and renewable energy measures. Many of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

The AFA 4198, constructed in 1983, is a 9,784 ft^2 structure with 1 floor. The building serves primarily as fire station.

ENERGY USAGE OVERVIEW

The electricity, natural gas and water at the AFA 4198 is provided by Colorado Springs Utilities. The 2011 utility usage for the building is given in the table below.

	Electricity (kWh)	Natural Gas (CF)
Jan-2011	17,360	294,200
Feb-2011	15,040	268,200
Mar-2011	16,560	237,000
Apr-2011	15,440	163,600
May-2011	16,720	109,000
Jun-2011	17,600	68,100
Jul-2011	18,960	58,500
Aug-2011	18,160	46,800
Sep-2011	15,600	114,700
Oct-2011	15,200	126,700
Nov-2011	12,720	186,600
Dec-2011	17,120	234,500

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. Details of the calculations and assumptions for each ECM are presented in later sections of this report.

Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings(kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio
Bundled ECMs with < 10 year simple payback	28,719.44 (14.7%)	220.70 (11.7%)	2,416.20	6,510.00	2.69	0.4
Bundled all ECMs	60,783.33 (31.2%)	182.95 (9.7%)	4,221.60	114,214.00	27.05	0.0

Lighting Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
Install low-wattage T8 lighting	15,111 (7.8%)	(-34.68) (-1.8%)	798	4,650.00	5.8	0.2

HVAC & DHW Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
Implement Thermostat Setbacks at Night	11,941.67 (6.1%)	253.97 (13.4%)	1,513.80	120.00	0.08	12.6
Improve Fan Drive Efficiency	994 (0.5%)	(-0.88) (-0.0%)	57	240.00	4.2	0.2
CAV w/ Reheat to VAV w/ Reheat	35,786 (18.4%)	(-34.14) (-1.8%)	2,040	70,944.00	34.8	0.0
Constant Speed to Variable Speed Pump	858 (0.4%)	(-2.79) (-0.1%)	43	5,500.00	128.8	0.0

Plug Loads Conservation Measures – Summary

ECM Name	Annual Electricity	Annual Gas	Total Annual	Total	Simple	Savings to

	Savings (kWh/yr)	Savings (MMBtu/yr)	Savings ($/yr)	Installed Cost ($)	Payback Period (yrs)	Investment Ratio (%)
Replace desktop computers with laptops	4,061 (2.1%)	(-4.87) (-0.3%)	228	31,500.00	138.0	0.0
Computer power management	2,036 (1.0%)	(-2.44) (-0.1%)	114	1,500.00	13.1	0.1

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LIGHTING ENERGY EFFICIENCY MEASURES 66
HVAC EFFICIENCY MEASURES 67
PLUG LOADS CONSERVATION MEASURES 69

INTRODUCTION

Climate Data

AFA 4198 is located at 3116 Academy Drive, Air Force Academy, CO 80840, USA. The site is at latitude and longitude of approximately 38.99, and -104.87, respectively.

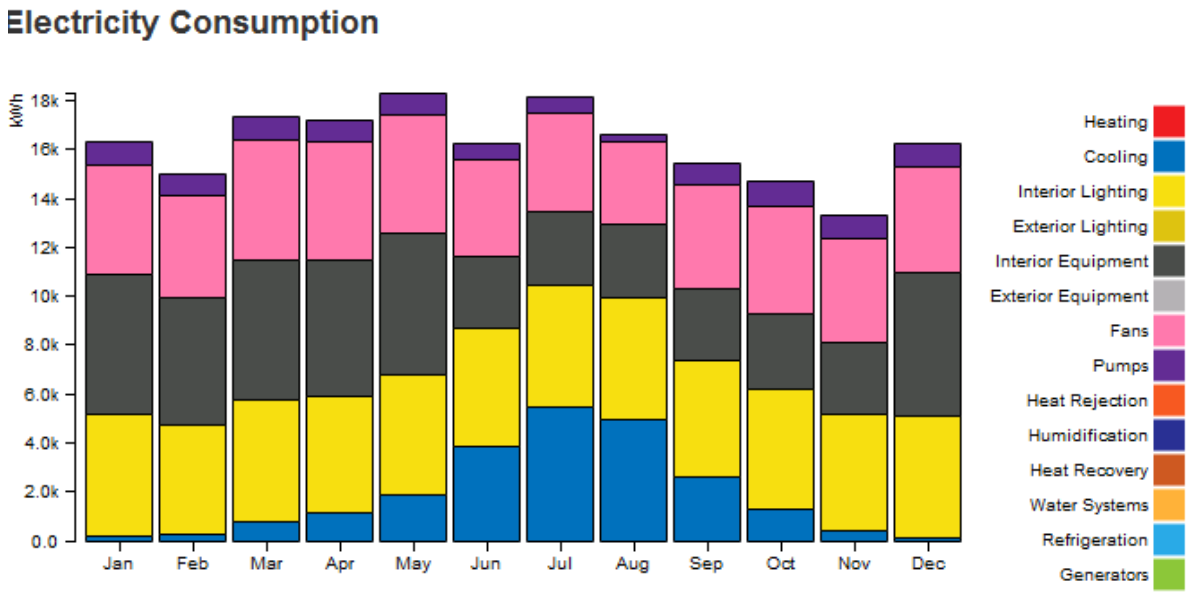
Energy Use and Utility Data

The electricity, natural gas and water at AFA 4198 is provided by Colorado Springs Utilities. The blended utility rates for electricity and natural gas were calculated to be $0.06/kWh and $0.314/cf, respectively. The utility use for the campus is given in the tables below.

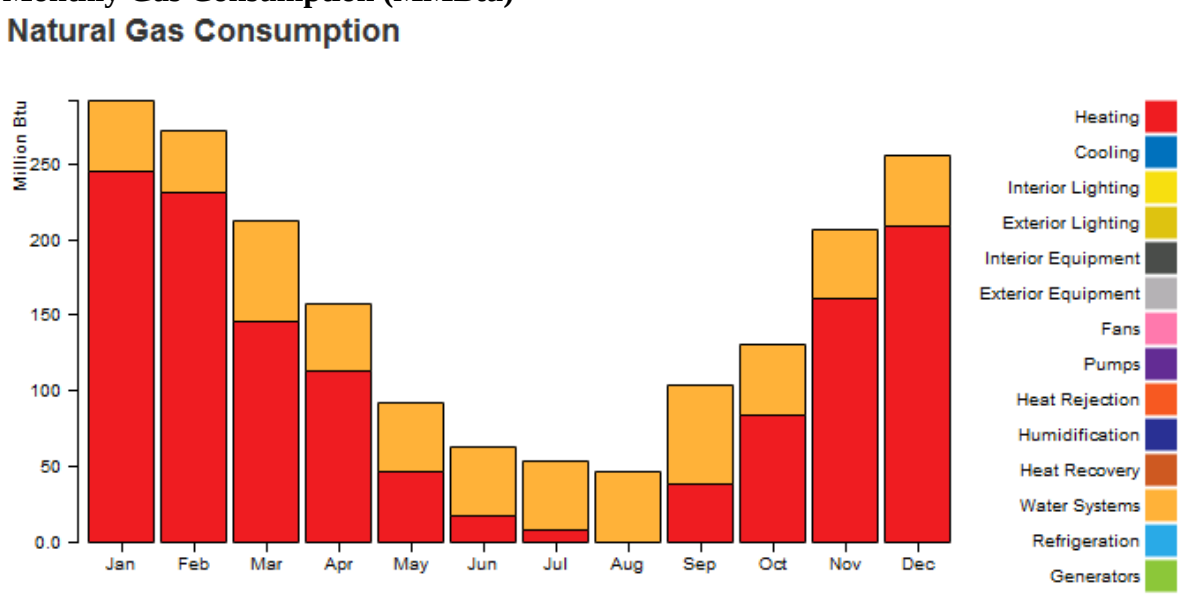
	Electricity (kWh)	Natural Gas (CF)
Jan-2011	17,360	294,200
Feb-2011	15,040	268,200
Mar-2011	16,560	237,000
Apr-2011	15,440	163,600
May-2011	16,720	109,000
Jun-2011	17,600	68,100
Jul-2011	18,960	58,500
Aug-2011	18,160	46,800
Sep-2011	15,600	114,700
Oct-2011	15,200	126,700
Nov-2011	12,720	186,600
Dec-2011	17,120	234,500

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



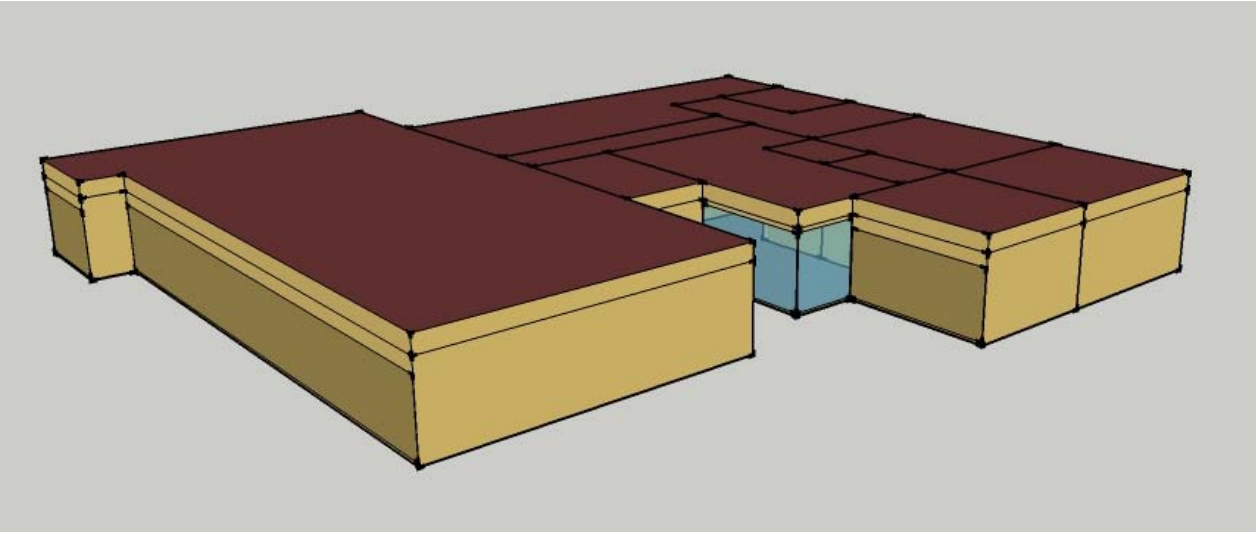
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the AFA 4198 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

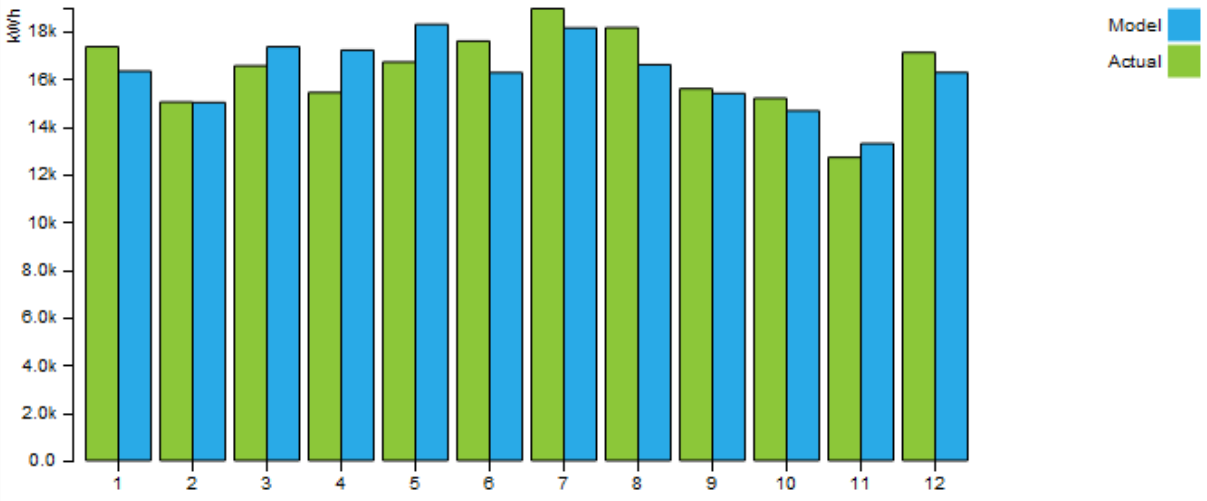


The graphs below show the average actual utility consumption versus the calibrated energy model.

Electricity Consumption (kWh)

CV(RMSE) = 6.77

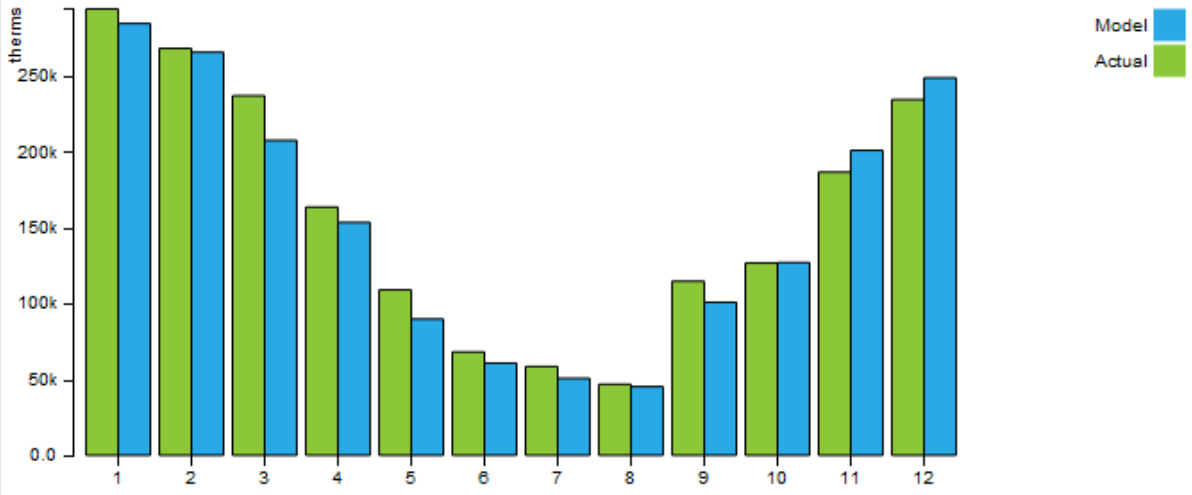
NMBE = 0.87



Natural Gas Consumption (therms)

CV(RMSE) = 8.81

NMBE = 4.15



ENERGY CONSERVATION MEASURES

Lighting Energy Efficiency Measures

Install low-wattage T8 lighting.

The lighting system in this building uses more power per area than is required with the latest lighting technologies. Replace the lighting system with a newer, more efficient lighting technology. Newer technologies provide the same amount of light but use less energy in the process.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/ yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
1	Install low-wattage T8 lighting	15,111 (7.8%)	(-34.68) (-1.8%)	798	4,650.00	5.8	0.2

HVAC Efficiency Measures

Implement thermostat setbacks at night.

Currently, the HVAC system is working constantly to meet the temperature setpoints. Temperature setbacks during low occupancy periods can significantly reduce energy consumption.

It is recommended that thermostats be programmed to setback the temperature setpoints at night and on weekends.

ECM#	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
2	Implement Thermostat Setbacks at Night	11,941.67 (6.1%)	253.97 (13.4%)	1,513.80	120.00	0.08	12.6

Replace standard v-belts with cogged v-belts.

Cogged v-belts can be used with the same pulleys as equivalent rated v-belts. They run cooler, last longer, and have an efficiency that is on the order of 2%–3% higher than standard v-belts due to the elimination of slippage. The belts associated with the largest motors and the motors that are run closest to full load should be given priority when making replacements.

It is recommended that standard v-belts be replaced with cogged v-belts.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
3	Improve Fan Belt Efficiency	994 (0.5%)	(-0.88) (-0.0%)	57	240.00	4.2	0.2

Replace CAV system with a VAV system

The current HVAC system is a Constant Air Volume (CAV) system with electric re-heat elements serving as terminal units. In a CAV system, variations in the thermal requirements of the building are satisfied by varying the temperature of a constant volume of air delivered to the building. A constant fraction of outdoor air will mean that a constant volume of outdoor air will be delivered to the building. This volume can be set to satisfy applicable ventilation standards. CAV systems are far less energy efficient than VAV systems.

It is recommended that the VAV box and air outlet modification are implemented on this building, changing the building to only deliver the amount of air to a space that is needed for ventilation and cooling purposes.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
4	CAV w/ Reheat to VAV w/ Reheat	35,786 (18.4%)	(-34.14) (-1.8%)	2,040	70,944.00	34.8	0.0

Convert CHW and HW pumping systems to variable speed

The HVAC hot water and chilled water coils throughout the facility feeding the AHUs are 3-way control valves. Older HVAC designs necessitated the need for 3-way control valves, but in newer designs with VFD control, 3-way valves waste energy and aren't necessary.

Remove the 3-way control valves and install 2-way control valves. This will also require VFDs on the CHW and HW pumps. For all new construction projects, all of the control valves feeding the AHU heating and cooling coils need to be specified as 2-way control valves.

This project is not economically feasible for this building due to the high cost of implementation, but should be specified for all new construction projects.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
5	Constant Speed to Variable Speed Pump	858 (0.4%)	(-2.79) (-0.1%)	43	5,500.00	128.8	0.0

Plug Loads Conservation Measures

The facility has desktop computers. The typical office space is set up with a 17 inch LCD monitor. The desktop computers are standard desktop tower configuration. The NREL team recorded the total connected electrical load at 150 Watts per desktop computer.

Replace the computer/monitor combination with an laptop computer which will have a much lower connected load and lower energy consumption.

This project is not economically feasible for this building, but should be specified as computers are replaced. The small incremental cost is typically justified by the energy savings.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
6	Replace desktop computers with laptops	4,061 (2.1%)	(-4.87) (-0.3%)	228	31,500.00	138.0	0.0

The facility has all desktop computers. The typical office space is set up with a 17-inch Samsung, LCD monitor (Model: Sync Master 740n) and a Hewlet-Packard computer. The computer has a connected electrical load of 57 Watts, and the monitors have a connected electrical load of 19 Watts. When placed in sleep mode' the screen's connected load is reduced to 0.69 Watts and the computers connected load is reduced to 2.0 Watts.

There are software programs available that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
7	Computer power mgmt	2,036 (1.0%)	(-2.44) (-0.1%)	114	1,500.00	13.1	0.1

AFA 6202

Energy Audit Report

6201 Pine Drive, Air Force Academy, CO 80840, USA

Wednesday, May 28, 2014

Prepared By: simuwatt Energy Auditor

EXECUTIVE SUMMARY

The following report summarizes the results from the AFA 6202 Energy Efficiency and Renewable Energy Site Assessment of the AFA 6202 building in 6201 Pine Drive, Air Force Academy, CO 80840, USA. During the site visit, the team identified 7 energy conservation, water conservation, and renewable energy measures. Many of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

AFA 6202, constructed in 1960, is an 8,611 ft^2 structure with 1 floor. The building serves as a fire station.

ENERGY USAGE OVERVIEW

The electricity, natural gas, and water at the AFA 6202 is provided by Colorado Springs Utilities. The 2012 utility usage for the building is given in the table below.

	Electricity (kWh)	Natural Gas (CF)
Jan-2012	11,880	111,600
Feb-2012	14,800	123,600
Mar-2012	18,240	95,000
Apr-2012	15,520	64,700
May-2012	17,320	74,700
Jun-2012	17,640	16,500
Jul-2012	15,880	2,500
Aug-2012	20,200	23,500
Sep-2012	13,960	63,200
Oct-2011	11,400	95,500
Nov-2011	12,640	126,500
Dec-2011	13,240	172,600

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. Details of the calculations and assumptions for each ECM are presented in later sections of this report.

Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings (kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio
Bundled ECMs with < 10 year simple payback	28,738.89 (16.3%)	53.62 (5.6%)	1,892.90	12,010.00	6.34	0.2
Bundled all ECMs	61,033.33 (34.5%)	38.40 (4.0%)	3,782.91	114,214.00	30.19	0.0

Lighting Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
Install low-wattage T8 lighting	20,106 (11.4%)	(-25.71) (-2.7%)	1,126	4,650.00	4.1	0.2

HVAC & DHW Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
Implement Thermostat Setbacks at Night	1,758.33 (1.0%)	95.49 (10.0%)	405.30	120.00	0.30	3.4
Improve Fan Drive Efficiency	903 (0.5%)	(-0.01) (-0.0%)	54	240.00	4.4	0.2
CAV w/ Reheat to VAV w/ Reheat	35,364 (20.0%)	(-4.92) (-0.5%)	2,107	70,944.00	33.7	0.0
Constant Speed to	4,889 (2.8%)	(-13.15) (-1.4%)	252	5,500.00	21.8	0.0

Variable Speed Pump						

Plug Loads Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
Replace desktop computers with laptops	2,475 (1.4%)	(-2.35) (-0.2%)	141	31,500.00	223.1	0.0
Computer power management	1,239 (0.7%)	(-1.16) (-0.1%)	71	1,500.00	21.2	0.0

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INTRODUCTION

Climate Data

AFA 6202 is located at 6201 Pine Drive, Air Force Academy, CO 80840, USA. The site is at a latitude and longitude of approximately 38.98, and -104.87, respectively.

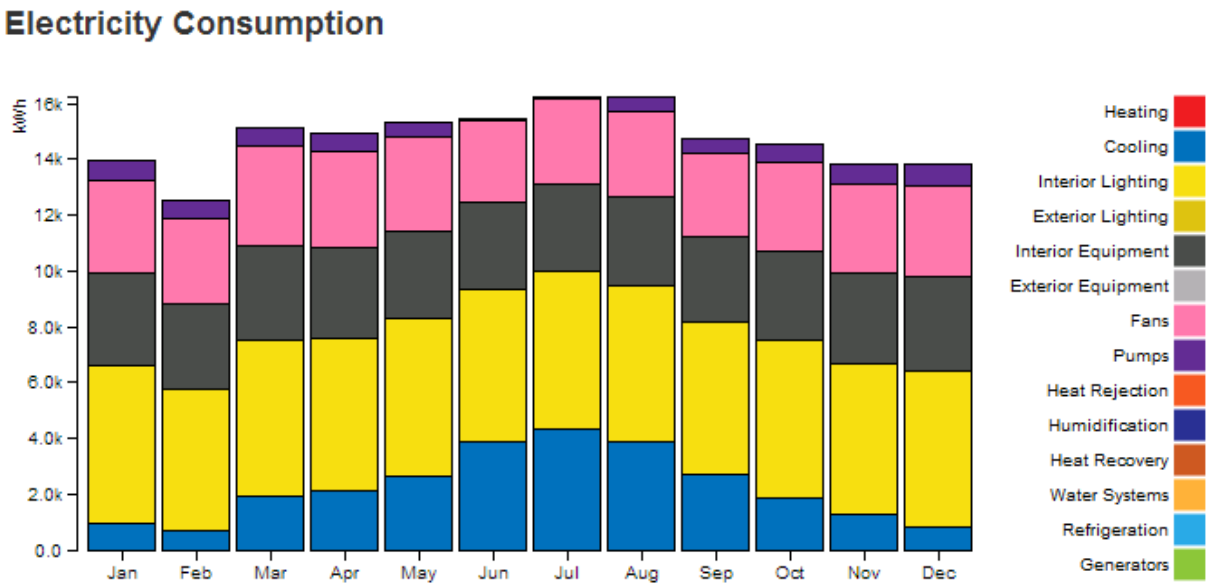
Energy Use and Utility Data

The electricity, natural gas, and water at the AFA 6202 is provided by Colorado Springs Utilities. The blended utility rates for electricity and natural gas were calculated to be $0.06/kWh and $0.314/ccf, respectively. The 2012 fiscal year utility usage for the building is given in the tables below.

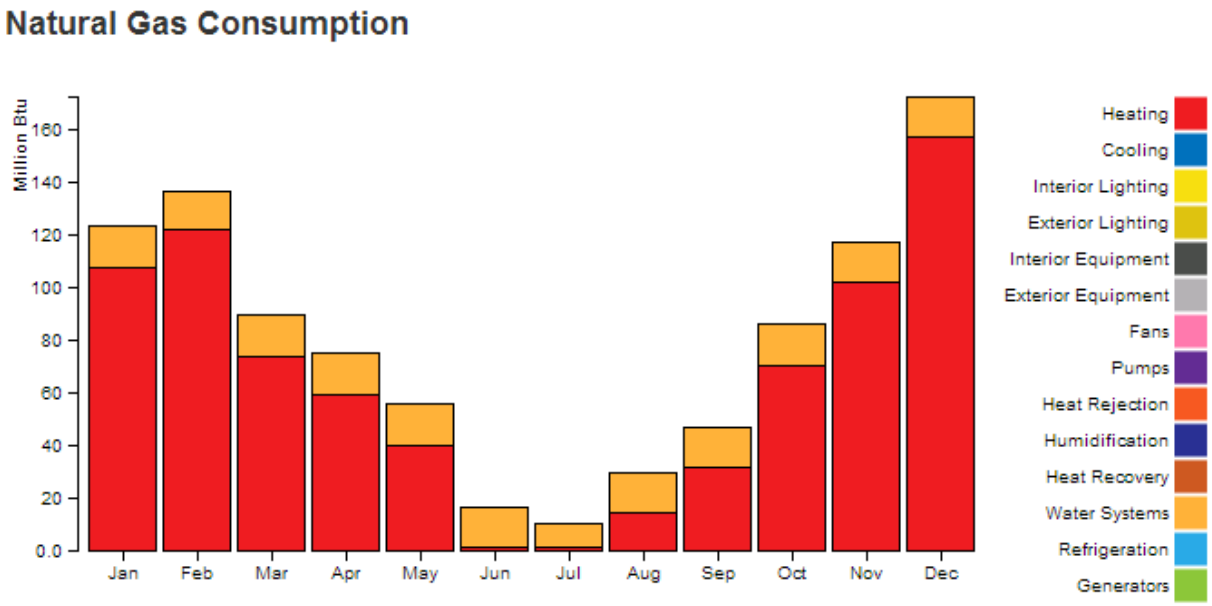
	Electricity (kWh)	Natural Gas (CF)
Jan-2012	11,880	111,600
Feb-2012	14,800	123,600
Mar-2012	18,240	95,000
Apr-2012	15,520	64,700
May-2012	17,320	74,700
Jun-2012	17,640	16,500
Jul-2012	15,880	2,500
Aug-2012	20,200	23,500
Sep-2012	13,960	63,200
Oct-2011	11,400	95,500
Nov-2011	12,640	126,500
Dec-2011	13,240	172,600

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



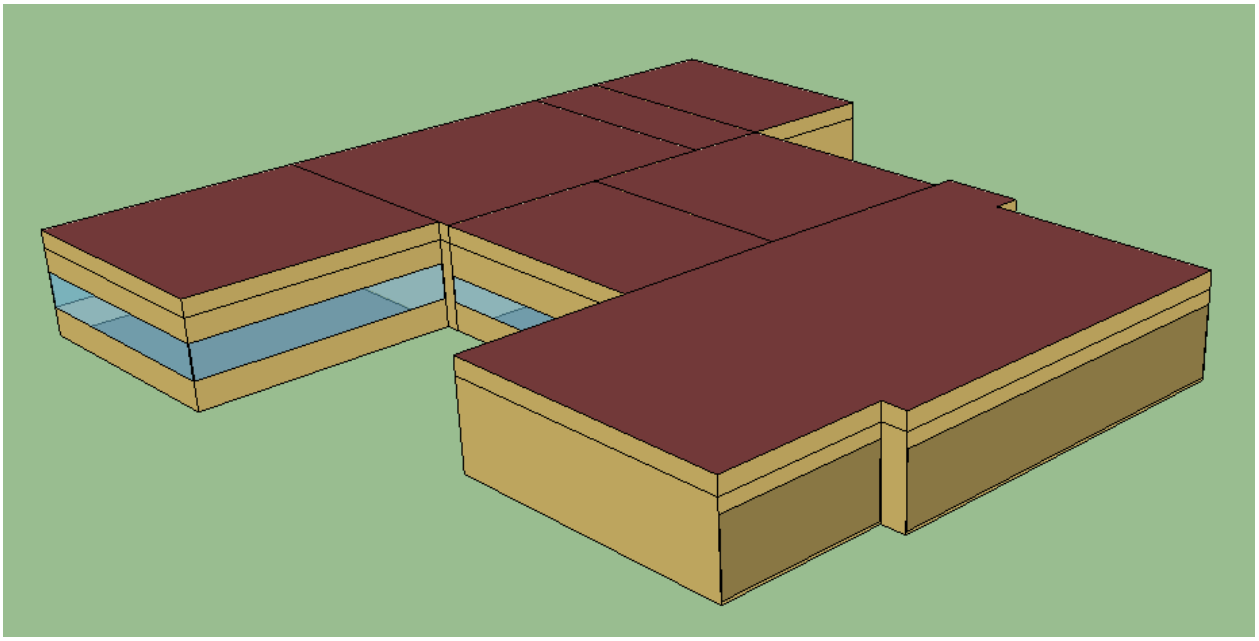
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the AFA 6202 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

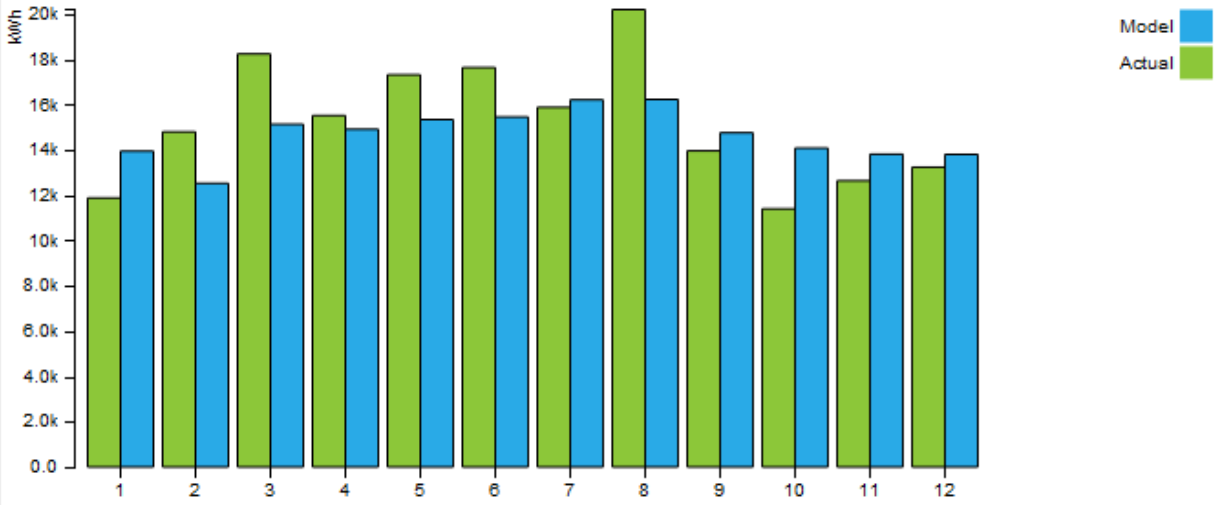


The graphs below show the average actual utility consumption versus the calibrated energy model.

Electricity Consumption (kWh)

CV(RMSE) = 14.49

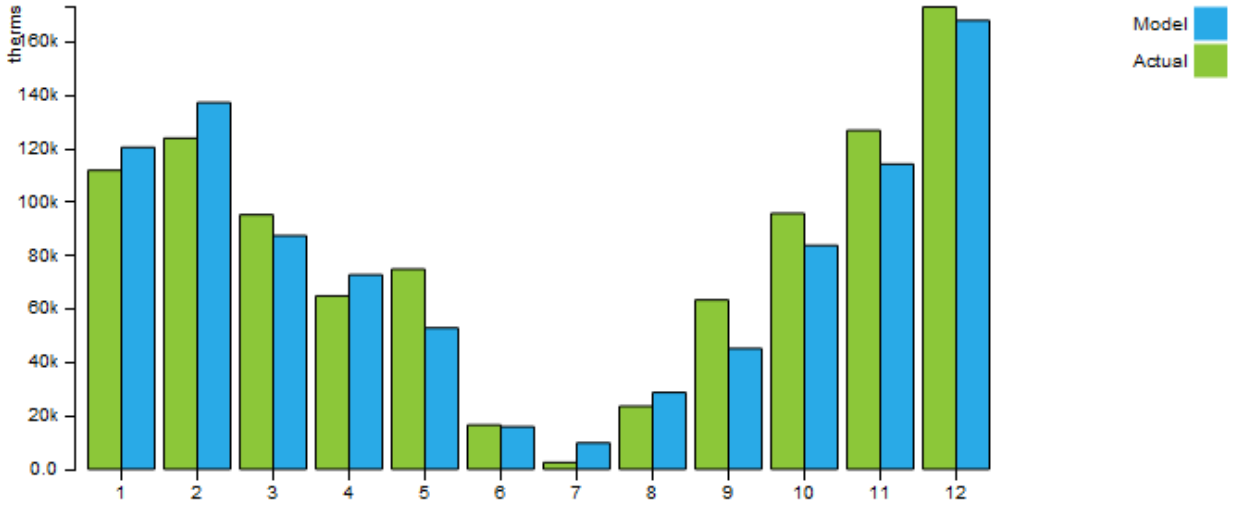
NMBE = 3.88



Natural Gas Consumption (therms)

CV(RMSE) = 14.89

NMBE = 4.05



ENERGY CONSERVATION MEASURES

Lighting Energy Efficiency Measures

Install low-wattage T8 lighting

The lighting system in this building uses more power per area than is required with the latest lighting technologies. Replace the lighting system with a newer, more efficient lighting technology. Newer technologies provide the same amount of light but use less energy in the process.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
1	Install low-wattage T8 lighting Only	20,106 (11.4%)	(-25.71) (-2.7%)	1,126	4,650.00	4.1	0.2

HVAC Efficiency Measures

Implement thermostat setbacks at night.

Currently, the HVAC system is working constantly to meet the temperature setpoints. Temperature setbacks during low occupancy periods can significantly reduce energy consumption.

It is recommended that thermostats be programmed to setback the temperature setpoints at night and on weekends.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
2	Implement Thermostat Setbacks at Night	1,758.33 (1.0%)	95.49 (10.0%)	405.30	120.00	0.30	3.4

Replace standard v-belts with cogged v-belts.

Cogged v-belts can be used with the same pulleys as equivalent rated v-belts. They run cooler, last longer, and have an efficiency that is on the order of 2%–3% higher than standard v-belts due to the elimination of slippage. The belts associated with the largest motors and the motors that are run closest to full load should be given priority when making replacements.

It is recommended that standard v-belts be replaced with cogged v-belts.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
3	Improve Fan Belt Efficiency	903 (0.5%)	(-0.01) (-0.0%)	54	240.00	4.4	0.2

Replace CAV system with a VAV system

The current HVAC system is a Constant Air Volume (CAV) system with electric re-heat elements serving as terminal units. In a CAV system, variations in the thermal requirements of the building are satisfied by varying the temperature of a constant volume of air delivered to the building. A constant fraction of outdoor air will mean that a constant volume of outdoor air will be delivered to the building. This volume can be set to satisfy applicable ventilation standards. CAV systems are far less energy efficient than VAV systems.

It is recommended that the VAV box and air outlet modification are implemented on this building, changing the building to only deliver the amount of air to a space that is needed for ventilation and cooling purposes.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
4	CAV with Reheat to VAV with Reheat	35,364 (20.0%)	(-4.92) (-0.5%)	2,107	70,944.00	33.7	0.0

Convert CHW and HW pumping systems to variable speed

The HVAC hot water and chilled water coils throughout the facility feeding the AHUs are 3-way control valves. Older HVAC designs necessitated the need for 3-way control valves, but in newer designs with VFD control, 3-way valves waste energy and aren't necessary.

Remove the 3-way control valves and install 2-way control valves. This will also require VFDs on the CHW and HW pumps. For all new construction projects, all of the control valves feeding the AHU heating and cooling coils need to be specified as 2-way control valves.

This project is not economically feasible for this building due to the high cost of implementation, but should be specified for all new construction projects.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
5	Constant Speed to Variable Speed Pump	4,889 (2.8%)	(-13.15) (-1.4%)	252	5,500.00	21.8	0.0

Plug Loads Conservation Measures

The facility has desktop computers. The typical office space is set up with a 17 inch LCD monitor. The desktop computers are standard desktop tower configuration. The NREL team recorded the total connected electrical load at 150 Watts per desktop computer.

Replace the computer/monitor combination with a laptop computer which will have a much lower connected load and lower energy consumption.

This project is not economically feasible for this building, but should be specified as computers are replaced. The small incremental cost is typically justified by the energy savings.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
6	Replace desktop computers with laptops	2,475 (1.4%)	(-2.35) (-0.2%)	141	31,500.00	223.1	0.0

The facility has all desktop computers. The typical office space is set up with a 17-inch Samsung, LCD monitor (Model: Sync Master 740n) and a Hewlet-Packard computer. The computer has a connected electrical load of 57 Watts, and the monitors have a connected electrical load of 19 Watts. When placed in sleep mode' the screen's connected load is reduced to 0.69 Watts and the computers connected load is reduced to 2.0 Watts.

There are software programs available that perform the following functions:

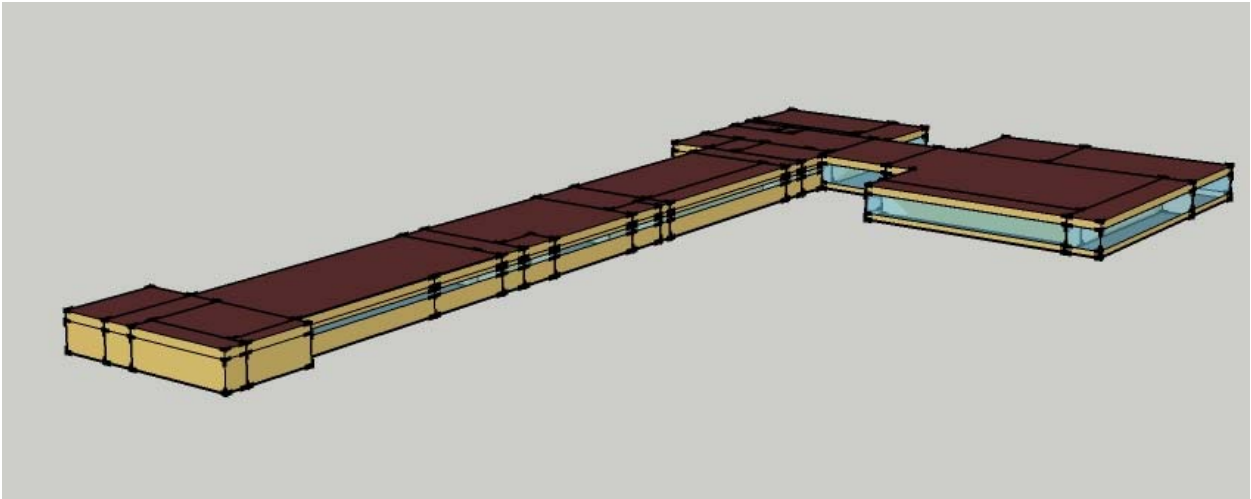
- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
7	Computer power mgmt	1,239 (0.7%)	(-1.16) (-0.1%)	71	1,500.00	21.2	0.0

Building 8116 and 8120

Energy Audit Report

Edgerton Drive, Air Force Academy, CO 80840, USA



Thursday, May 29, 2014

Prepared By: simuwatt Energy Auditor

EXECUTIVE SUMMARY

The following report summarizes the results from the 8116/8120 Energy Efficiency and Renewable Energy Site Assessment of 8116/8120 building in Edgerton Drive, Air Force Academy, CO 80840, USA. During the site visit, the team identified 14 energy conservation, water conservation, and renewable energy measures. Many of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

8116/8120, constructed in 1956, is a 52,820 ft^2 structure with 1 floor. There are a couple of areas which have office and storage space in lofted areas of the shops. The building serves primarily as maintenance shops, wood shops, carpentry shops, in 8116 and is primarily office space on the 8120 side.

ENERGY USAGE OVERVIEW

The electricity, natural gas and water at the AFA 4198 is provided by Colorado Springs Utilities. The utility use for the buildings are given in the tables below.

	Electricity (kWh)	Natural Gas (CF)
Jan-2011	64,284	770,500
Feb-2011	72,528	658,500
Mar-2011	83,189	414,400
Apr-2011	69,043	328,100
May-2011	85,196	286,800
Jun-2011	86,496	136,300
Jul-2011	106,880	134,000
Aug-2011	91,631	74,500
Sep-2011	82,458	138,900
Oct-2011	77,926	303,800
Nov-2011	76,555	486,400
Dec-2011	76,555	788,500

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. Details of the calculations and assumptions for each ECM are presented in later sections of this report.

Energy Conservation Measures – All Measures Combined Impact

ECM	Annual Electricity Savings(kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio
All Bundled	299,786.11 (35.9%)	2,445.22 (60.5%)	25,665.00	935,529.00	36.45	0.0

Building Envelope Energy Efficiency Measures – Summary

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
1	Reduce infiltration in welding and wood shops	14,600.00 (1.7%)	261.21 (6.5%)	1,696.20	1,200.00	0.71	1.4
2	Add exterior insulation	63,394 (7.6%)	766.55 (19.0%)	6,211	123,067.00	19.8	0.1
3	Replace exterior windows	4,378 (0.5%)	82.91 (2.1%)	523	642,187.00	1,227.9	0.0

Lighting Energy Efficiency Measures – Summary

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
4	Occupancy Sensors	7,419.44 (0.9%)	(-17.55) (-0.4%)	390.20	2,250.00	5.77	0.2
5	Replace T-8s with low wattage T-8s	54,394 (6.5%)	(-97.56) (-2.4%)	2,958	8,191.00	2.8	0.4

HVAC & DHW Efficiency Measures – Summary

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
6	Convert constant speed pumps to variable speed	10,930.56 (1.3%)	(-16.75) (-0.4%)	603.30	11,000.00	18.23	0.1
7	Replace existing motors with HE motors	7,113.89 (0.9%)	(-15.96) (-0.4%)	376.70	7,892.00	20.95	0.0
8	Replace belts with cogged v-belts	2,766.67 (0.3%)	(-5.99) (-0.1%)	147.30	1,440.00	9.78	0.1
9	Thermostat scheduling change	10,752.78 (1.3%)	618.39 (15.3%)	2,586.60	240.00	0.09	10.8
10	CAV to VAV fans	10,631 (1.3%)	(-6.26) (-0.2%)	618	70,944.00	114.8	0.0

Plug Loads Conservation Measures – Summary

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
11	Schedule shared plug loads	42,238.89 (5.1%)	(-100.95) (-2.5%)	2,217.60	7,500.00	3.38	0.3
12	Replace desktop with laptops	14,289 (1.7%)	(-22.67) (-0.6%)	786	60,000.00	76.3	0.0
13	Computer power	7,142 (0.9%)	(-11.38) (-0.3%)	393	3,000.00	7.6	0.1

	management						
14	**Remove excess refrigerators**	**4,833 (0.6%)**	**(-7.74) (-0.2%)**	**266**	**200.00**	**0.8**	**1.3**

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INTRODUCTION

CLIMATE DATA

8116/8120 is located at Edgerton Drive, Air Force Academy, CO 80840, USA. The city is at latitude and longitude of approximately 38.96, and -104.83, respectively.

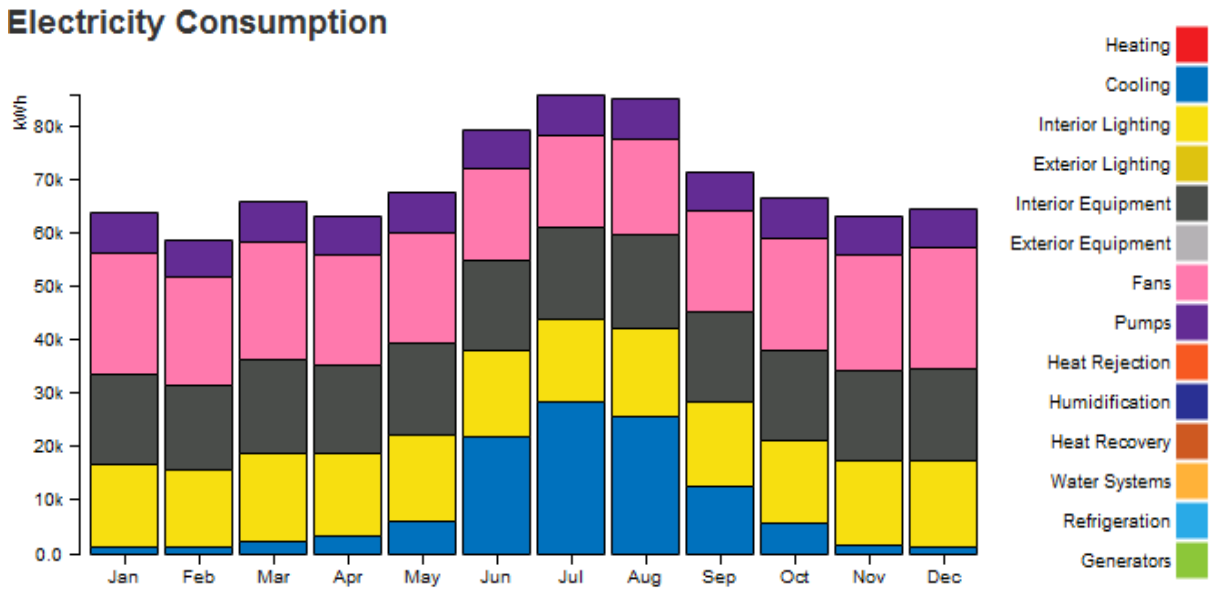
Energy Use and Utility Data

The electricity, natural gas and water at 8116/8120 is provided by Colorado Springs Utilities. The utility use for the buildings are given in the tables below. The blended utility rates for electricity and natural gas were calculated to be $0.06/kWh and $0.314/ccf, respectively. The utility use for the campus is given in the tables below.

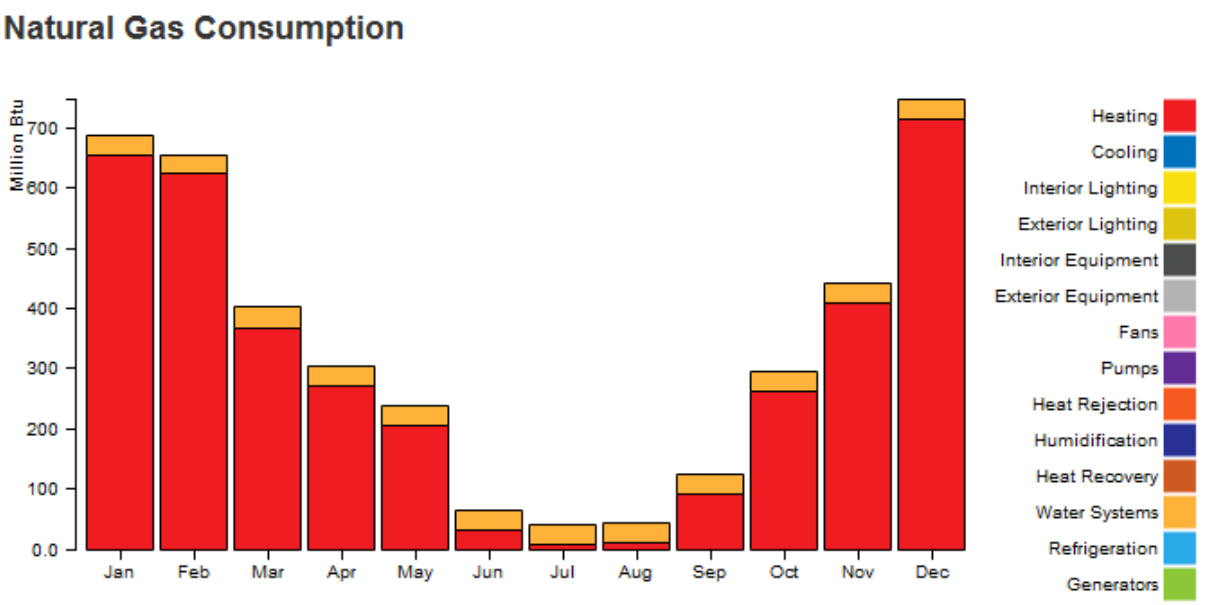
	Electricity (kWh)	Natural Gas (CF)
Jan-2011	64,284	770,500
Feb-2011	72,528	658,500
Mar-2011	83,189	414,400
Apr-2011	69,043	328,100
May-2011	85,196	286,800
Jun-2011	86,496	136,300
Jul-2011	106,880	134,000
Aug-2011	91,631	74,500
Sep-2011	82,458	138,900
Oct-2011	77,926	303,800
Nov-2011	76,555	486,400
Dec-2011	76,555	788,500

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



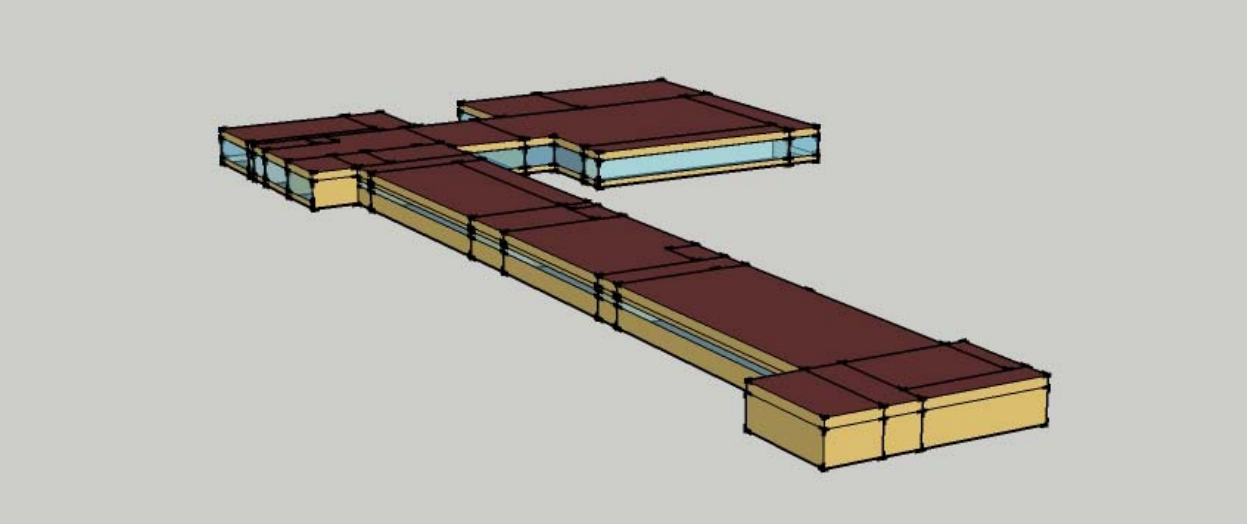
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Afa 8116/8120 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

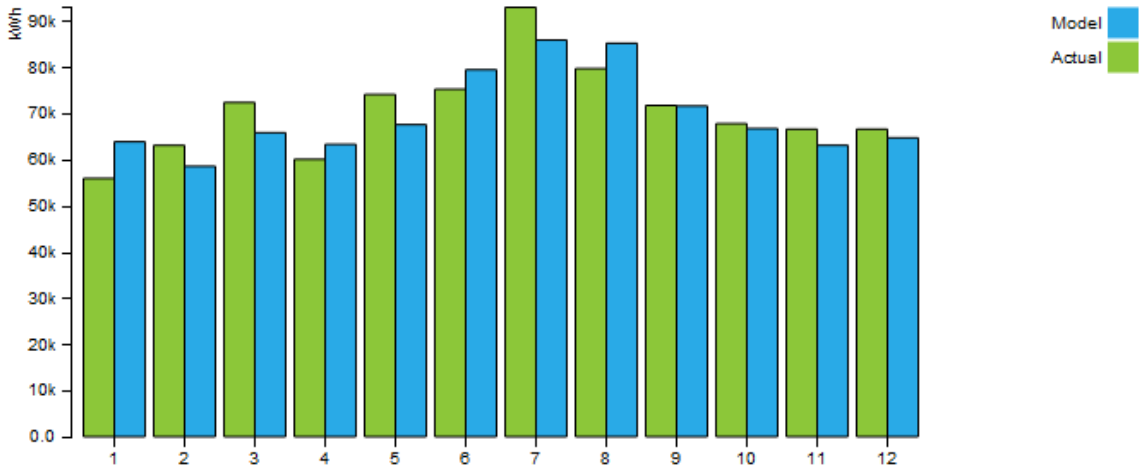


The graphs below show the average actual utility consumption versus the calibrated energy model.

Electricity Consumption (kWh)

CV(RMSE) = 7.34

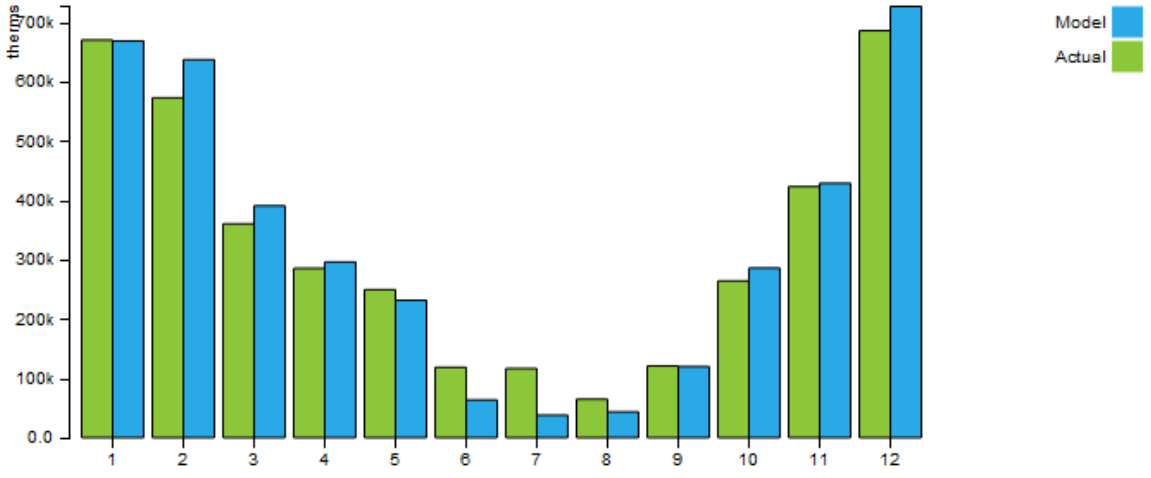
NMBE = 1.34



Natural Gas Consumption (therms)

CV(RMSE) = 12.11

NMBE = 0.06



ENERGY CONSERVATION MEASURES

Building Envelope Energy Efficiency Measures

The building has loading dock doors at various points through the maintenance shops. These doors appeared to have significant air leakage, allowing for a significant amount of outside air to infiltrate the building. The windows should also be re-sealed to prevent air infiltration. A considerable number of openings had air leakage.

An air curtain should be installed be installed on each of the loading dock doors. This will greatly reduce outside air from infiltrating during periods of time when doors are open.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
1	Reduce infiltration in welding and wood shops	14,600.00 (1.7%)	261.21 (6.5%)	1,696.20	1,200.00	0.71	1.4

The insulation on the exterior of the building was noted to be very thin, and several occupants complained of hot/cold spots along the perimeter of the building. Adding exterior insulation would save energy, and improve occupant comfort.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
2	Add exterior insulation	63,394 (7.6%)	766.55 (19.0%)	6,211	123,067.00	19.8	0.1

The windows in this building are single pane windows with an aluminum frame. Single pane windows perform poorly with respect to energy efficiency of the building since the u-value of single pane windows is much higher than double or triple pane windows with a thermally broken frame.

This measure was shown to not be cost effective for this building. Consider replacing at the time of major renovation or building remodel.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
3	**Replace exterior windows**	**4,378 (0.5%)**	**82.91 (2.1%)**	**523**	**642,187.00**	**1,227.9**	**0.0**

Lighting Energy Efficiency Measures

No occupancy sensors are currently installed. However, occupancy sensors can save considerable energy by turning off lights when not needed and/or when spaces are left unoccupied.

Install passive electronic sensors to automatically activate and deactivate space lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as occupant's move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. In many instances, a simple wall switch replacement is adequate. In other cases a ceiling-mount sensor or wall-mount sensor may provide better coverage. In rooms with multiple lighting circuits or devices, multi-pole power packs and auxiliary relays can be configured to operate from a single sensor head. In larger spaces, multiple sensors can be wired in parallel to keep all lights on if any one sensor is triggered.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
4	**Occupancy Sensors**	**7,419.44 (0.9%)**	**(-17.55) (-0.4%)**	**390.20**	**2,250.00**	**5.77**	**0.2**

Install low-wattage T8 lighting

The model's initial building lighting power was 57,687 watts, a lighting power density of 1.10 W/ft^2.

The lighting system in this building uses more power per area than is required with the latest lighting technologies. Replace the lighting system with a newer, more efficient lighting technology. Newer technologies provide the same amount of light but use less energy in the process.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
5	**Replace T-8s with low wattage T-8s**	**54,394 (6.5%)**	**(-97.56) (-2.4%)**	**2,958**	**8,191.00**	**2.8**	**0.4**

HVAC Efficiency Measures

The HVAC hot water coils throughout the facility feeding the AHU heating coils are 3-way control valves. Older HVAC designs necessitated the need for 3-way control valves, but in newer designs with VFD control, 3-way valves waste energy and aren't necessary, and the flow through the loop can be modulated to slow down when full flow is not needed to meet space conditioning requirements.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
6	**Convert constant speed pumps to variable speed**	**10,930.56 (1.3%)**	**(-16.75) (-0.4%)**	**603.30**	**11,000.00**	**18.23**	**0.1**

The Copper Development Association has a line of ultra-efficient motors in the US market which exceed NEMA Premium standards. These motors utilize a die cast copper rotor which reduces the energy requirements of the motor and allows the motor to run cooler. The motor also features an improved heat dissipation system and new low friction bearings; both of which help extend the life of the motor. The motor also has a smaller weight and size compared to the standard NEMA Premium efficiency motors. The motors are showing efficiency improvements on the order of 3-10% more efficient than current NEMA Premium standards.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
7	**Replace existing motors with HE motors**	**7,113.89 (0.9%)**	**(-15.96) (-0.4%)**	**376.70**	**7,892.00**	**20.95**	**0.0**

Replace the current V-belts with cogged V-belts. Cogged V-belts have slots that run perpendicular to the belt's length. The slots reduce the bending resistance of the belt. Cogged V-belts can be used with the same pulleys as equivalent rated V-belts. They run cooler, last longer, and have an efficiency that is on the order of 2%-3% higher than standard V-belts.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
8	**Replace belts with cogged v-belts**	**2,766.67 (0.3%)**	**(-5.99) (-0.1%)**	**147.30**	**1,440.00**	**9.78**	**0.1**

The AHUs were observed to operate continuously in this building. The temperature is not set back, and the exhaust fans operate continuously. The chilled water system operates on the same schedule as the AHUs. The AHUs also continue to ventilate spaces when the building is unoccupied.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
9	**Thermostat scheduling change**	**10,752.78 (1.3%)**	**618.39 (15.3%)**	**2,586.60**	**240.00**	**0.09**	**10.8**

Add a variable frequency drive (VFD) to the fan on the air handler. In a constant volume reheat system, unneeded conditioned air is bypassed directly to the return air stream when the VAV boxes are throttled back. However, energy is still expended moving this air. Installing a VFD on the fan allows the system to lower the fan speed when less cooling is needed, minimizing the amount of air being moved and conditioned.

This measure was not found to be cost effective in this building, consider implementing this measure at the time of major renovation or system replacement.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
10	**CAV to VAV fans**	**10,631 (1.3%)**	**(-6.26) (-0.2%)**	**618**	**70,944.00**	**114.8**	**0.0**

Plug Load Efficiency Measures

Currently there are no plug load scheduling control devices. However, scheduling control devices can save considerable energy by turning off plug loads when not needed and/or when spaces are left unoccupied. These should be used on any shared equipment, and non critical workstation devices.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
11	**Schedule shared plug loads**	**42,238.89 (5.1%)**	**(-100.95) (-2.5%)**	**2,217.60**	**7,500.00**	**3.38**	**0.3**

The facility has desktop computers. The typical office space is set up with a 17 inch LCD monitor. The desktop computers are standard desktop tower configuration. The NREL team recorded the total connected electrical load at 150 Watts per desktop computer.

Replace the computer/monitor combination with an laptop computer which will have a much lower connected load and lower energy consumption.

This project is not economically feasible for this building, but should be specified as computers are replaced. The small incremental cost is typically justified by the energy savings.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
12	**Replace Desktop with Laptops**	**14,289 (1.7%)**	**(-22.67) (-0.6%)**	**786**	**60,000.00**	**76.3**	**0.0**

The facility has all desktop computers. The typical office space is set up with a 17-inch Samsung, LCD monitor (Model: Sync Master 740n) and a Hewlet-Packard computer. The computer has a connected electrical load of 57 Watts, and the monitors have a connected electrical load of 19 Watts. When placed in sleep mode' the screen's connected load is reduced to 0.69 Watts and the computers connected load is reduced to 2.0 Watts.

There are software programs available that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu /yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
13	**Computer power mgmt**	**7,142 (0.9%)**	**(-11.38) (-0.3%)**	**393**	**3,000.00**	**7.6**	**0.1**

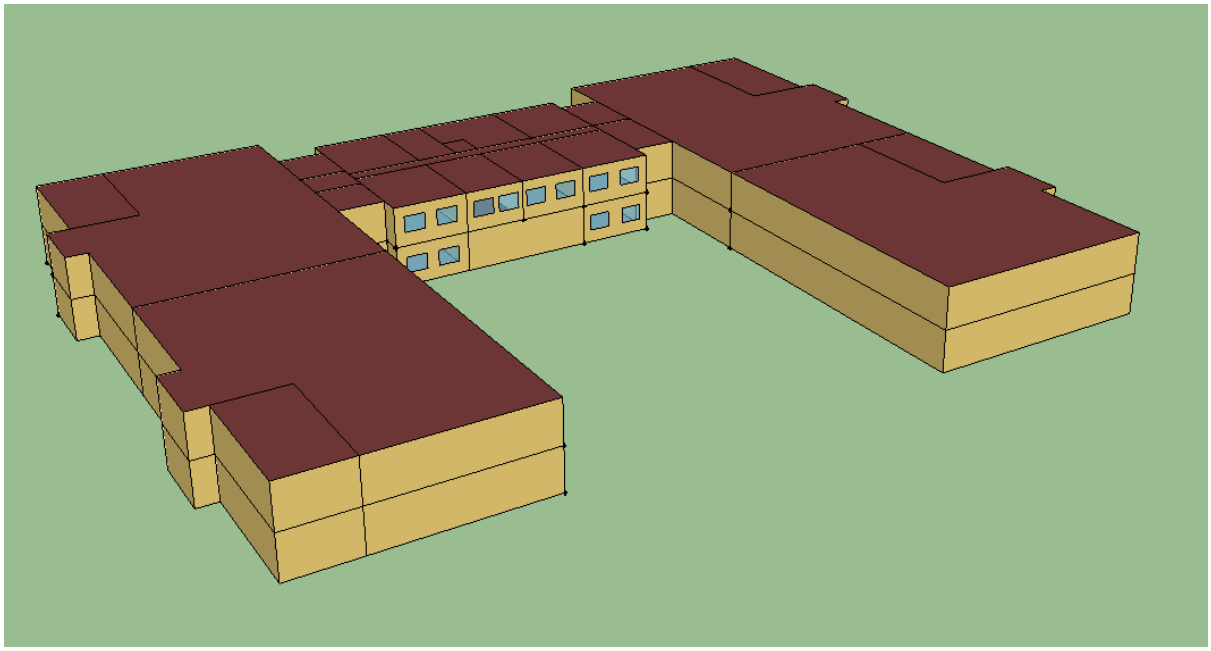
During the energy audit, it was found that there were a large number of refrigerators that were either unused or underutilized. A survey should be performed that is used to determine which refrigerators are necessary, and which can be consolidated.

ECM #	ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu /yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)	Savings to Investment Ratio (%)
14	**Remove excess refrigerators**	**4,833 (0.6%)**	**(-7.74) (-0.2%)**	**266**	**200.00**	**0.8**	**1.3**

Building 20105

Energy Audit Report

Old Ironside Drive, Fort Bliss, TX 79918, USA



Monday, July 14, 2014

Prepared By:

simuwatt

EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 20105 in Old Ironside Drive, Fort Bliss, TX 79918, USA. During the site visit, the team identified 7 energy conservation, water conservation, and renewable energy measures. Some of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

Building 20105, constructed in 2009, is a 48,675 ft^2 structure with 2 floors. The building serves primarily as office and training space.

ENERGY USAGE OVERVIEW

The electricity at Ft. Bliss is provided by the El Paso Electric Company. The 2012 electricity usage and cost for the building is given in the table below.

	Electricity (kWh)	Electricity Cost
Jan-12	25,347	$1,584
Feb-12	25,439	$1,590
Mar-12	28,523	$1,783
Apr-12	29,833	$1,865
May-12	35,634	$2,227
Jun-12	34,991	$2,187
Jul-12	36,158	$2,260
Aug-12	36,158	$2,260
Sep-12	33,811	$2,113
Oct-12	29,783	$1,861
Nov-12	24,070	$1,504
Dec-12	21,021	$1,314

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. The following measures could not be analyzed due to data loss and software limitations at the time of the demonstration:

- Reduce DHW set point and eliminate one storage tank
- Raise space temps for communications equipment rooms
- Put exterior lighting on photo cell and occupancy sensors
- Replace HIDs with low wattage LEDs

Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings(kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	103,733.33 (30.7%)	33.44 (3.7%)	10,578.20	48,746.00	4.61

Lighting Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement occupancy sensor lighting controls throughout building	20,031 (5.9%)	(-22.32) (-2.5%)	1,620	18,000.00	11.1
Install low-wattage T8 lighting when lamps fail (or LEDs)	15,161 (4.5%)	(-26.09) (-2.9%)	1,159	746.00	0.6

HVAC & DHW Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)	48,877.78 (14.5%)	88.27 (9.8%)	6,411.20	17,000.00	2.65
Recommission VAV boxes and reset space temps	27,222 (8.1%)	(-37.99) (-4.2%)	2,061	5,000.00	2.4

Plug Loads Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Remove excess refrigerators	300 (0.1%)	(-0.25) (-0.0%)	19	500.00	26.0
Computer power management	6,417 (1.9%)	(-3.38) (-0.4%)	436	4,500.00	10.3
Schedule controlled advanced power strips on shared equipment	4,161.11 (1.2%)	(-3.15) (-0.4%)	14.40	3,000.00	208.33

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INTRODUCTION

CLIMATE DATA

Building 20105 is located at Old Ironside Drive, Fort Bliss, TX 79918, USA. The site is at a latitude and longitude of approximately 31.85, and -106.35, respectively. A Google Earth satellite image of the building is shown below.

The table below shows the monthly average climate conditions in Fort Bliss, TX[1].

[1] http://www.weatherbase.com. Accessed July, 2014.

MONTHLY - WEATHER AVERAGES SUMMARY [Show All Data] [°C] °F

Average Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62	44	48	55	62	71	80	80	78	73	64	51	44

Average High Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	75	57	62	68	77	86	95	93	91	86	77	64	57

Average Low Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48	32	35	41	48	57	66	69	68	60	50	37	32

Average Precipitation — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in	9.2	0.5	0.4	0.4	0.3	0.4	0.8	1.6	1.6	1.3	0.9	0.5	0.6

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.8	11.5	12.4	13.4	14.3	14.7	14.4	13.7	12.7	11.8	11	10.6

Average Number of Days Above 90F/32C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	103	---	---	0.1	1	13.9	26.6	25.9	22.5	12.4	0.5	---	---

Average Number of Days Below 32F/0C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	55.3	18.7	9.2	3.9	0.4	---	---	---	---	---	0.3	5.6	17.2

Energy Use and Utility Data

The electricity at Ft. Bliss is provided by the El Paso Electric Company. The 2012 electricity usage and cost for the building is given in the table below. Electricity costs are primarily driven by the demand charge of $16.76/kW and the summer on-peak rate of $0.14335/kWh between 12:00pm-6:00pm during the months of June through September. Off-peak rates of $0.00527 are almost negligible in comparison.

	Electricity (kWh)	Electricity Cost
Jan-12	25,347	$1,584
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Mar-12	28,523	$1,783
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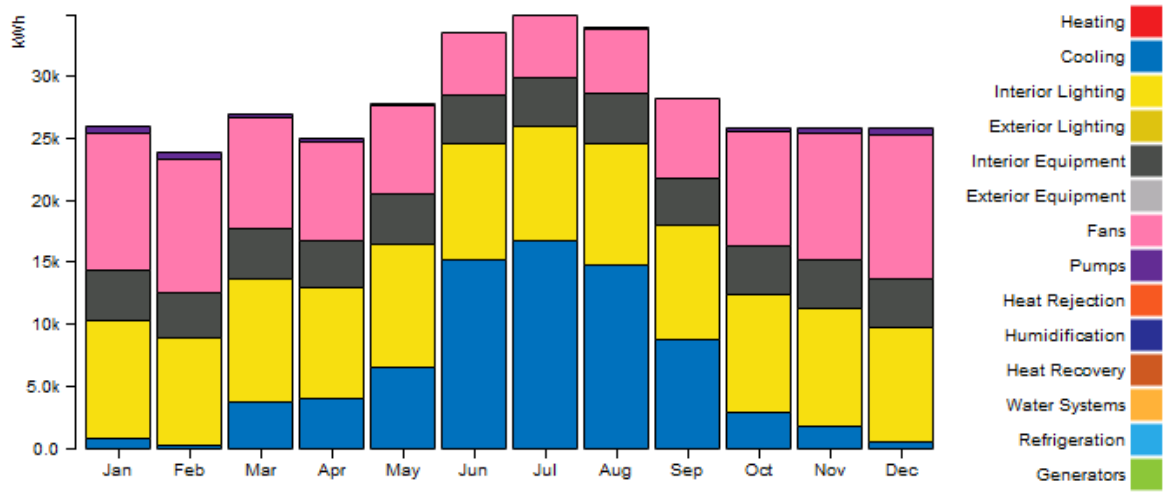
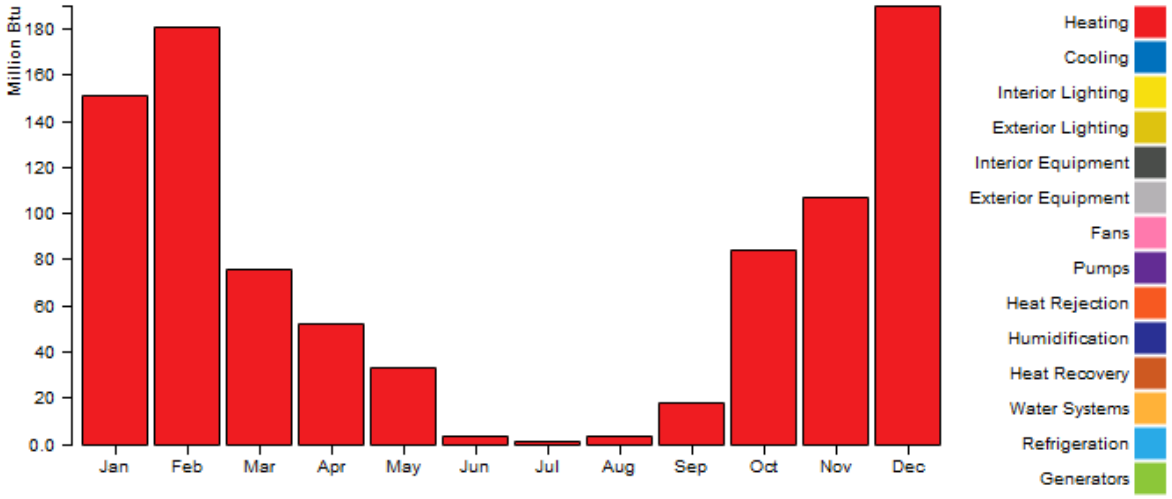
Dec-12	21,021	$1,314

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



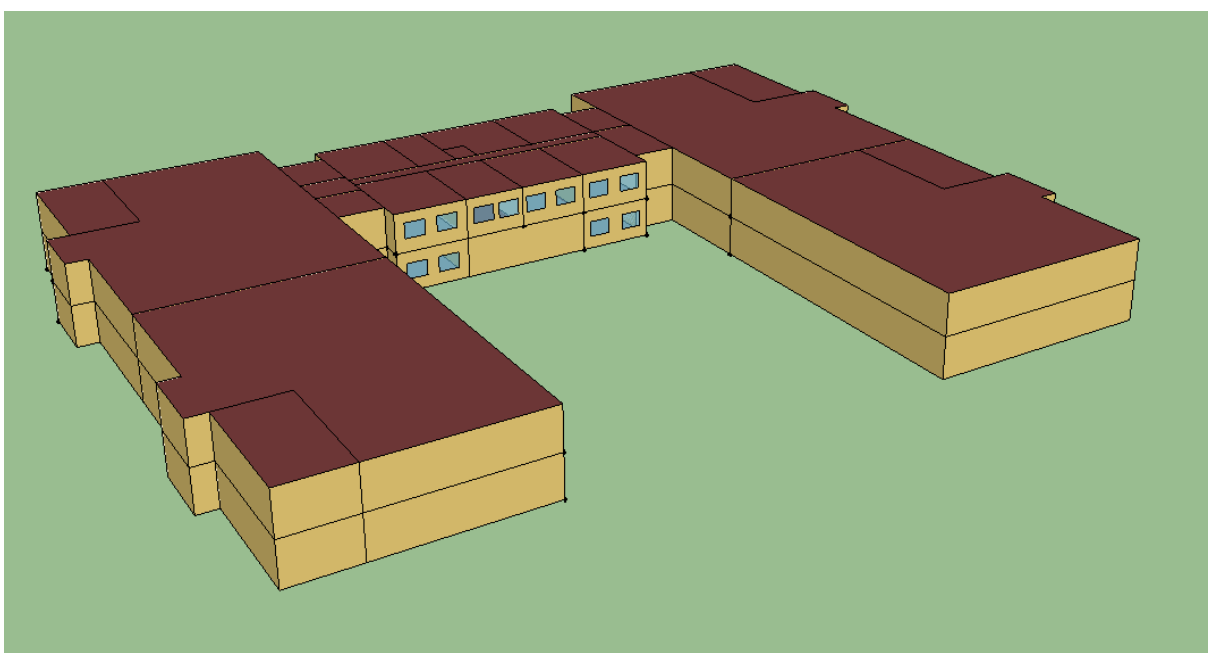
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Ft. Bliss 20105 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

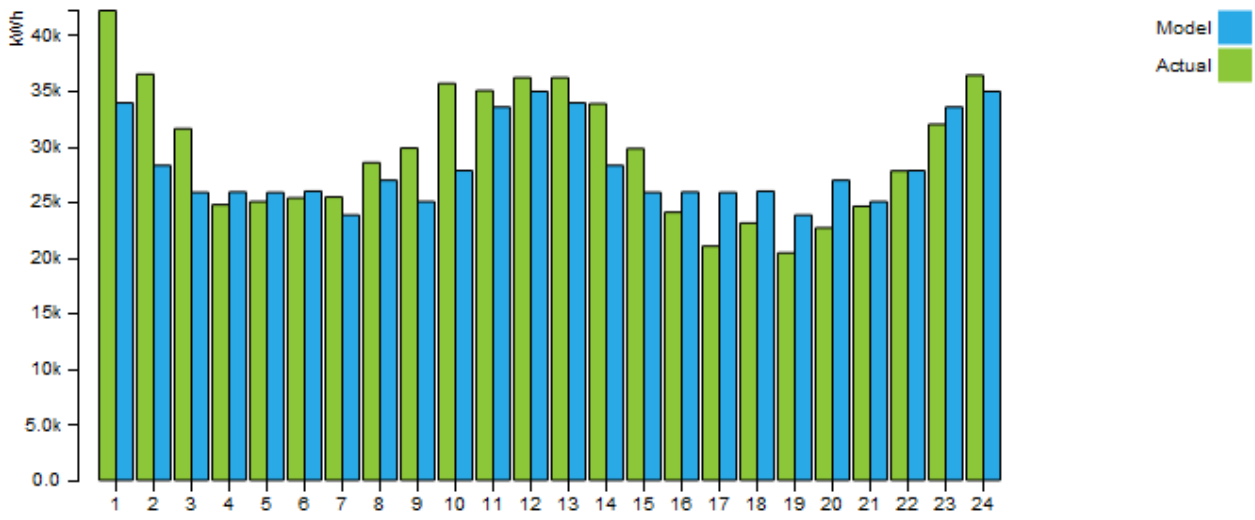


The graphs below show the average actual utility consumption versus the calibrated energy model for the past two years.

Electricity Consumption (kWh)

CV(RMSE) = 13.87

NMBE = 4.76



ENERGY CONSERVATION MEASURES

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement occupancy sensor lighting controls throughout building	**20,031 (5.9%)**	**(-22.32) (-2.5%)**	**1,620**	**18,000.00**	**11.1**
Install low-wattage T8 lighting when lamps fail (or LEDs)	**15,161 (4.5%)**	**(-26.09) (-2.9%)**	**1,159**	**746.00**	**0.6**

Lighting Energy Efficiency Measures

Install occupancy sensors to lights throughout the building

Category: Electric Lighting Controls
Description: Occupancy sensors save energy by turning off lights when not needed and/or when spaces are left unoccupied. Install a passive electronic sensor to automatically activate and deactivate lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as people move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. In many instances, a simple wall switch replacement is adequate. In other cases, a ceiling-mount sensor or alternatively placed wall-mount sensor may provide better coverage. In rooms with multiple lighting circuits or devices, multi-pole power packs and auxiliary relays can be configured to operate from a single sensor head. In larger spaces, multiple sensors can be wired in parallel to keep all lights on if any one sensor is triggered.

Install low-wattage T8 lighting when lamps fail

Category: Lighting Equipment
Description: Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color

Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

HVAC & DHW Efficiency Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)	**48,877.78 (14.5%)**	**88.27 (9.8%)**	**6,411.20**	**17,000.00**	**2.65**
Re-commission VAV boxes and reset space temps	**27,222 (8.1%)**	**(-37.99) (-4.2%)**	**2,061**	**5,000.00**	**2.4**

Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)

RTU retrofit kits were modeled to include converting the current air delivery system to a variable air volume system, adding demand controlled ventilation, and adding economizer controls. Each measure is described individually below.

CAV with Reheat to VAV with Reheat Air Handler

Category: HVAC Whole System
Description: Add a variable frequency drive (VFD) to the fan on the handler. In a constant volume reheat system, unneeded conditioned air is bypassed directly to the return air stream when the VAV boxes are throttled back. However, energy is still expended moving this air. Installing a VFD on the fan and eliminating the bypass allows the system to lower the fan speed when less cooling is needed, minimizing the amount of air being moved and conditioned.

Enable Demand Controlled Ventilation

Category: Ventilation
Description: The facility currently does not have a demand controlled ventilation system or CO_2 sensors in the air delivery system. Outside air is introduced and conditioned at a fixed rate based on the maximum design. Since the building occupancy fluctuates and is often less than the maximum design occupancy, it is being over-ventilated and consuming more energy than necessary. The building CO_2 level is closely related to the occupancy. The typical outside CO_2 level is relatively low concentration, around 400 to 500 ppm, and is used to dilute the higher indoor CO_2 levels. Demand controlled ventilation could be implemented by deploying CO_2 sensors located in each AHU return air duct and in densely occupied spaces, such as conference rooms. Implementation of this ECM will require:

- Rebalance the open/closed outside air dampers to a lower minimum ventilation rate.

- Program demand ventilation controls into each AHU, controlling modulating dampers in mixed air AHUs and VFDs in outside air units. Ventilation will be generally controlled from return air sensors, but will be increased as needed based on densely occupied space sensors.
- Commission the project.

Enable Economizer Control

Category: Cooling
Description: There is currently not a functioning air side economizer enabled in the building. Air side economizers use cold outside air to either assist the mechanical cooling system, or if the air is cold enough, provide all of the cooling for a facility. In order for an air side economizer to function properly, all of the outside air damper actuators need to have modulating capabilities. In addition to that, new control sequences need to be written into the building automation control system to enable the air-side economizer when outside air temperatures are below 60°F-65°F and the interior space temperatures are calling for cooling. The building would realize the following operational benefits by utilizing an air-side economizer:

- Reduction in cooling system energy use
- Reduction in mechanical cooling system run time
- Possible improvement in indoor air quality

Re-commission VAV boxes and reset space temps

Category: HVAC Controls
Description: Currently the space temperature setpoints have to be set lower to maintain comfort in the building, because several air terminals are not functioning properly. Re-commissioning the air terminals in the space will allow the space temperature setpoints to be reset. This analysis assumes that the space temperature cooling setpoint is increased from 70°F to 74°F.

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Remove excess refrigerators	**300 (0.1%)**	**(-0.25) (-0.0%)**	**19**	**500.00**	**26.0**
Computer power management	**6,417 (1.9%)**	**(-3.38) (-0.4%)**	**436**	**4,500.00**	**10.3**
Schedule controlled advanced power strips on shared equipment	**4,161.11 (1.2%)**	**(-3.15) (-0.4%)**	**14.40**	**3,000.00**	**208.33**

Plug Loads Conservation Measures

Remove excess refrigerators and incrementally install Energy Star models

Category: Electric Equipment
Description: The assessment team observed excess refrigerators in the building. The refrigerators were older Top Mount Freezer without through-the-door ice models and were not Energy Star rated. It is recommended that site staff remove excess refrigerators and replace all older refrigerators with newer Energy Star rated models incrementally as the older models approach the end of their useful life.

Implement Computer Power Management

Category: Electric Equipment
Description: The facility has all desktop computers. The typical office space is set up with a 17-inch Samsung, LCD monitor (Model: Sync Master 740n) and a Hewlet-Packard computer. The computer has a connected electrical load of 57 Watts, and the monitors have a connected electrical load of 19 Watts. When placed in sleep mode' the screen's connected load is reduced to 0.69 Watts and the computers connected load is reduced to 2.0 Watts.

There are software programs available that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

Schedule controlled advanced power strips on shared equipment

Category: Equipment Controls
Description: Many buildings have electric equipment that runs unnecessarily at night. Turning this equipment off at night with schedule controlled advanced power strips can provide energy savings without impacting the day-to-day operation of the building occupants. Before implementing this change, make sure that equipment can be brought back online quickly enough in the morning to avoid issues with occupants overriding the controls due to productivity losses.

ECM Name	Annual Electricity	Annual Gas Savings	Total Annual Savings ($/yr)	Total Installed	Simple Payback

	Savings (kWh/yr)	(MMBtu/yr)		Cost ($)	Period (yrs)
Bundled all ECMs	**103,733.33 (30.7%)**	**33.44 (3.7%)**	**10,578.20**	**48,746.00**	**4.61**

Bundled Measures

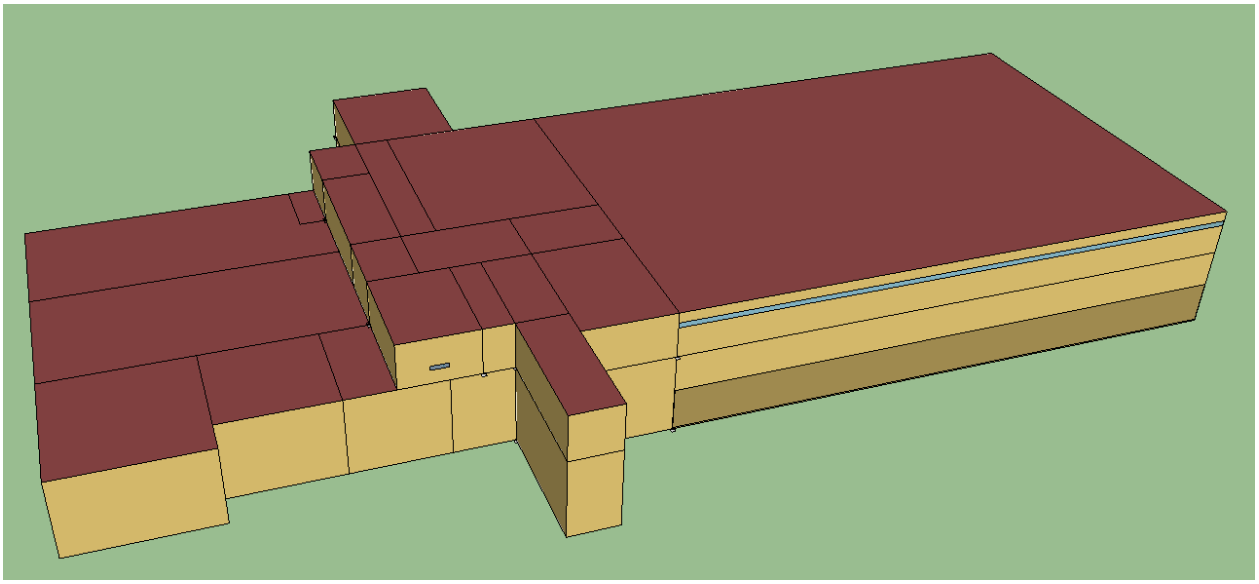
Category: All Measures
Description: All measures were bundled into a single measure so that interactions between ECMs are accurately accounted for, which can make a big difference in the viability of the ECMs. The following measures were included in the bundle:

- *Install occupancy sensors to lights throughout the building*
- Install low-wattage T8 lighting when lamps fail
- *Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)*
- *Re-commission VAV boxes and reset space temps*
- *Remove excess refrigerators and incrementally install Energy Star models*
- Implement Computer Power Management
- *Schedule controlled advanced power strips on shared equipment*

Building 20107

Energy Audit Report

Old Ironside Drive, Fort Bliss, TX 79918, USA



Monday, July 21, 2014

Prepared By: simuwatt Energy Auditor

EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 20107 in Old Ironside Drive, Fort Bliss, TX 79918, USA. During the site visit, the team identified 10 energy conservation measures. Some of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

Building 20107, constructed in 2010, is a 31,751 ft^2 structure with 2 floors. The building serves primarily as office and vehicle maintenance shop.

ENERGY USAGE OVERVIEW

The electricity at Ft. Bliss is provided by the El Paso Electric Company. The 2012 electricity usage and cost for the building is given in the table below.

	Electricity (kWh)	Electricity Cost
Jan-12	22,924	$1,433
Feb-12	20,152	$1,260
Mar-12	19,509	$1,219
Apr-12	18,741	$1,171
May-12	28,069	$1,754
Jun-12	30,434	$1,902
Jul-12	26,287	$1,643
Aug-12	24,085	$1,505
Sep-12	23,736	$1,484
Oct-12	23,031	$1,439
Nov-12	19,592	$1,225
Dec-12	30,400	$1,425

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. The following measures could not be analyzed due to data loss and software limitations at the time of the demonstration:

- Schedule exhaust fan
- Set unit level controls to 80°F heating and 50°F cooling in mechanical room
- Reduce DHW set point
- Replace HIDs with low wattage LEDs
- Delamp restrooms and rm 100
- Remove drinking fountain coolers for occupancy sensors

Bundled Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings (kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	44,580.56 (14.9%)	(-1.06) (-0.8%)	3,181.70	43,608.00	13.71

Lighting Energy Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Re-configure controls for photo cells in high bay	8,761 (2.9%)	(-13.85) (-10.8%)	592	5,000.00	8.5
Implement bi-level occupancy switching in lobby and stairwells	108 (0.0%)	(-0.04) (-0.0%)	8	1,600.00	195.1
Install low-wattage T8 lighting when lamps fail	12,553 (4.2%)	(-4.75) (-3.7%)	901	320.00	0.4
Implement occupancy sensor lighting controls (rm 117, 116, 110)	1,163.89 (0.4%)	(-0.57) (-0.4%)	97.80	1,200.00	12.27

HVAC Energy Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault	7,097.22 (2.4%)	18.91 (14.7%)	1,086.50	27,000.00	24.85

detection and diagnostics)					

Plug Loads Energy Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Schedule controlled advanced power strips on shared equipment	4,277.78 (1.4%)	(-1.91) (-1.5%)	378.50	1,000.00	2.64
Remove excess refrigerators, replace the old units with energy star	444 (0.1%)	(-0.11) (-0.1%)	30	1,440.00	48.2
Computer power management	3,761 (1.3%)	(-1.25) (-1.0%)	227	4,500.00	19.8
Vending machine misers	7,897 (2.6%)	(-1.52) (-1.2%)	134	1,200.00	8.9

Envelope Energy Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Reduce infiltration (missing threshold and air seal canteen doors)	206 (0.1%)	0.72 (0.6%)	12	348.00	28.8

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INTRODUCTION

CLIMATE DATA

Building 20107 is located at Old Ironside Drive, Fort Bliss, TX 79918, USA with a latitude and longitude of approximately 31.8, and -106.3, respectively. A Google Earth satellite image of the building is shown below.

The table below shows the monthly average climate conditions in Fort Bliss, TX[2].

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[2] http://www.weatherbase.com. Accessed July, 2014.

MONTHLY - WEATHER AVERAGES SUMMARY [Show All Data] [°C] °F

Average Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62	44	48	55	62	71	80	80	78	73	64	51	44

Average High Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	75	57	62	68	77	86	95	93	91	86	77	64	57

Average Low Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48	32	35	41	48	57	66	69	68	60	50	37	32

Average Precipitation — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in	9.2	0.5	0.4	0.4	0.3	0.4	0.8	1.6	1.6	1.3	0.9	0.5	0.6

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.8	11.5	12.4	13.4	14.3	14.7	14.4	13.7	12.7	11.8	11	10.6

Average Number of Days Above 90F/32C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	103	---	---	0.1	1	13.9	26.6	25.9	22.5	12.4	0.5	---	---

Average Number of Days Below 32F/0C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	55.3	18.7	9.2	3.9	0.4	---	---	---	---	---	0.3	5.6	17.2

Energy Use and Utility Data

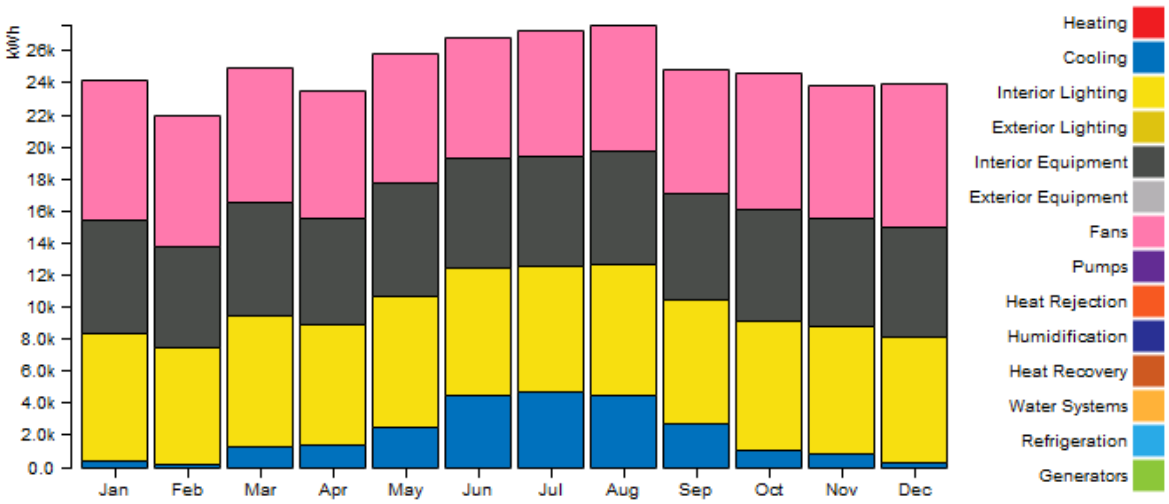
The electricity at Ft. Bliss is provided by the El Paso Electric Company. The 2012 electricity usage and cost for the building is given in the table below. Electricity costs are primarily driven by the demand charge of $16.76/kW and the summer on-peak rate of $0.14335/kWh between 12:00pm-6:00pm during the months of June through September. Off-peak rates of $0.00527 are almost negligible in comparison.

	Electricity (kWh)	Electricity Cost
Jan-12	22,924	$1,433
Feb-12	20,152	$1,260
Mar-12	19,509	$1,219
Apr-12	18,741	$1,171
May-12	28,069	$1,754
Jun-12	30,434	$1,902
Jul-12	26,287	$1,643
Aug-12	24,085	$1,505
Sep-12	23,736	$1,484
Oct-12	23,031	$1,439
Nov-12	19,592	$1,225

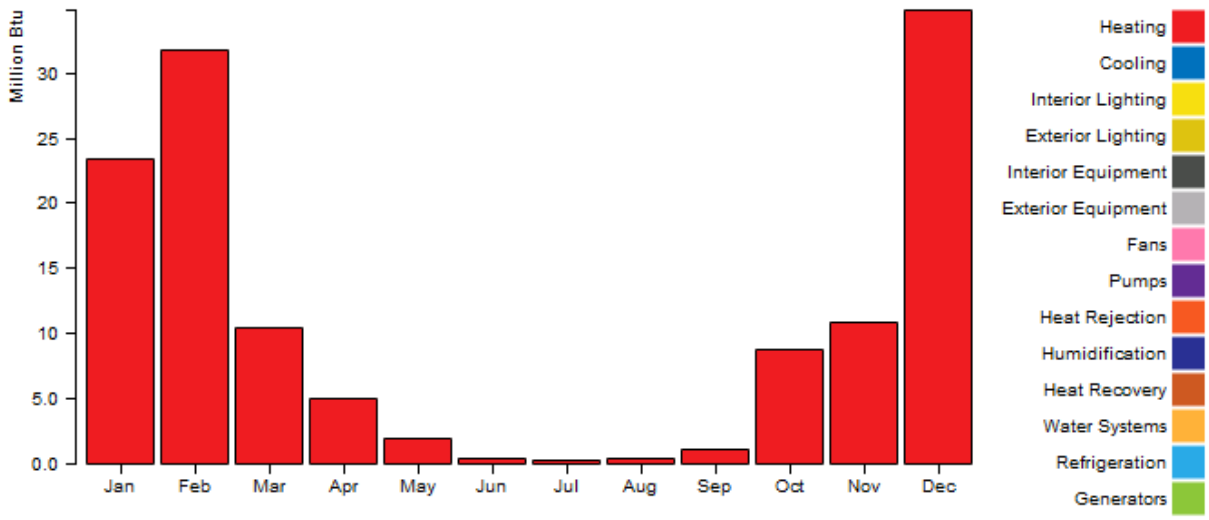
Dec-12	30,400	$1,425

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



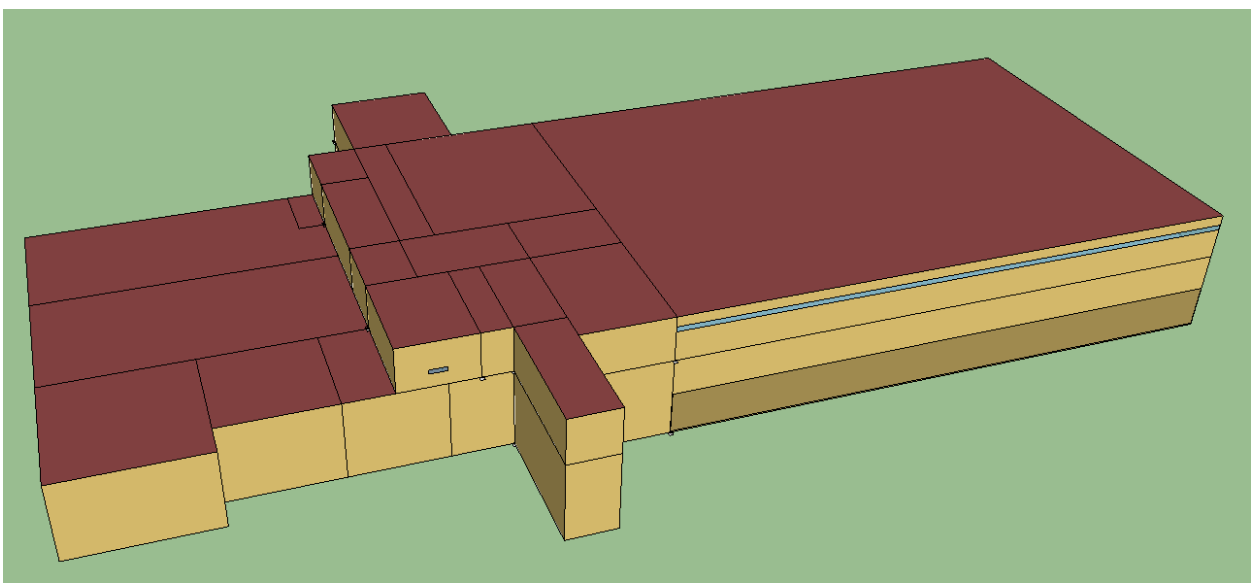
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Building 20107 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

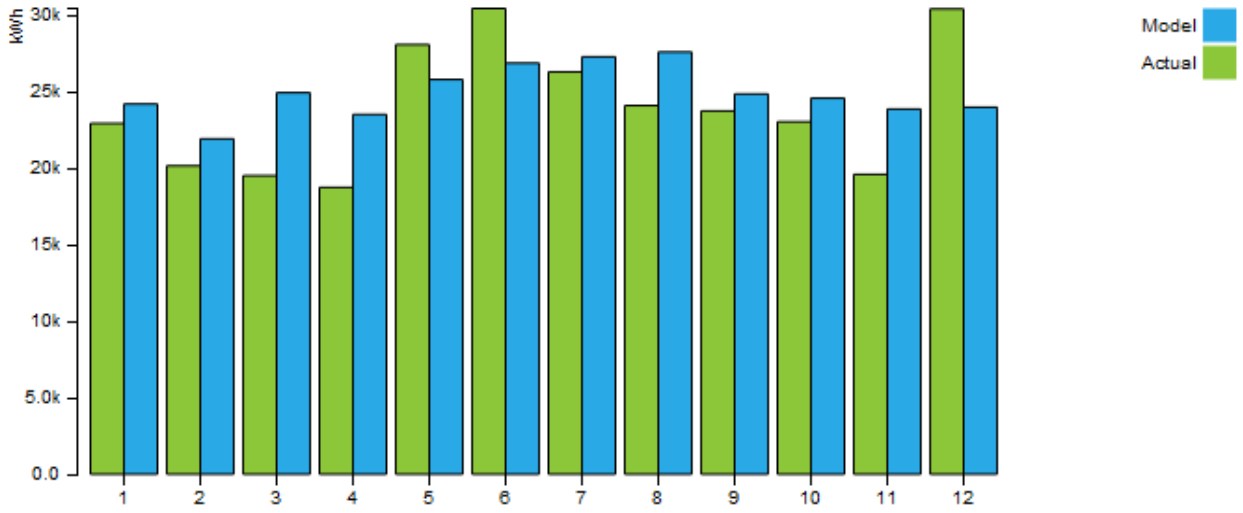


The graphs below show the average actual utility consumption versus the calibrated energy model for the past two years.

Electricity Consumption (kWh)

CV(RMSE) = 15.49

NMBE = -4.69



ENERGY CONSERVATION MEASURES

During the site visit, the team identified 10 energy conservation measures. Some of the identified measures have payback periods ranging from 1-10 years. Energy savings, cost savings, installation costs, simple payback periods, and measure descriptions are presented in the following sections organized by building energy system.

Lighting Energy Conservation Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Re-configure controls for photo cells in high bay	**8,761 (2.9%)**	**(-13.85) (-10.8%)**	**592**	**5,000.00**	**8.5**
Implement bi-level occupancy switching in lobby and stairwells	**108 (0.0%)**	**(-0.04) (-0.0%)**	**8**	**1,600.00**	**195.1**
Install low-wattage T8 lighting when lamps fail	**12,553 (4.2%)**	**(-4.75) (-3.7%)**	**901**	**320.00**	**0.4**
Implement occupancy sensor lighting controls (rm 117, 116, 110)	**1,163.89 (0.4%)**	**(-0.57) (-0.4%)**	**97.80**	**1,200.00**	**12.27**

Re-configure controls for photo cells in high bay

Category: Electric Lighting Controls
Description: Currently, the high bay has no daylighting controls but receives a significant amount of daylight through the windows. It is recommended that daylighting controls be added to the space to automatically dim the electric lighting to maintain 50 foot-candles on the floor of the workshop. This measure will require all fixture ballasts be replaced with dimming ballasts and bulbs, in addition to, the photosensor and controls.

Implement bi-level occupancy switching in lobby and stairwells

Category: Electric Lighting Controls
Description: Occupancy sensors save energy by turning off lights when not needed and/or when spaces are left unoccupied. Passive electronic sensor can automatically activate and deactivate lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as people move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. Stairwell lighting can be

reduced by 50% while still maintaining adequate lighting requirements for egress. This measure is not financially viable, and not recommended for implementation due to the long payback.

Install low-wattage T8 lighting when lamps fail

Category: Lighting Equipment
Description: Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

Implement occupancy sensor lighting controls (rm 117, 116, 110)

Category: Electric Lighting Controls
Description: Occupancy sensors save energy by turning off lights when not needed and/or when spaces are left unoccupied. Install a passive electronic sensor to automatically activate and deactivate lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as people move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. In many instances, a simple wall switch replacement is adequate. In other cases, a ceiling-mount sensor or alternatively placed wall-mount sensor may provide better coverage. In rooms with multiple lighting circuits or devices, multi-pole power packs and auxiliary relays can be configured to operate from a single sensor head. In larger spaces, multiple sensors can be wired in parallel to keep all lights on if any one sensor is triggered.

HVAC Energy Conservation Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)	**7,097.22 (2.4%)**	**18.91 (14.7%)**	**1,086.50**	**27,000.00**	**24.85**

Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)

RTU retrofit kits were modeled to include converting the current air delivery system to a variable air volume system, adding demand controlled ventilation, adding economizer controls, and fault detection and diagnostics. Each measure is described individually below.

CAV with Reheat to VAV with Reheat Air Handler

Category: HVAC Whole System
Description: Add a variable frequency drive (VFD) to the fan on the handler. In a constant volume reheat system, unneeded conditioned air is bypassed directly to the return air stream when the VAV boxes are throttled back. However, energy is still expended moving this air. Installing a VFD on the fan and eliminating the bypass allows the system to lower the fan speed when less cooling is needed, minimizing the amount of air being moved and conditioned.

Enable Demand Controlled Ventilation

Category: Ventilation
Description: The facility currently does not have a demand controlled ventilation system or CO_2 sensors in the air delivery system. Outside air is introduced and conditioned at a fixed rate based on the maximum design. Since the building occupancy fluctuates and is often less than the maximum design occupancy, it is being over-ventilated and consuming more energy than necessary. The building CO_2 level is closely related to the occupancy. The typical outside CO_2 level is relatively low concentration, around 400 to 500 ppm, and is used to dilute the higher indoor CO_2 levels. Demand controlled ventilation could be implemented by deploying CO_2 sensors located in each AHU return air duct and in densely occupied spaces, such as conference rooms. Implementation of this ECM will require:

- Rebalance the open/closed outside air dampers to a lower minimum ventilation rate.
- Program demand ventilation controls into each AHU, controlling modulating dampers in mixed air AHUs and VFDs in outside air units. Ventilation will be generally controlled from return air sensors, but will be increased as needed based on densely occupied space sensors.
- Commission the project.

Enable Economizer Control

Category: Cooling

Description: There is currently not a functioning air side economizer enabled in the building. Air side economizers use cold outside air to either assist the mechanical cooling system, or if the air is cold enough, provide all of the cooling for a facility. In order for an air side economizer to function properly, all of the outside air damper actuators need to have modulating capabilities. In addition to that, new control sequences need to be written into the building automation control system to enable the air-side economizer when outside air temperatures are below 60F-65F and the interior space temperatures are calling for cooling. The building would realize the following operational benefits by utilizing an air-side economizer:

- Reduction in cooling system energy use
- Reduction in mechanical cooling system run time
- Possible improvement in indoor air quality

Plug Loads Energy Conservation Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Schedule controlled advanced power strips on shared equipment	**4,277.78 (1.4%)**	**(-1.91) (-1.5%)**	**378.50**	**1,000.00**	**2.64**
Remove excess refrigerators, replace the old units with energy star	**444 (0.1%)**	**(-0.11) (-0.1%)**	**30**	**1,440.00**	**48.2**
Computer power management	**3,761 (1.3%)**	**(-1.25) (-1.0%)**	**227**	**4,500.00**	**19.8**
Vending machine misers	**7,897 (2.6%)**	**(-1.52) (-1.2%)**	**134**	**1,200.00**	**8.9**

Schedule controlled advanced power strips on shared equipment

Category: Equipment Controls
Description: Many buildings have electric equipment that runs unnecessarily at night, such as, network printers and desktop printers. Turning this equipment off at night with schedule controlled advanced power strips can provide energy savings without impacting the day-to-day operation of the building occupants. Before implementing this change, make sure that equipment can be brought back online quickly enough in the morning to avoid issues with occupants overriding the controls due to productivity losses.

Remove excess refrigerators and incrementally install Energy Star models

Category: Electric Equipment
Description: The assessment team observed excess refrigerators in the building. The refrigerators were older Top Mount Freezer without through-the-door ice models and were not Energy Star rated. It is recommended that site staff remove excess refrigerators and replace all older refrigerators with newer Energy Star rated models incrementally as the older models approach the end of their useful life.

Implement Computer Power Management

Category: Electric Equipment
Description: The facility has all desktop computers. The typical office space is set up with a 17-inch Samsung, LCD monitor (Model: Sync Master 740n) and a Hewlet-Packard computer. The

computer has a connected electrical load of 57 Watts, and the monitors have a connected electrical load of 19 Watts. When placed in sleep mode' the screen's connected load is reduced to 0.69 Watts and the computers connected load is reduced to 2.0 Watts.

There are software programs available that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

Vending machine misers

Category: Equipment Controls
Description: The assessment team observed three refrigerated vending machines in the building. The vending machines cycle throughout the day and night to keep beverages cool. Vending machine misers are small, easy to use devices that can reduce the energy consumed in refrigerated vending machines by 46%. The controller uses an infrared occupancy sensor to power down the unit when no occupants are present and has some intelligent control, in that it will record the time intervals when the building is not occupied and power down the machine during these periods. The refrigerated vending machine misers keep the beverages cold, while simultaneously reducing the energy consumption of the machine.

Envelope Energy Conservation Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Reduce infiltration (missing threshold and air seal canteen doors)	**206 (0.1%)**	**0.72 (0.6%)**	**12**	**348.00**	**28.8**

Reduce infiltration (missing threshold and air seal canteen doors)

Category: Infiltration
Description: The assessment team observed areas of infiltration in this building. It is recommended that site staff conduct spot air sealing of doors, windows, and exterior wall penetrations to reduce the amount of infiltration.

Bundled Energy Conservation Measures

ECM Name	Annual Electricity Savings (kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	**44,580.56 (14.9%)**	**(-1.06) (-0.8%)**	**3,181.70**	**43,608.00**	**13.71**

Bundled all ECMs

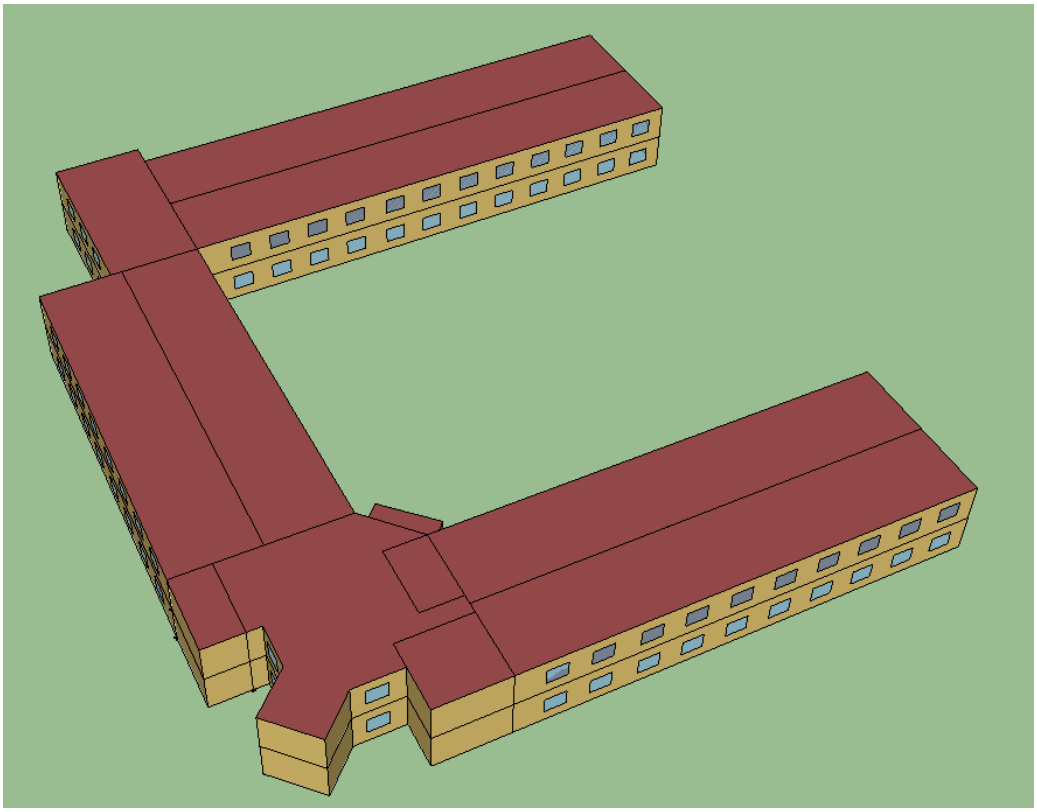
Category: All Measures
Description: All measures were bundled into a single measure so that interactions between ECMs are accurately accounted for, which can make a big difference in the viability of the ECMs. The following measures were included in the bundle:

- Implement RTU retrofit kits (ACR controllers) (CV to VAV, DCV, OA economizer, fault detection and diagnostics)
- Implement occupancy sensor lighting controls (rm 117, 116, 110)
- Re-configure controls for photo cells in high bay
- Implement bi-level occupancy switching in lobby and stairwells
- Install low-wattage T8 lighting when lamps fail (or LEDs)
- Remove excess refrigerators, replace the old units with energy star
- Schedule controlled advanced power strips on shared equipment
- Computer power management
- Vending machine misers
- Reduce infiltration (missing threshold and air seal canteen doors

Building 20355

Energy Audit Report

Ansbach Way, Fort Bliss, TX 79918, USA



Monday, July 14, 2014

Prepared By:

simuwatt

EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of Building 20355 in Ansbach Way, Fort Bliss, TX 79918, USA. During the site visit, the team identified 5 energy conservation, water conservation, and renewable energy measures. Some of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

Building 20355, constructed in 2009, is a 51,592 ft^2 structure with 2 floors. The building serves primarily as barracks.

ENERGY USAGE OVERVIEW

The electricity at Ft. Bliss is provided by the El Paso Electric Company. The most recent monthly electricity usage, peak demand, and electricity costs for the building are given in the table below.

	Electricity (kWh)	Peak Demand (kW)	Electricity Cost
Jan-13	30,107	79	$1,852
Feb-13	20,373	72	$1,253
Mar-13	25,577	108	$1,573
Apr-13	24,938	61	$1,534
May-13	29,035	79	$1,786
Jun-13	39,186	89	$2,410
Jul-13	37,984	91	$2,336
Aug-12	31,975	83	$1,966
Sep-12	26,803	69	$1,648
Oct-12	23,249	53	$1,430
Nov-12	19,626	48	$1,207
Dec-12	23,648	53	$1,454

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. The following measures could not be analyzed due to data loss and software limitations at the time of the demonstration:

- LED lighting replacements (retrofit all exterior HID wall packs)
- Exterior lighting on timer and photo cells (under canopy)
- Energy star washing machines
- Vending machine misers and timers on the ice machines

Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings(kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	32,611.11 (9.4%)	0.00 (0.0%)	2,762.50	53,566.00	19.39

Lighting Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Delamp all mechanical rooms	6 (0.0%)	0.00 (0.0%)	0	50.00	125.0
Daylight sensor in the lobby	5,272 (1.5%)	0.00 (0.0%)	588	5,000.00	8.5
Key card lighting controls	18,136 (5.2%)	0.00 (0.0%)	1,441	16,000.00	11.1

Plug Loads Conservation Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Key card plug load control	9,689 (2.8%)	0.00 (0.0%)	746	32,000.00	42.9

Building Envelope Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Spot air sealing	242 (0.1%)	0.00 (0.0%)	46	516.00	11.2

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INTRODUCTION

CLIMATE DATA

Building 20355 is located at Ansbach Way, Fort Bliss, TX 79918, USA. The city is at an elevation of TBD feet above sea level and its latitude and longitude are approximately 31.85, and -106.35, respectively. A Google Earth satellite image of the building is shown below.

The table below shows the monthly average climate conditions in Fort Bliss, TX[3].

---

[3] http://www.weatherbase.com. Accessed July, 2014.

MONTHLY - WEATHER AVERAGES SUMMARY [Show All Data] [°C] °F

Average Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62	44	48	55	62	71	80	80	78	73	64	51	44

Average High Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	75	57	62	68	77	86	95	93	91	86	77	64	57

Average Low Temperature — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48	32	35	41	48	57	66	69	68	60	50	37	32

Average Precipitation — Years on Record: 120

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in	9.2	0.5	0.4	0.4	0.3	0.4	0.8	1.6	1.6	1.3	0.9	0.5	0.6

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.8	11.5	12.4	13.4	14.3	14.7	14.4	13.7	12.7	11.8	11	10.6

Average Number of Days Above 90F/32C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	103	---	---	0.1	1	13.9	26.6	25.9	22.5	12.4	0.5	---	---

Average Number of Days Below 32F/0C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	55.3	18.7	9.2	3.9	0.4	---	---	---	---	---	0.3	5.6	17.2

Energy Use and Utility Data

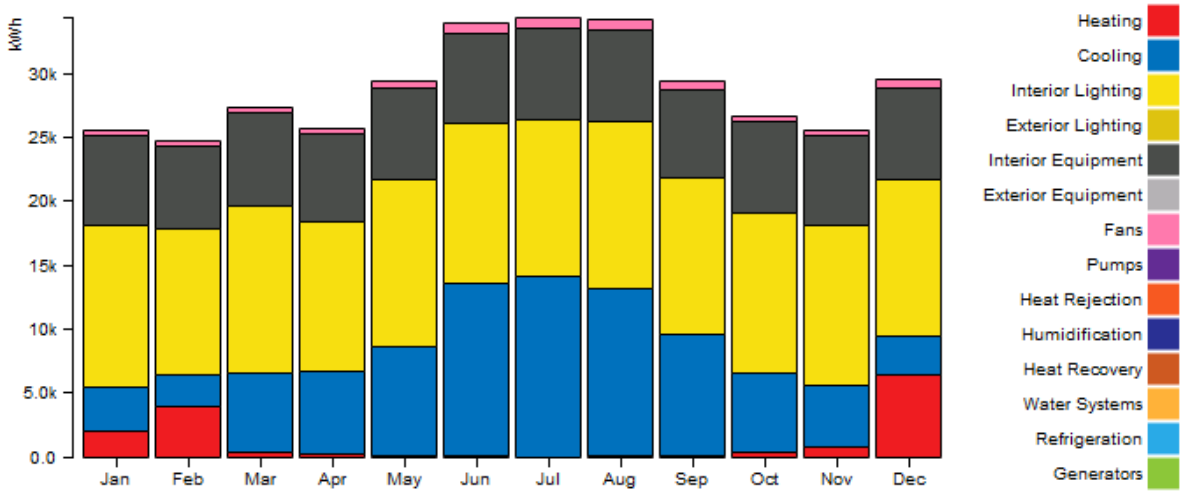
The electricity at Ft. Bliss is provided by the El Paso Electric Company. The 2012 electricity usage and cost for the building is given in the table below. Electricity costs are primarily driven by the demand charge of $16.76/kW and the summer on-peak rate of $0.14335/kWh between 12:00pm-6:00pm during the months of June through September. Off-peak rates of $0.00527 are almost negligible in comparison.

	Electricity (kWh)	Peak Demand (kW)	Electricity Cost
Jan-13	30,107	79	$1,852
Feb-13	20,373	72	$1,253
Mar-13	25,577	108	$1,573
Apr-13	24,938	61	$1,534
May-13	29,035	79	$1,786
Jun-13	39,186	89	$2,410
Jul-13	37,984	91	$2,336
Aug-12	31,975	83	$1,966
Sep-12	26,803	69	$1,648
Oct-12	23,249	53	$1,430

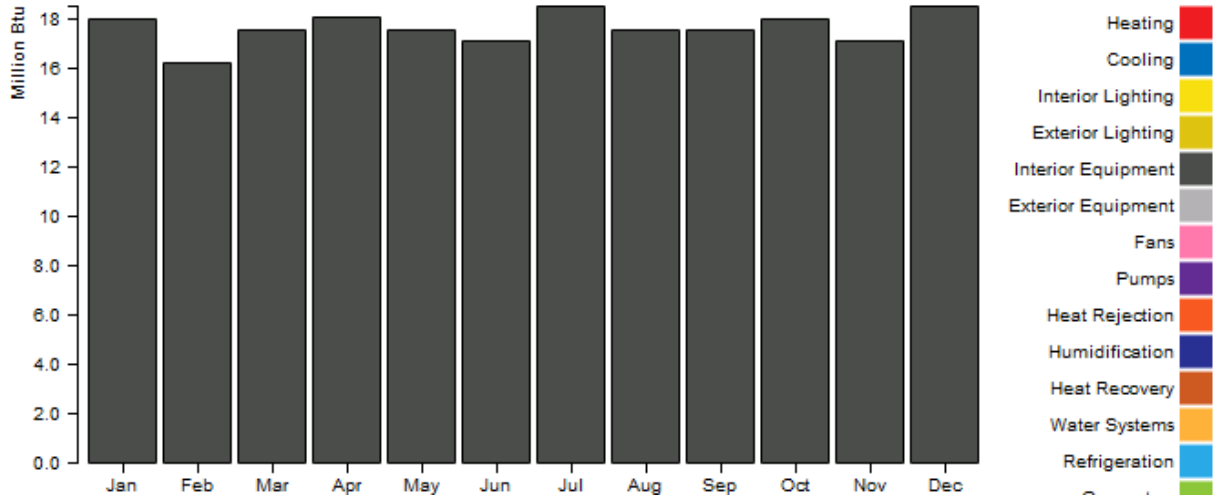
Nov-12	19,626	48	$1,207
Dec-12	23,648	53	$1,454

The modeled energy usage can be seen below in the energy consumption by month for electricity and natural gas.

Monthly Electricity Consumption (kWh)



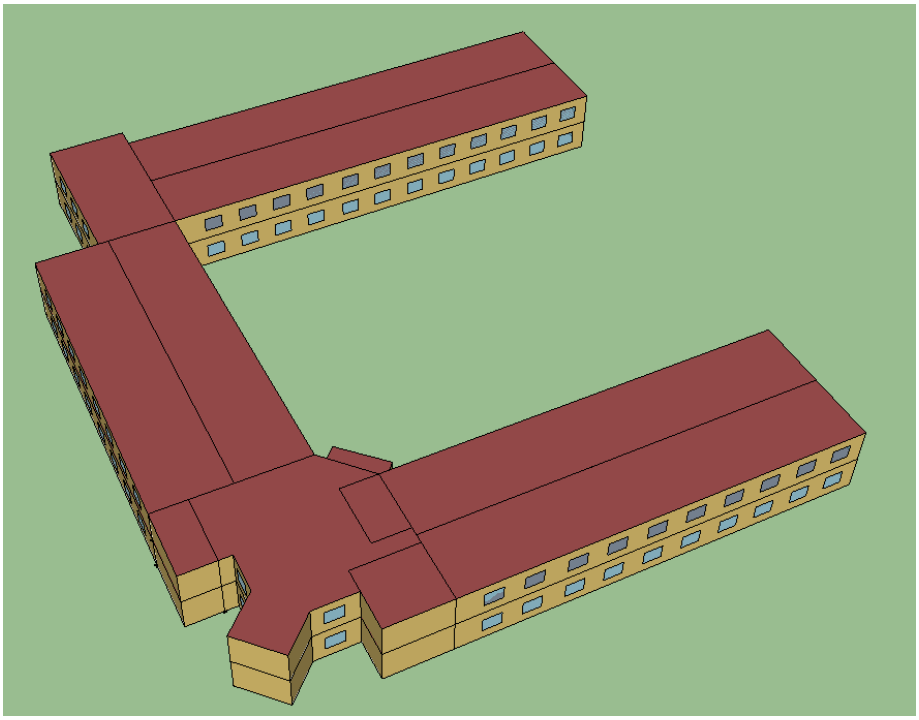
Monthly Gas Consumption (MMBtu)



Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Ft. Bliss 20355 building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

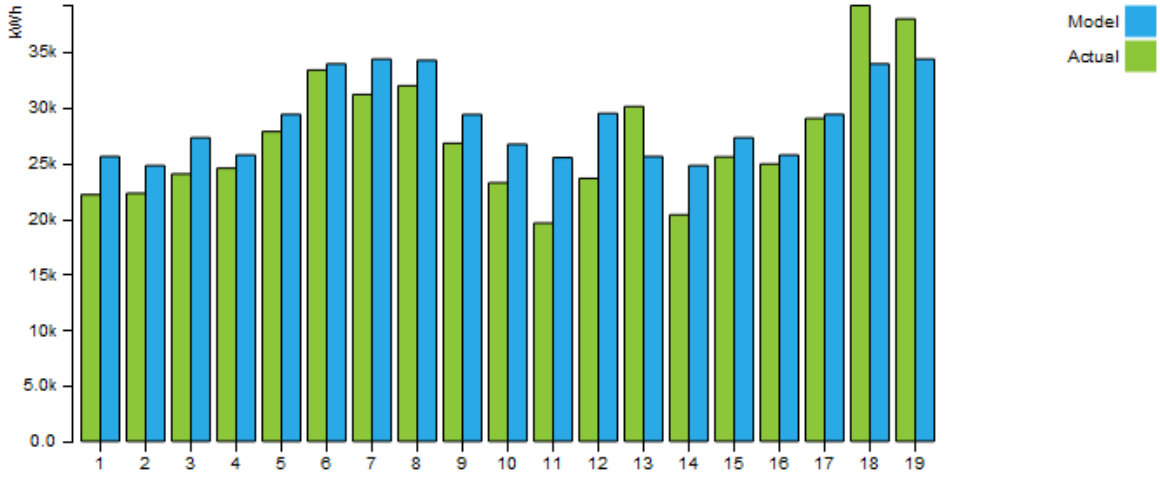


The graphs below show the average actual utility consumption versus the calibrated energy model for the past years and seven months.

Electricity Consumption (kWh)

CV(RMSE) = 12.81

NMBE = -6.04



ENERGY CONSERVATION MEASURES

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Delamp all mechanical rooms	**6 (0.0%)**	**0.00 (0.0%)**	**0**	**50.00**	**125.0**
Daylight sensor in the lobby	**5,272 (1.5%)**	**0.00 (0.0%)**	**588**	**5,000.00**	**8.5**
Key card lighting controls	**18,136 (5.2%)**	**0.00 (0.0%)**	**1,441**	**16,000.00**	**11.1**

Lighting Energy Efficiency Measures

Delamp all mechanical rooms

Category: Lighting Equipment
Description: The lighting systems in the mechanical rooms use more power per area than is required and are overlit. The fixtures in the mechanical rooms could be de-lamped to reduce energy, but maintain adequate lighting levels. Due to the low usage schedule, this measure is not recommended at this time, but as lamps fail they may not need to be replaced.

Daylight sensor in the lobby
Category: Electric Lighting Controls
Description: Currently, the lobby has no daylighting controls but receives a significant amount of daylight through the windows. It is recommended that daylighting controls be added to the space to automatically dim the electric lighting to maintain 30 foot-candles on the floor of the lobby. This measure will require all fixture ballasts be replaced with dimming ballasts and bulbs, in addition to, the photosensor and controls.

Key card lighting controls

Category: Lighting Equipment
Description: Currently, there are no lighting controls in any of the barracks. It is recommended that key-card lighting controls be implemented to ensure that lights are off when the space is unoccupied.

Plug Loads Conservation Measures

Key card plug load control

Category: Electric Equipment
Description: Currently, there are no plug load controls in any of the barracks. It is recommended that key-card plug load controls be implemented to ensure that non-critical plug loads are off when the space is unoccupied.

Building Envelope Energy Efficiency Measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Spot air sealing	**242 (0.1%)**	**0.00 (0.0%)**	**46**	**516.00**	**11.2**

Spot air sealing

Category: Infiltration
Description: The assessment team observed areas of infiltration in this building. It is recommended that site staff conduct spot air sealing of doors, windows, and exterior wall penetrations to reduce the amount of infiltration.

Bundled Measures

ECM Name	Annual Electricity Savings(kWh)	Annual Gas Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	**32,611.11 (9.4%)**	**0.00 (0.0%)**	**2,762.50**	**53,566.00**	**19.39**

All Measures

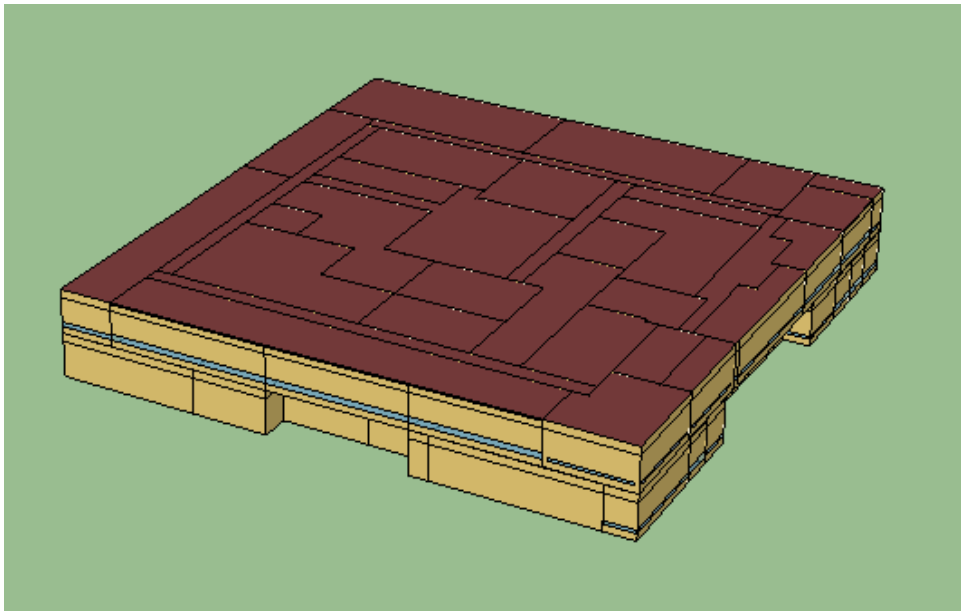
Category: All Measures
Description: All measures were bundled into a single measure so that interactions between ECMs are accurately accounted for, which can make a big difference in the viability of the ECMs. The following measures were included in the bundle:

- Install occupancy sensors to lights throughout the building
- Delamp all mechanical rooms
- Daylight sensor in the lobby
- Key card lighting controls
- Key card plug load control
- Spot air sealing

Building 662

Energy Audit Report

Cleveland Avenue, Tyndall AFB, FL 32403, USA



Monday, August 4, 2014

Prepared By:

simuwatt

EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 662 on Cleveland Avenue, Tyndall AFB, FL 32403, USA. During the site visit, the team identified 10 energy conservation measures. Some of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

Building 662, constructed in 1980, is an 81,402 ft^2 structure with 1 floor. The building serves primarily as office space.

ENERGY USAGE OVERVIEW

The annual electricity consumption was reported to be 625,208 kWh in 2012 at a cost of $45,828. The 2012 monthly electricity usage and cost for building 662 is given in the table below.

Table 16: 2012 Monthly Energy and Cost Summary for Building 662

	Electricity Use (kWh)	Electricity Cost ($)
Jan-12	55,893	$4,097
Feb-12	57,992	$4,251
Mar-12	54,346	$3,984
Apr-12	50,907	$3,732
May-12	45,214	$3,314
Jun-12	53,666	$3,934
Jul-12	50,342	$3,690
Aug-12	52,769	$3,868
Sep-12	43,869	$3,216
Oct-12	50,390	$3,694
Nov-12	52,070	$3,817
Dec-12	57,750	$4,233

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. The following measures could not be analyzed due to data loss and software limitations at the time of the demonstration:

- Implement economizers
- Energy recovery

Table 17: Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Annual Cost Savings ($/yr)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	218,450.00 (34.2%)	0.00 (0.0%)	16,013.70	794,348.00	49.60

Table 18: Lighting Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace lighting with low wattage T-8s	41,406 (6.5%)	0.00 (0.0%)	3,035	30,780.00	10.1
Occupancy sensors for lighting	18,058 (2.8%)	0.00 (0.0%)	1,324	57,200.00	43.2

Table 19: HVAC Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace air-cooled chillers with more efficient units	49,811 (7.8%)	0.00 (0.0%)	3,652	150,000.00	41.1
Replace the current CV system with a VAV system	46,128 (7.2%)	0.00 (0.0%)	3,382	141,888.00	42.0
Demand controlled ventilation	6,136 (1.0%)	0.00 (0.0%)	450	5,000.00	11.1
Cogged v-belts	2,242 (0.4%)	0.00 (0.0%)	165	480.00	2.9

Table 20: Plug Load Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Place shared equipment on scheduled power strips	11,575.00 (1.8%)	0.00 (0.0%)	848.60	8,500.00	10.02
Remove personal printers and replace them with network printers	4,075 (0.6%)	0.00 (0.0%)	299	4,600.00	15.4
Replace desktop computers with laptops and docking stations	61,253 (9.6%)	0.00 (0.0%)	4,490	396,000.00	88.2
Computer power management	21,039 (3.3%)	0.00 (0.0%)	1,542	4,500.00	2.9

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INTRODUCTION

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 662 on Cleveland Avenue, Tyndall AFB, FL 32403, USA.

Climate Data

Building 662 is located on Cleveland Avenue, Tyndall AFB, FL 32403, USA with a latitude and longitude of approximately 30.07, and -85.60, respectively. Figure 10 shows a Google Earth aerial satellite image of Building 662.

Figure 10: Aerial view of Building 662 taken from Google Earth

The table below shows the monthly average climate conditions at Tyndall AFB[4].

[4] http://www.weatherbase.com. Accessed July, 2014.

Table 21: Monthly weather averages for Tyndall Air Force Base

Average Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	66	53	55	59	68	75	78	80	80	78	69	59	55

Average High Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	75	60	64	68	75	82	86	87	87	86	78	69	62

Average Low Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	59	44	46	51	59	66	73	75	75	71	62	50	46

Average Precipitation — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in	53.2	3.3	3.8	4.7	4.4	2.3	4.8	7.4	6.4	6	3.7	2.9	3.8

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.9	11.6	12.4	13.3	14.1	14.5	14.3	13.6	12.7	11.8	11.1	10.7

Energy Use and Utility Data

Building 662 is an all-electric building. The annual electricity consumption was reported to be 625,208 kWh in 2012 at a cost of $45,828. The average electric rate in 2012 was $0.0733/kWh. The 2012 monthly electricity usage and cost for Building 662 is given in the table below.

Table 22: 2012 Monthly Energy and Cost Summary for Building 662

	Electricity Use (kWh)	Electricity Cost ($)
Jan-12	55,893	$4,097
Feb-12	57,992	$4,251
Mar-12	54,346	$3,984
Apr-12	50,907	$3,732
May-12	45,214	$3,314
Jun-12	53,666	$3,934
Jul-12	50,342	$3,690
Aug-12	52,769	$3,868
Sep-12	43,869	$3,216
Oct-12	50,390	$3,694
Nov-12	52,070	$3,817
Dec-12	57,750	$4,233

Figure 11 shows the modeled monthly energy consumption breakdown by end use. Figure 12 shows the modeled annual electricity cost breakdown by end use. Cooling, reheat, and lighting are the largest energy consumers and most costly end uses.

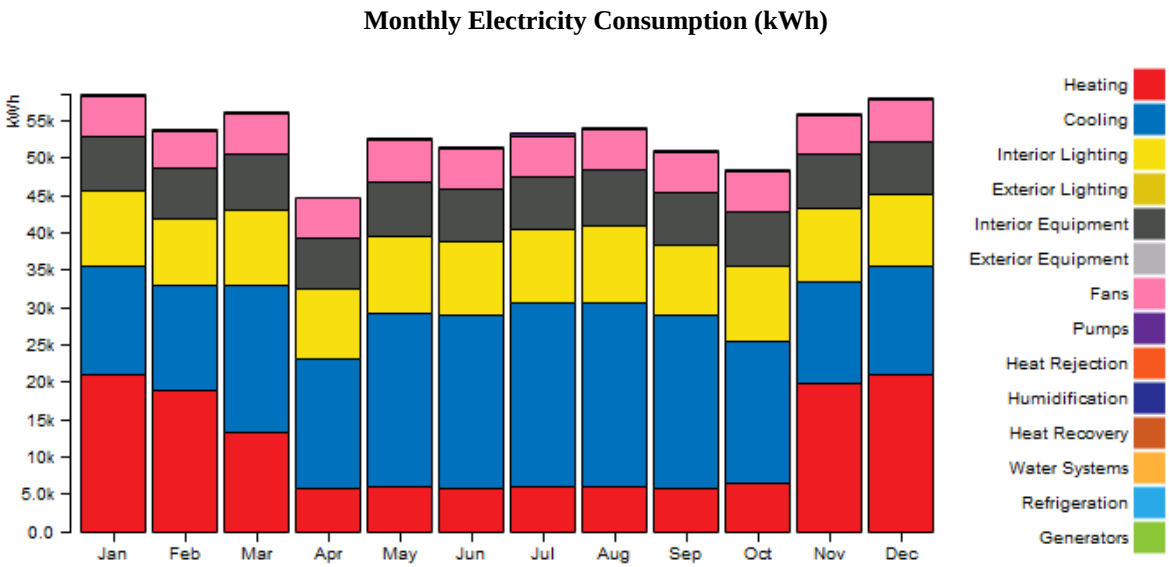


Figure 11: Building 662 modeled monthly electricity consumption breakdown by end use

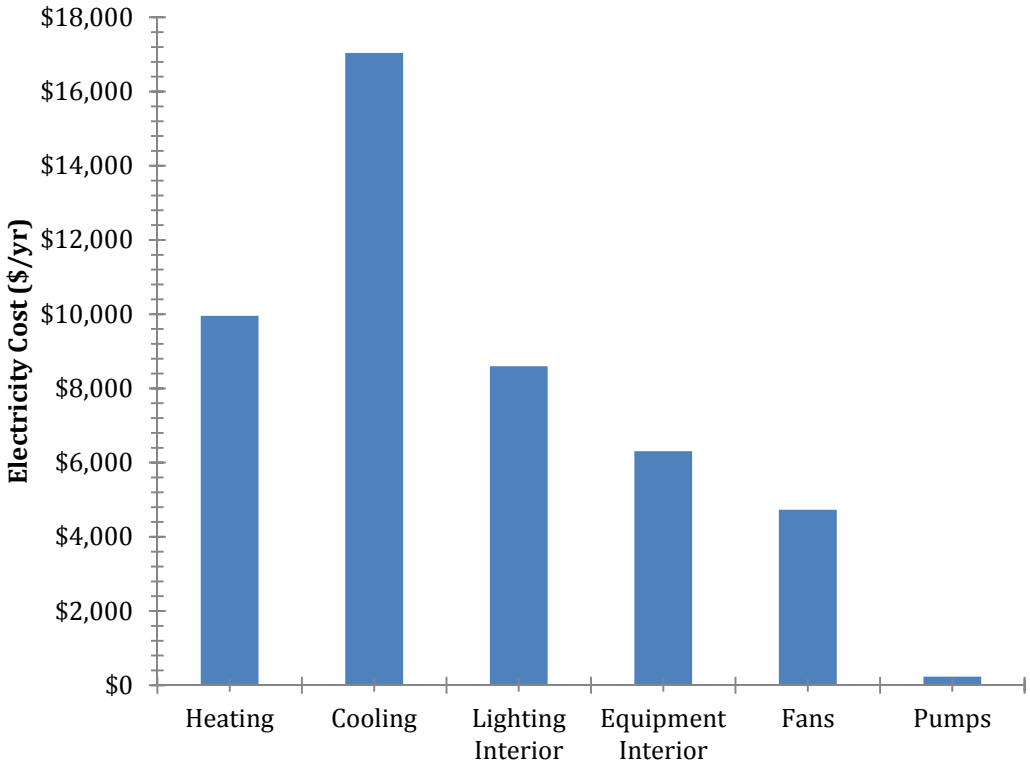


Figure 12: Building 662 modeled annual electricity cost breakdown by end use

Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for Tyndall AFB Building 662. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

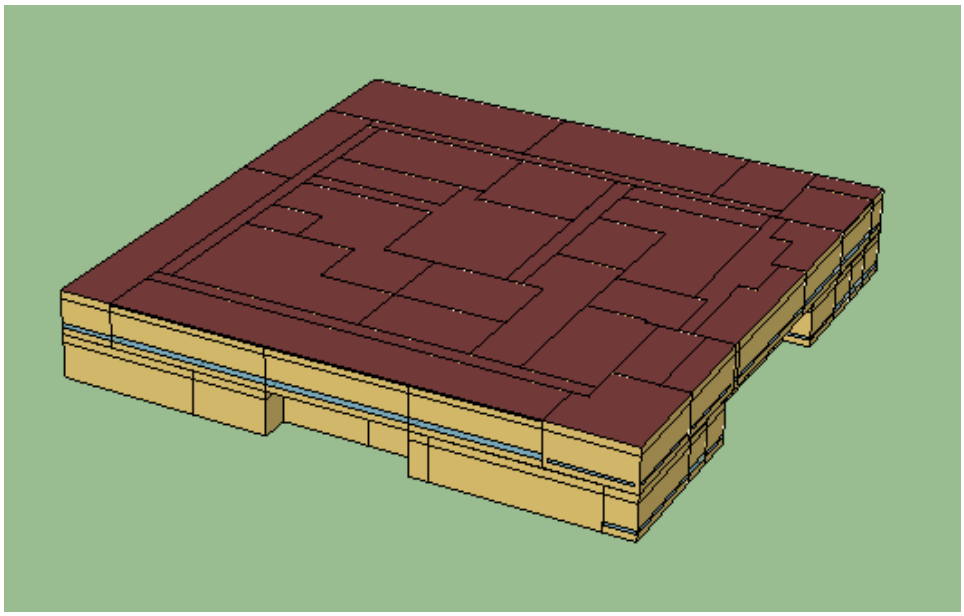


Figure 13: 3-D rendering of the Building 662 energy model generated in Trimble SketchUp

Figure 14 shows the monthly actual utility consumption versus the calibrated energy model for the 2012 calendar year. The energy model was calibrated within a normalized mean biased error of 5% and a coefficient of variation of the root mean square error of 15% relative to monthly utility data in accordance with AHSRAE Guideline 14-2002.

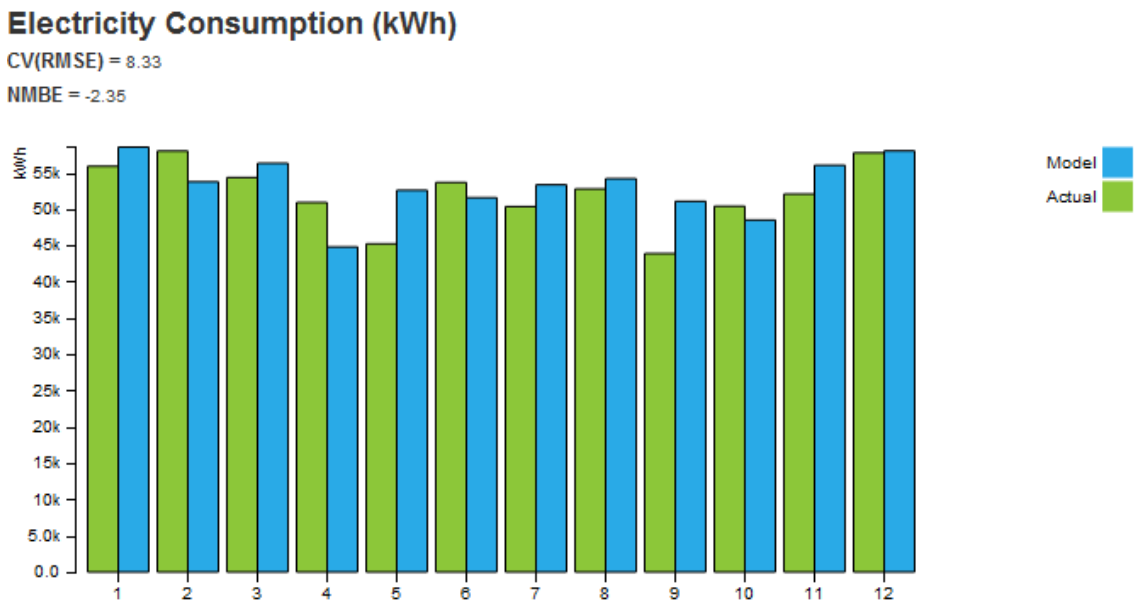


Figure 14: OpenStudio calibration of monthly modeled energy consumption versus actual utility data

Table 23 shows baseline model annual energy and cost characteristics for Tyndall AFB Building 662. This baseline model is used as the reference building for calculating energy and cost savings from simulating the implementation of energy conservation measures described in detail later in this report.

Table 23: Baseline energy model annual energy and cost characteristics

	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kW)	Electricity Consumption (kWh/yr)	Annual Utility Cost ($/yr)
Baseline	**27**	**114.21**	**639,331**	**$46,866.80**

ENERGY CONSERVATION MEASURES

Lighting Energy Efficiency Measures

The following section provides a detailed description of the two lighting energy efficiency measures that were identified during the site visit. Table 24 shows the summary of all lighting efficiency measures, and is followed by the detailed description of each individual measure.

Table 24: Summary of lighting energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace lighting with low wattage T-8s	**41,406 (6.5%)**	**0.00 (0.0%)**	**3,035**	**30,780.00**	**10.1**
Occupancy sensors for lighting nb	**18,058 (2.8%)**	**0.00 (0.0%)**	**1,324**	**57,200.00**	**43.2**

Replace lighting with low wattage T-8s

Category: Lighting Equipment
Description: Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

Table 25: Energy and cost savings for replace lighting with low wattage T-8s ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
41,405.56 (6.5%)	**0.00 (0.0%)**	**3,035.30**	**30,780.00**	**10.14**

Assumptions:

- 1,539 32W T8 lamps in 722 light fixtures throughout the building are replaced with 25W low-wattage T8 lamps.

- The combined labor and material cost was estimated to be $20 per lamp, for a total implementation cost of $30,780.

Occupancy sensors for lighting

Category: Electric Lighting Controls
Description: Occupancy sensors save energy by turning off lights when not needed and/or when spaces are left unoccupied. Install a passive electronic sensor to automatically activate and deactivate lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as people move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. In many instances, a simple wall switch replacement is adequate. In other cases, a ceiling-mount sensor or alternatively placed wall-mount sensor may provide better coverage. In rooms with multiple lighting circuits or devices, multi-pole power packs and auxiliary relays can be configured to operate from a single sensor head. In larger spaces, multiple sensors can be wired in parallel to keep all lights on if any one sensor is triggered.

Table 26: Energy and cost savings for Occupancy sensors for lighting ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
18,058.33 (2.8%)	**0.00 (0.0%)**	**1,323.80**	**57,200.00**	**43.21**

Assumptions:
- Occupancy sensors are installed in 143 spaces in the building.
- The combined labor and material cost was estimated to be $400 per space, for a total implementation cost of $57,200.

HVAC Energy Efficiency Measures

The following section provides a detailed description of the four HVAC energy efficiency measures that were identified during the site visit. Table 27 shows the summary of all HVAC efficiency measures, and is followed by the detailed description of each individual measure.

Table 27: Summary of HVAC energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace air-cooled chillers with more efficient units	49,811 (7.8%)	0.00 (0.0%)	3,652	150,000.00	41.1
Replace the current CV system with a VAV system	46,128 (7.2%)	0.00 (0.0%)	3,382	141,888.00	42.0
Demand controlled ventilation	6,136 (1.0%)	0.00 (0.0%)	450	5,000.00	11.1
Cogged v-belts	2,242 (0.4%)	0.00 (0.0%)	165	480.00	2.9

Replace air-cooled chillers with more efficient units

Category: HVAC Cooling
Description: Chillers can last for many years. Newer chillers can have efficiencies (COPs) significantly better than existing chillers. Replacing a chiller with a more efficient model may pay back in buildings with high cooling loads.

Table 28: Energy and cost savings for replace air-cooled chillers with more efficient units ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
49,811 (7.8%)	0.00 (0.0%)	3,652	150,000.00	41.1

Assumptions:
- The existing 5.5 COP chiller was replaced with a more efficient 7.0 COP chiller.
- The combined labor and material cost was estimated to be $150,000 per chiller, for a total implementation cost of $150,000.

Replace the current constant volume air system with a variable air volume

Category: HVAC Whole System
Description: Add a variable frequency drive (VFD) to the fan on the handler. In a constant volume reheat system, the fan runs at full speed while the temperature of the air is varied to meet setpoint in the space. In some instances, unneeded conditioned air is bypassed directly to the return air stream when VAV terminals are throttled back. Installing a VFD on the fan allows the system to lower the fan speed when less cooling is needed, which saves energy by minimizing the amount of air being moved and conditioned.

Table 29: Energy and cost savings for replace the current CV system with a VAV system ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
46,127.78 (7.2%)	0.00 (0.0%)	3,381.60	141,888.00	41.96

Assumptions:
- The existing 2 CAV air loops are converted to VAV air loops by putting VFDs on the fans, VAV terminals in the spaces, and proper control points and logic for operation.
- The combined labor and material cost was estimated to be $70,944 per air loop, for a total implementation cost of $141,888.

Demand controlled ventilation

Category: HVAC Ventilation
Description: The facility currently does not have a demand controlled ventilation system or CO2 sensors in the air delivery system. Outside air is introduced and conditioned at a fixed rate based on the maximum design. Since the building occupancy fluctuates and is often less than the maximum design occupancy, it is being over-ventilated and consuming more energy than necessary. The building CO2 level is closely related to the occupancy. The typical outside CO2 level is relatively low concentration, around 400 to 500 ppm, and is used to dilute the higher indoor CO2 levels. Demand controlled ventilation could be implemented by deploying CO2 sensors located in each AHU return air duct and in densely occupied spaces, such as conference rooms. Implementation of this ECM will require:
- Rebalance the open/closed outside air dampers to a lower minimum ventilation rate.
- Program demand ventilation controls into each AHU, controlling modulating dampers in mixed air AHUs and VFDs in outside air units. Ventilation is typically controlled from return air sensors, and increased as needed based on densely occupied space sensors.
- Commission the project.

Table 30: Energy and cost savings for demand controlled ventilation ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
6,136.11 (1.0%)	**0.00 (0.0%)**	**449.90**	**5,000.00**	**11.11**

Assumptions:

- The existing 2 air loops are retrofitted for demand controlled ventilation.
- The combined labor and material cost was estimated to be $2,500 per air loop, for a total implementation cost of $5,000.

Cogged V-belts

Category: HVAC Distribution
Description: Cogged v-belts can be used with the same pulleys as equivalent rated v-belts. They run cooler, last longer, and have an efficiency that is on the order of 2%-3% higher than standard v-belts due to the elimination of slippage. The belts associated with the largest motors and the motors that are run closest to full load should be given priority when making replacements. It is recommended that standard v-belts be replaced with cogged v-belts. Improvements in belt efficiency result in energy savings at the motor. The three common belt efficiency measures are belt tightening (1%-5% savings per motor), replace standard v-belts with cogged v-belts (2% savings per motor), and replace standard belts with synchronous belts (3% savings per motor). Well-adjusted belts run cooler, last longer, and operate at higher efficiency than standard belts. The belts associated with the largest motors, longest run times, and that are run closest to full load should be given priority when making replacements.

Table 31: Energy and cost savings for cogged v-belts ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
2,241.67 (0.4%)	**0.00 (0.0%)**	**164.50**	**480.00**	**2.92**

Assumptions:

- The existing 2 fans drives are retrofitted with cogged V-belts improving the overall drive efficiency by 3%.
- The combined labor and material cost was estimated to be $240 per fan, for a total implementation cost of $480.

Plug Loads Energy Efficiency Measures

The following section provides a detailed description of the four plug load energy efficiency measures that were identified during the site visit. Table 32 shows the summary of all plug load efficiency measures, and is followed by the detailed description of each individual measure.

Table 32: Summary of plug load energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Place shared equipment on scheduled power strips	11,575.00 (1.8%)	0.00 (0.0%)	848.60	8,500.00	10.02
Remove personal printers and replace them with network printers	4,075 (0.6%)	0.00 (0.0%)	299	4,600.00	15.4
Replace desktop computers with laptops and docking stations	61,253 (9.6%)	0.00 (0.0%)	4,490	396,000.00	88.2
Computer power management	21,039 (3.3%)	0.00 (0.0%)	1,542	4,500.00	2.9

Place shared equipment on scheduled power strips

Category: Equipment Controls
Description: Many buildings have electric equipment that runs unnecessarily at night. Turning this equipment off at night can provide energy savings without impacting the day-to-day operation of the building occupants. Before implementing this change, make sure that equipment can be brought back online quickly enough in the morning to avoid issues with occupants overriding the controls due to productivity losses.

Table 33: Energy and cost savings for place shared equipment on scheduled power strips ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
11,575.00 (1.8%)	0.00 (0.0%)	848.60	8,500.00	10.02

Assumptions:

- The following equipment was placed on scheduled power strips: 3 vending machines, 27 personal coffee machines, 3 commercial coffee machines, 36 desktop printer, 35 networked printers, 3 projectors, and 18 water coolers.
- Equipment was turned off between the hours of 5pm and 7am, every day of the week.
- The combined labor and material cost was estimated to be $100 per device, for a total implementation cost of $8,500.

Remove personal printers and replace them with network printers

Category: Electric Equipment
Description: Several personal printers, not including large printer/copier machines, were observed throughout the building. Most of these printers appeared antiquated and were most likely energy inefficient. Investing in high-efficiency, high-output central printing stations would reduce energy use by reducing the need for personal printers. Eliminate personal printers and have all personal use the current network printers.

Table 34: Energy and cost savings for remove personal printers ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
4,075 (0.6%)	0.00 (0.0%)	299	4,600.00	15.4

Assumptions:
- The existing 46 desktop printers, estimated to have a load of 40 Watts each, are removed.
- The combined labor and material cost was estimated to be $100 per printer, for a total cost of $4,600.

Replace desktop computers with laptops and docking stations

Category: Electric Equipment
Description: Several standard desktop tower computers and LCD monitors were observed during the site assessment. Desktop computers typically use between 150-240 Watts per computer. Replace the computer/monitor combination with an laptop computer which will have a much lower connected load and lower energy consumption for the same computing capabilities. If this project is not economically feasible for this building, then laptops should be specified as computers are replaced. The small incremental cost is typically justified by the energy savings.

Table 35: Energy and cost savings for replace desktop computers with laptops and docking stations ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback

	(MMBtu/yr)			Period (yrs)
61,252.78 (9.6%)	**0.00 (0.0%)**	**4,490.20**	**396,000.00**	**88.19**

Assumptions:

- The existing 198 desktop computers, estimated to have a load of 240 Watts each, are replaced with laptops rated at 60 Watts each.
- The combined labor and material cost was estimated to be $2000 per computer, for a total cost of $396,000.

Computer power management

Category: Electric Equipment
Description: Several standard desktop tower computers and LCD monitors were observed during the site assessment. When put into sleep mode, the energy consumption of this equipment is significantly reduced. There are software programs available that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images.

Table 36: Energy and cost savings for computer power management ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
21,038.89 (3.3%)	**0.00 (0.0%)**	**1,542.30**	**4,500.00**	**2.92**

Assumptions:

- The existing desktop computers are connected to centralized computer power management software that will reduce equipment power by 20%.
- The combined labor and material cost was estimated to be $4,500 per implementation, for a total implementation cost of $4,500.
- License renewal fees are estimated at $500/yr.

Bundled Energy Efficiency Measures

The following section provides a detailed description of the bundled measures that were identified during the site visit.

Bundled all ECMs

Category: All Measures
Description: All measures were bundled into a single measure so that interactions between ECMs are accurately accounted for, which can make a big difference in the viability of the ECMs. The following measures were included in the bundle:

- Replace air-cooled chillers with more efficient units
- Replace the current CV system with a VAV system
- Remove personal printers and replace them with network printers
- Replace desktop computers with laptops and docking stations
- Demand controlled ventilation
- Replace lighting with low wattage T-8s
- Occupancy sensors for lighting
- Place shared equipment on scheduled power strips
- Computer power management
- Cogged V belts

Table 37: Energy and cost savings for bundled all ECMs

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
218,450.00 (34.2%)	0.00 (0.0%)	16,013.70	794,348.00	49.60

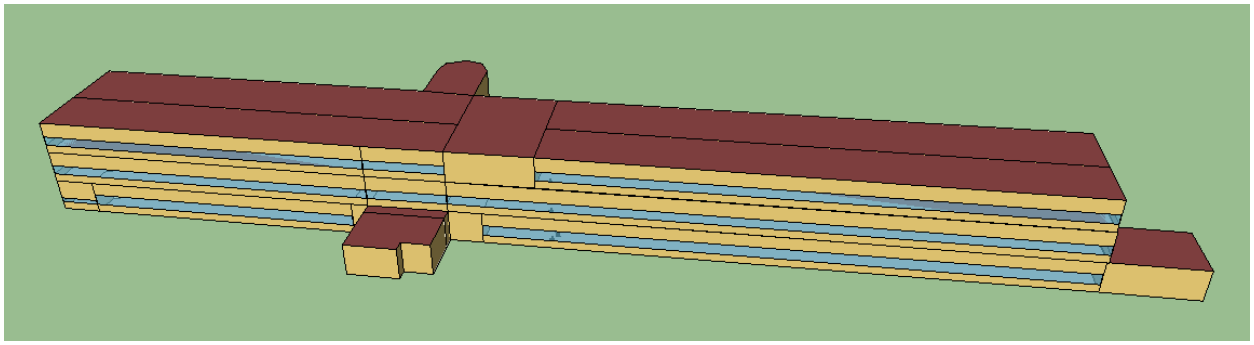
Assumptions:

- All individual measure assumptions are included in the bundle measures.

Building 1060 final

Energy Audit Report

406-416 Minnesota Avenue, Tyndall AFB, FL 32403, USA



Thursday, August 7, 2014

Prepared By:

simuwatt

EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 1060 on 406-416 Minnesota Avenue, Tyndall AFB, FL 32403, USA. During the site visit, the team identified 9 energy conservation measures. Some of the identified measures have payback periods ranging from 1-10 years.

SITE OVERVIEW

Building 1060 final, constructed in 1985, is a 34,000 ft^2 structure with 3 floors. The building serves primarily as barracks space.

ENERGY USAGE OVERVIEW

The annual electricity consumption was reported to be in 499,980 kWh in 2012 at a cost of $36,649. The 2012 monthly natural gas usage and cost for Building 1060 was reported to be 966 MMBtu at a cost of $8,606. The 2012 monthly natural gas usage and cost for Building 1060 is given in the table below.

Table 38: 2012 Monthly Energy and Cost Summary for Building 1060

	Natural Gas Use (MMBtu)	Natural Gas Cost ($)
Jan-12	154.2	$1,374
Feb-12	101.0	$900
Mar-12	124.8	$1,112
Apr-12	104.4	$930
May-12	63.5	$566
Jun-12	43.7	$389
Jul-12	48.9	$436
Aug-12	43.6	$389
Sep-12	48.8	$435
Oct-12	50.5	$450
Nov-12	65.2	$581
Dec-12	117.2	$1,044

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. The following measures could not be analyzed due to data loss and software limitations at the time of the demonstration:

- Convert constant flow hot water pumping system to variable flow
- Improve motor efficiency on pumps
- Implement economizers

- Energy recovery

Table 39: Energy Conservation Measures – All Measures Combined Impact

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Annual Cost Savings ($/yr)	Installation Cost ($)	Simple Payback Period (yrs)
Bundled all ECMs	103,369 (21%)	131 (13%)	8,744	450,360	52

Table 40: Lighting Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace lighting with low wattage T-8s	5,469 (1.1%)	0.34 (0.0%)	404	3,880.00	9.6

Table 41: HVAC Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Convert constant flow chilled water pumping system to variable flow	40,222 (8.2%)	0.00 (0.0%)	2,948	100,000.00	33.9
Replace existing hot water boilers with condensing boilers	0 (0.0%)	152.20 (15.2%)	1,356	15,000.00	11.1
Demand controlled ventilation	2,211 (0.5%)	(-4.43) (-0.4%)	123	5,000.00	40.8
Cogged v-belts	2,517 (0.5%)	0.99 (0.1%)	193	480.00	2.5
Implement card readers that turn off HVAC, plug loads, and lighting	15,555.56 (3.2%)	(-61.47) (-6.2%)	592.80	220,000.00	371.12

Table 42: Plug Load Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace current refrigerators with energy star units	5,381 (1.1%)	3.64 (0.4%)	427	70,000.00	164.0
Replace CRT TVs with LCD TVs	37,736 (7.7%)	26.76 (2.7%)	3,005	28,000.00	9.3

Table 43: Domestic Hot Water Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace existing domestic hot water boilers with condensing boilers	0 (0.0%)	6.98 (0.7%)	62	8,000.00	128.6

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INTRODUCTION

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of the Building 1060 on 406-416 Minnesota Avenue, Tyndall AFB, FL 32403, USA.

Climate Data

Building 1060 final is located at 406-416 Minnesota Avenue, Tyndall AFB, FL 32403, USA with a latitude and longitude of approximately 30.07, and -85.59, respectively. Figure 15 shows a Google Earth aerial satellite image of Building 1060.

Figure 15: Aerial view of Building 1060 taken from Google Earth

The table below shows the monthly average climate conditions in Tyndall, AFB[5].

[5] http://www.weatherbase.com. Accessed July, 2014.

Table 44: Monthly weather averages for Tyndall Air Force Base

Average Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	66	53	55	59	68	75	78	80	80	78	69	59	55

Average High Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	75	60	64	68	75	82	86	87	87	86	78	69	62

Average Low Temperature — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	59	44	46	51	59	66	73	75	75	71	62	50	46

Average Precipitation — Years on Record: 21

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in	53.2	3.3	3.8	4.7	4.4	2.3	4.8	7.4	6.4	6	3.7	2.9	3.8

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.9	11.6	12.4	13.3	14.1	14.5	14.3	13.6	12.7	11.8	11.1	10.7

Energy Use and Utility Data

Building 1060 reported an annual electricity consumption of 499,980 kWh in 2012 at a cost of $36,649. The 2012 monthly natural gas usage and cost for Building 1060 is given in the table below with an annual consumption of 966 MMBtu in 2012 at a cost of $8,606. The average electric rate in 2012 was $0.0733/kWh and the average natural gas rate was $8.91/MMBtu.

Table 45: 2012 Monthly Energy and Cost Summary for Building 1060

	Natural Gas Use (MMBtu)	Natural Gas Cost ($)
Jan-12	154.2	$1,374
Feb-12	101.0	$900
Mar-12	124.8	$1,112
Apr-12	104.4	$930
May-12	63.5	$566
Jun-12	43.7	$389
Jul-12	48.9	$436
Aug-12	43.6	$389
Sep-12	48.8	$435
Oct-12	50.5	$450
Nov-12	65.2	$581

Dec-12	117.2	$1,044

Figure 16 shows the modeled monthly energy consumption breakdown by end use. Figure 17 shows the modeled annual natural gas consumption by end use. Figure 18 shows the modeled annual electricity cost breakdown by end use. Cooling, reheat, and lighting are the largest energy consumers and most costly end uses.

Monthly Electricity Consumption (kWh)

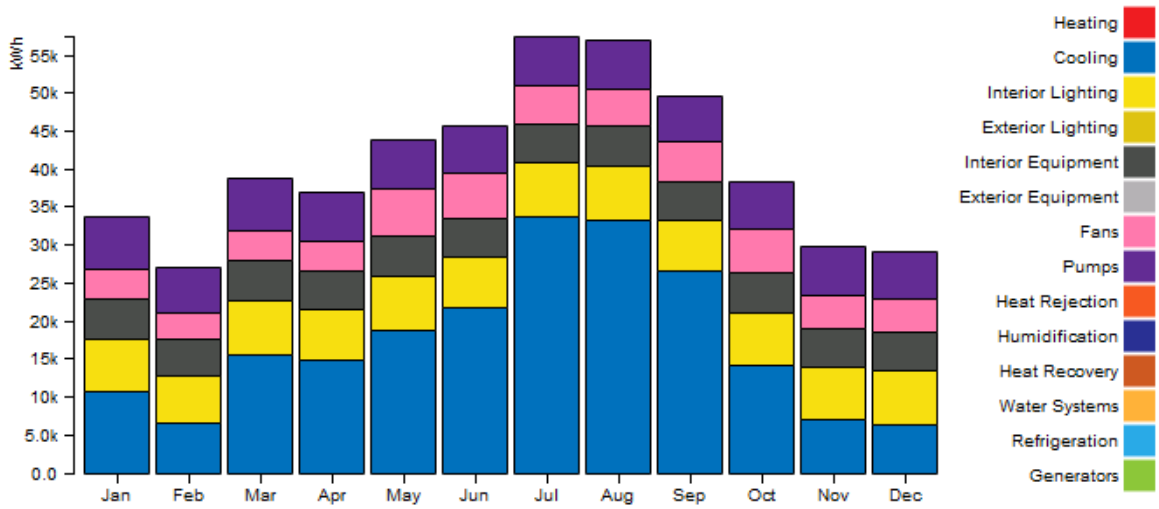


Figure 16: Building 1060 modeled monthly electricity consumption breakdown by end use

Monthly Natural Gas Consumption (kWh)

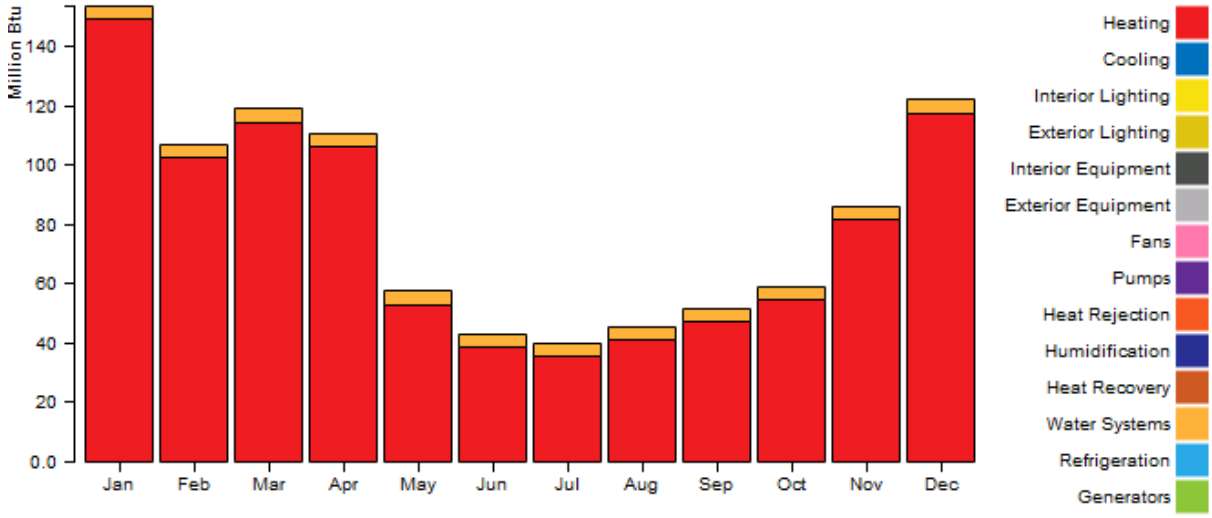


Figure 17: Building 1060 modeled monthly natural gas consumption breakdown by end use

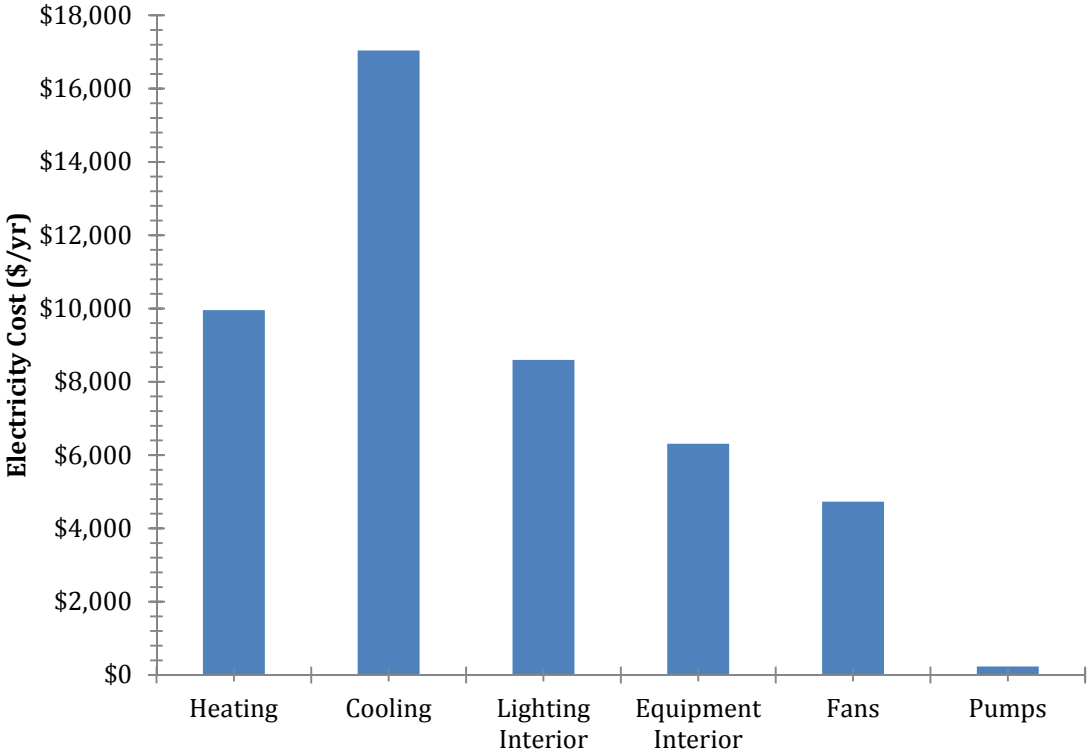


Figure 18: Building 1060 modeled annual electricity cost breakdown by end use

Calculation Methods

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Tyndall AFB Building 1060. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

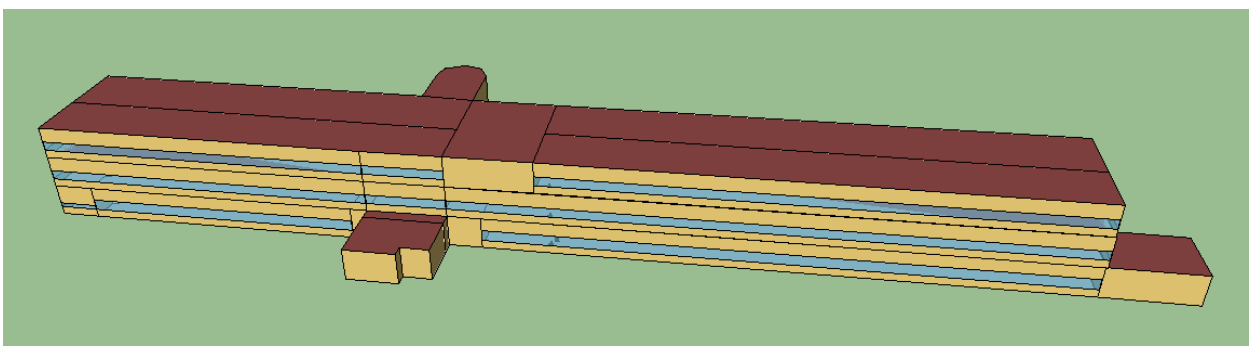


Figure 19: 3-D rendering of the Building 1060 energy model generated in Trimble SketchUp

Figure 14 shows the annual and monthly actual utility consumption versus the calibrated energy model for the 2012 calendar year. The energy model was calibrated within a normalized mean biased error of 5% and a coefficient of variation of the root mean square error of 15% relative to monthly utility data in accordance with AHSRAE Guideline 14-2002.

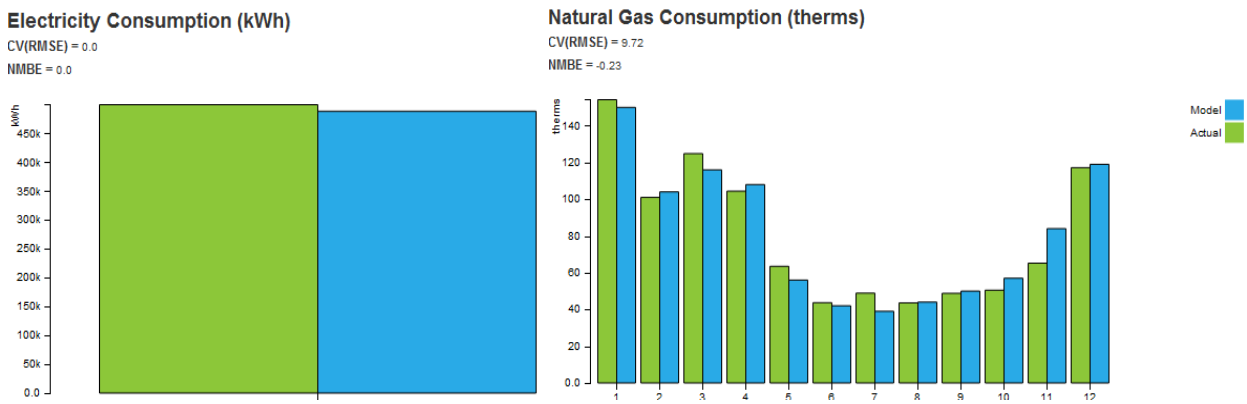


Figure 20: OpenStudio calibration of modeled annual electricity (left) and monthly natural gas consumption versus actual utility data

Table 23 shows baseline model annual energy and cost characteristics for Tyndall AFB Building 1060. This baseline model is used as the reference building for calculating energy and cost savings from simulating the implementation of energy conservation measures described in detail later in this report.

Table 46: Baseline energy model annual energy and cost characteristics

Design Alternative Name	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kWh/yr)	Electricity Consumption (kWh/yr)	Natural Gas Consumption (MMBTU/yr)	Annual Utility Cost
Baseline	**69**	**33,768.33**	**1,756.94**	**1,052.95**	**$44,668.32**

ENERGY CONSERVATION MEASURES

Lighting Energy Efficiency Measures

The following section provides a detailed description of the one lighting energy efficiency measure that was identified during the site visit. Table 24 shows the summary of all lighting efficiency measures, and is followed by the detailed description of each individual measure.

Table 47: Summary of lighting energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace lighting with low wattage T-8s	**5,469 (1.1%)**	**0.34 (0.0%)**	**404**	**3,880.00**	**9.6**

Replace lighting with low wattage T-8s

Category: Lighting Equipment
Description: Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

Table 48: Energy and cost savings for replace lighting with low wattage T-8s ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
5,469.44 (1.1%)	**0.34 (0.0%)**	**404.10**	**3,880.00**	**9.60**

Assumptions:
- 194 32W T8 lamps in 100 light fixtures throughout the building are replaced with 25W low-wattage T8 lamps.
- The combined labor and material cost was estimated to be $20 per lamp, for a total implementation cost of $3,880.

HVAC Energy Efficiency Measures

The following section provides a detailed description of the five HVAC energy efficiency measures that were identified during the site visit. Table 27 shows the summary of all HVAC efficiency measures, and is followed by the detailed description of each individual measure.

Table 49: Summary of HVAC energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Convert constant flow chilled water pumping system to variable flow	40,222 (8.2%)	0.00 (0.0%)	2,948	100,000.00	33.9
Replace existing hot water boilers with condensing boilers	0 (0.0%)	152.20 (15.2%)	1,356	15,000.00	11.1
Demand controlled ventilation	2,211 (0.5%)	(-4.43) (-0.4%)	123	5,000.00	40.8
Cogged v-belts	2,517 (0.5%)	0.99 (0.1%)	193	480.00	2.5
Implement card readers that turn off HVAC, plug loads, and lighting	15,555.56 (3.2%)	(-61.47) (-6.2%)	592.80	220,000.00	371.12

Convert constant flow chilled water pumping system to variable flow

Category: HVAC Distribution
Description: The HVAC chilled water pumps are constant speed with 3-way control valves feeding the coils in the AHUs throughout the facility. Older HVAC designs required 3-way control valves for constant speed pumping and constant flow chillers. However, if the chiller is capable of operating at variable flow-rates or a primary-secondary pumping design is used, 3-way control valves and can be replaced with 2-way control valves and VFDs can be installed on the distribution pumps, to reduce pumping energy.

Table 50: Energy and cost savings for replace lighting with low wattage T-8s ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
40,222	0.00	2,948	100,000.00	33.9

(8.2%)	**(0.0%)**			

Assumptions:

- VFDs are installed on the chilled water pumps, all 3-way valves are replaced with 2-way valves, and the necessary controls are implemented.
- The chiller is able of operating at variable flow down to 50% of the rated gpm.
- The combined labor and material cost was estimated to be $100,000 per chilled water loop, for a total implementation cost of $100,000.

Replace existing hot water boilers with condensing boilers

Category: HVAC Heating
Description: Install a high efficiency condensing boiler plant to meet the building's heating needs. The footprint for the new condensing boilers should be specified to fit in the mechanical room once the existing system is removed. Condensing boilers operate at efficiencies on the order of 90%-98%, by recovering the latent heat of vaporization from water vapor in the exhaust, through the condensing process. The condensate can be acidic and requires the proper material selection for plumbing components. Depending on the exhaust gas temperature, PVC, CPVC, and ABS are the most common plastic pipes that are recommended for corrosive condensate drainage. Another operational advantage of a hot water condensing boiler is the ability to implement a variable temperature, variable flow control algorithm. This is achieved through the installation of variable frequency drive (VFD) hot water supply pumps. The hot water supply temperature is then modulated based on exterior ambient temperatures. This measure should be implemented in conjunction with variable flow hot water pumping.

Table 51: Energy and cost savings for replace existing hot water boilers with condensing boilers ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
0.00 (0.0%)	**152.20 (15.2%)**	**1,355.90**	**15,000.00**	**11.06**

Assumptions:

- The existing 80% efficient boiler is replaced with a 95.3% efficient condensing boiler
- The combined labor and material cost was estimated to be $15,000 per boiler, for a total implementation cost of $15,000.

Demand controlled ventilation

Category: Ventilation
Description: The facility currently does not have a demand controlled ventilation system or CO2 sensors in the air delivery system. Outside air is introduced and conditioned at a fixed rate based on the maximum design. Since the building occupancy fluctuates and is often less than the maximum design occupancy, it is being over-ventilated and consuming more energy than

necessary. The building CO2 level is closely related to the occupancy. The typical outside CO2 level is relatively low concentration, around 400 to 500 ppm, and is used to dilute the higher indoor CO2 levels. Demand controlled ventilation could be implemented by deploying CO2 sensors located in each AHU return air duct and in densely occupied spaces, such as conference rooms. Implementation of this ECM will require:

- Rebalance the open/closed outside air dampers to a lower minimum ventilation rate.
- Program demand ventilation controls into each AHU, controlling modulating dampers in mixed air AHUs and VFDs in outside air units. Ventilation will be generally controlled from return air sensors, but will be increased as needed based on densely occupied space sensors.
- Commission the project.

Table 52: Energy and cost savings for demand controlled ventilation ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
2,211.11 (0.5%)	**(-4.43) (-0.4%)**	**122.60**	**5,000.00**	**40.78**

Assumptions:

- The existing 2 air loops are retrofitted for demand controlled ventilation.
- The combined labor and material cost was estimated to be $2,500 per air loop, for a total implementation cost of $5,000.

Cogged v-belts

Category: HVAC Distribution
Description: Cogged v-belts can be used with the same pulleys as equivalent rated v-belts. They run cooler, last longer, and have an efficiency that is on the order of 2%-3% higher than standard v-belts due to the elimination of slippage. The belts associated with the largest motors and the motors that are run closest to full load should be given priority when making replacements. It is recommended that standard v-belts be replaced with cogged v-belts. Improvements in belt efficiency result in energy savings at the motor. The three common belt efficiency measures are belt tightening (1%-5% savings per motor), replace standard v-belts with cogged v-belts (2% savings per motor), and replace standard belts with synchronous belts (3% savings per motor). Well-adjusted belts run cooler, last longer, and operate at higher efficiency than standard belts. The belts associated with the largest motors, longest run times, and that are run closest to full load should be given priority when making replacements.

Table 53: Energy and cost savings for cogged v-belts ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
2,517 (0.5%)	**0.99 (0.1%)**	**193**	**480.00**	**2.5**

Assumptions:

- The existing 2 fans drives are retrofitted with cogged V-belts improving the overall drive efficiency by 3%.
- The combined labor and material cost was estimated to be $240 per fan, for a total implementation cost of $480.

Implement card readers that turn off HVAC, plug loads, and lighting

Category: HVAC Controls
Description: Currently, there are no occupancy controls for lighting, plug loads, or HVAC in any of the barracks. It is recommended that key-card controls be implemented to ensure that lighting, non-critical plug loads, and HVAC are off when the space is unoccupied.

Table 54: Energy and cost savings for implement card readers that turn off energy systems ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
15,555.56 (3.2%)	**(-61.47) (-6.2%)**	**592.80**	**220,000.00**	**371.12**

Assumptions:

- Equipment operating times were reduced by 5%, lighting operating times were reduced by 10%, and a 2°F cooling temperature setback was simulated between 10am-4pm.
- A total of 44 spaces were retrofitted with card-reader controls
- The combined labor and material cost was estimated to be $5,000 per space, for a total implementation cost of $220,000.

Plug Loads Energy Efficiency Measures

The following section provides a detailed description of the two plug load energy efficiency measures that were identified during the site visit. Table 55 shows the summary of all plug load efficiency measures, and is followed by the detailed description of each individual measure.

Table 55: Summary of plug load energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace current refrigerators with energy star units	**5,381 (1.1%)**	**3.64 (0.4%)**	**427**	**70,000.00**	**164.0**
Replace CRT TVs with LCD TVs	**37,736 (7.7%)**	**26.76 (2.7%)**	**3,005**	**28,000.00**	**9.3**

Replace current refrigerators with energy star units

Category: Electric Equipment
Description: The assessment team observed excess refrigerators in the building. The refrigerators were older Top Mount Freezer without through-the-door ice models and were not Energy Star rated. It is not economically feasible to replace all of the existing refrigerators at this time. However, it is recommended that site staff remove excess refrigerators and replace all older refrigerators with newer Energy Star rated models incrementally as the older models approach the end of their useful life.

Table 56: Energy and cost savings for replace current fridges with energy star units ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
5,380.56 (1.1%)	**3.64 (0.4%)**	**426.70**	**70,000.00**	**164.05**

Assumptions:

- A total of 70 existing standard 18 ft^3 with top mount freezers without through-the-door ice models are replaced with Energy Star models which consume 15% less energy.
- The combined labor and material cost was estimated to be $1,000 per refrigerator, for a total implementation cost of $70,000.

Replace CRT TVs with LCD TVs

Category: Electric Equipment
Description: The NREL team recorded several office locations still using CRT televisions. A

typical 32? CRT television has a connected electrical load rated around at 120 Watts when in use, and 15 Watts in sleep/standby mode. It is recommended that site staff locate and replace all of the CRT televisons with Energy Star rated televisions rated at 30 Watts when in use, and less than 1 watt in sleep/standby mode.

Table 57: Energy and cost savings for replace CRT TVs with LCD TVs ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
37,736.11 (7.7%)	**26.76 (2.7%)**	**3,004.70**	**28,000.00**	**9.32**

Assumptions:

- A total of 70 existing standard 34 inch CRT televisions are replaced with LCD Energy Star models which consume 88% less energy.
- The combined labor and material cost was estimated to be $400 per television, for a total implementation cost of $28,000.

Domestic Water Heating Energy Efficiency Measures

The following section provides a detailed description of the one domestic hot water energy efficiency measures that were identified during the site visit. Table 58 shows the summary of all domestic hot water efficiency measures, and is followed by the detailed description of each individual measure.

Table 58: Summary of domestic hot water energy efficiency measures

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Replace existing DHW boilers with condensing boilers	**0 (0.0%)**	**6.98 (0.7%)**	**62**	**8,000.00**	**128.6**

Replace existing DHW boilers with condensing boilers

Category: DHW Equipment
Description: Install a high efficiency condensing boiler to meet the building's domestic hot water needs. Condensing boilers operate at efficiencies on the order of 90%-98% by recovering the latent heat of vaporization from water vapor in the exhaust, through the condensing process. The condensate can be acidic and requires the proper material selection for plumbing components. Depending on the exhaust gas temperature, PVC, CPVC, and ABS are the most common plastic pipes that are recommended for corrosive condensate drainage.

Table 59: Energy and cost savings for replace existing DHW boilers with condensing boilers ECM

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
0.00 (0.0%)	**6.98 (0.7%)**	**62.20**	**8,000.00**	**128.62**

Assumptions:

- The existing 80% efficient domestic hot water boiler is replaced with a 93.1% efficient condensing boiler
- The combined labor and material cost was estimated to be $8,000 per boiler, for a total implementation cost of $8,000.

Bundled Energy Efficiency Measures

The following section provides a detailed description of the bundled measures that were identified during the site visit.

Bundled all ECMs

Category: All Measures
Description: All measures were bundled into a single measure so that interactions between ECMs are accurately accounted for, which can make a big difference in the viability of the ECMs. The following measures were included in the bundle:

- Replace lighting with low wattage T-8s
- Convert constant flow chw pumping system to variable flow
- Replace existing HW boilers with condensing boilers
- Demand controlled ventilation
- Cogged V belts
- Implement card readers that turn off HVAC, plug loads, and lighting
- Replace current fridges with energy star units
- Replace CRT TVs with LCD TVs
- Replace existing DHW boilers with condensing boilers

Table 60: Energy and cost savings for bundled all ECMs

Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
103,369 (21%)	131 (13%)	8,744	450,360	52

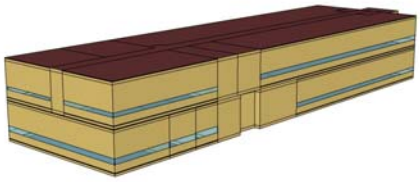
Assumptions:

- All individual measure assumptions are included in the bundle measures.

Bldg 259

Energy Audit Report

Monterey, CA 93943, USA



September 25, 2014

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EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of building 259 in Monterey, CA 93943, located on the Naval Support Activity campus. During the site visit on February 19th, 2014, the team identified five energy conservation measures with payback periods ranging from under a year to 8.1 years. The combined measures have a simple payback of 3.2 years. Installation of these five measures will reduce the building electrical energy consumption by 27.9 %, district heating by 34.1 % and save over 71,000 gallons of water per year. The estimated cost of implementation of the project is $18,232. The estimate does not include contractor mark up.

SITE OVERVIEW

Building 259, constructed in 1959, is a 14,737 ft^2 structure with 2 floors of block construction and double pane operable windows. The building serves primarily as Admin/professional office. The offices spaces do not have air conditioning. A first floor classroom is conditioned by ductless split DX units. The building is heated by fin tube radiation. Non-programmable thermostats set by the user control the heating temperature in each office. The building schedule is 5 am to 6 pm Monday through Friday.

ENERGY USAGE OVERVIEW

The electricity consumption was reported to be 68,756 kWh per year at a cost of $7,632. District heating steam enters at the bottom floor building main mechanical room. The steam is used to heat the building hot water loop. Building steam use data was not available so the modeled building consumption was used as the baseline. Also, a cost of district steam was not available, so a cost was calculated based on the provided natural gas rate and a combined boiler and steam distribution efficiency of 75 %. Using the natural gas cost and efficiency a total annual district heating cost of $9,102 was calculated. The annual water consumption was reported to be 26,493 thousand gallons per year.

Table 1: Monthly Energy and Cost Summary

	Electricity Use (kWh)	Electricity Cost ($)
Mar-13	7,704	963.7
Apr-13	7,040	880.6
May-13	6,240	780.6
Jun-13	6,720	840.6
Jul-13	5,600	700.5
Aug-13	6,240	780.6
Sep-13	4,800	600.4
Oct-13	7,680	960.7
Nov-13	7,200	900.6
Dec-13	8,640	1,080.8

Jan-14	5,920	740.5

Table 2: Baseline

Design Alternative Name	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kW)	Electricity (kWh)	District Heating (MMBTU)	Annual Utility Cost (kwh)	Annual Utility Cost (District Heating)	Annual Utility Cost (Total)
Baseline	**72**	**28**	**68,756**	**1179**	**$7,632**	**$9,102**	**$16,735**

Note: District heating utility information was not available. Baseline information was taken from the modeled energy consumption.

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. Details of the calculations and assumptions for each ECM are presented in later sections of this report.

Table 3: Energy Conservation Measures – All Measures Combined Impact

ECM	Annual Electricity Savings(kWh)	Annual District Heating Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
All Measures	**19,150 (27.9%)**	**402 (34.1%)**	**5,611**	**18,232**	**3.2**

Table 4: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Replace 32W T8 Lamps with 25W T8 Lamps	**5,956 (8.7%)**	**NA**	**$ 661**	**NA**	**$ 3,192**	**4.8**
Implement Night Time Thermostat Setback	**4,411 (6.4%)**	**310 (26.3%)**	**$ 490**	**$ 2,390**	**$ 5,000**	**1.7**
Reduce Electric Equipment Loads	**7,747 (11.3%)**	**NA**	**$ 860**	**NA**	**$ 7,000**	**8.1**
Install Aerators on Faucets to Reduce Water Flow Rate	**1,036 (1.5%)**	**NA**	**$ 115**	**NA**	**$ 40**	**0.3**
Retrocommission Building Steam Supply	**NA**	**92 (7.8%)**	**NA**	**$ 711**	**$ 3,000**	**2.7**
Note: Retro commissioning of building steam includes water savings of $384 per year.						

INTRODUCTION

CLIMATE DATA

Bldg 259 is located at Monterey, CA 93943, USA with a latitude and longitude of approximately 36.59, and -121.87, respectively.

Figure 21: Aerial view of Bldg 259 taken from Google Earth

The table below shows the monthly average climate conditions for Monterey, California.

Table 5: Monthly weather averages for Monterey, California.

Average Temperature													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	55.3	49.8	51.3	52.3	53.9	56	58.3	60	60.9	60.2	57.7	53.7	49.7
Average High Temperature													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62.4	57.8	58.5	59.2	60.5	62.2	64.6	66.1	67.3	67.3	65.5	61.7	57.6
Average Low Temperature													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48.3	41.8	44.1	45.4	47.3	49.7	52	53.9	54.4	53.1	49.8	45.7	41.8
Average Precipitation													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	17.8	3.8	3.6	3	1.2	0.5	0.1	---	0.1	0.2	0.9	1.9	2.6
Average Number of Days With Precipitation													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	74.2	11.7	12.5	9.1	7.1	3.9	2	1.2	1.8	1.6	4.1	7.9	11.3
Highest Recorded Temperature													Years on Record: 41
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	104	84	85	85	93	95	101	98	95	101	104	95	89
Lowest Recorded Temperature													Years on Record: 41
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	20	22	26	32	35	38	42	43	45	43	35	35	20
Average Length of Day													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.5	11.3	12.4	13.6	14.6	15.1	14.9	13.9	12.8	11.7	10.7	10.2
Average Number of Days Above 90F/32C													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	0.2	---	---	---	---	0.1	0.1	---	---	---	0.1	---	---
Average Number of Days Below 32F/0C													Years on Record: 30
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	1.6	0.7	---	---	---	---	---	---	---	---	---	---	0.9
Most Rain Reported in a Month													Years on Record: 41
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	37.7	10	7.3	9.6	7.1	2.4	1.6	0.7	1	3.1	2.5	6.5	9.8

ENERGY USE AND UTILITY DATA

Table 6: Utility Costs

Utility	Cost	Units
Electricity	0.111	$/kWh
Water	5.36	$/kgallon
Natural Gas	5.79	$/MMBtu

Steam	7.72	$/MMBtu

Note: District heating cost was calculated by using a boiler and steam distribution efficiency of 75%.

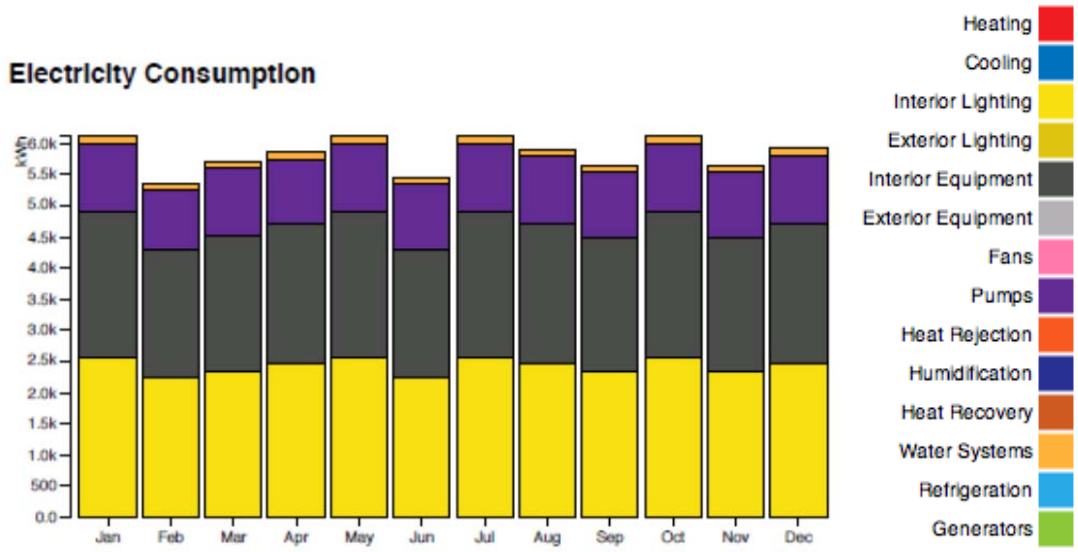


Figure 2: Bldg 259 modeled monthly electricity consumption breakdown by end use

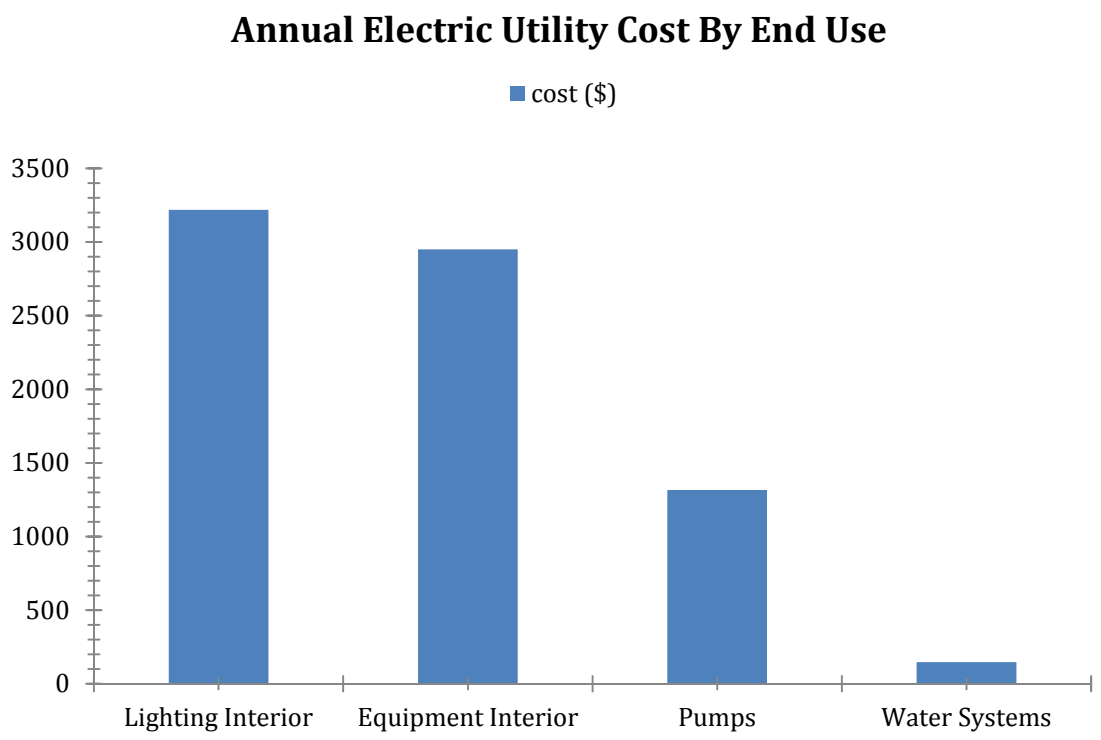


Figure 3: Bldg 259 annual energy cost breakdown by end use

CALCULATION METHODS

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the building 259. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

Figure 4: Model Zones

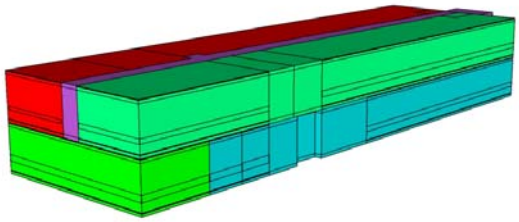
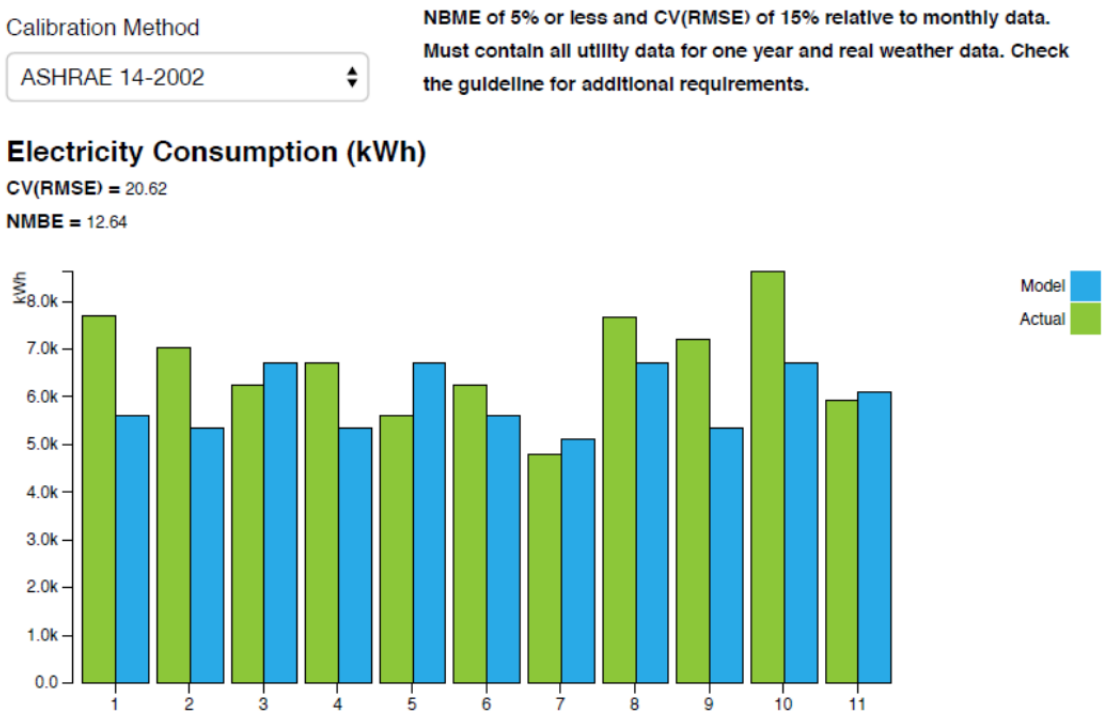


Figure 5: OpenStudio calibration of monthly energy consumption versus actual utility data



Energy Conservation Measures

ENERGY CONSERVATION MEASURE DESCRIPTIONS

Lighting Energy Efficiency Measures

Replace 32W T8 Lamps with 25W T8 Lamps

Category: Lighting Equipment

Existing Condition:

This audit collected information on the predominant types of lighting present, the type of fixtures used, and the general condition of the lighting systems; it also included a comprehensive fixture count. Interviews with people occupying the space and maintenance employees provided the operating hours of the lighting systems.

We found the following conditions:

- T8 32 watt fluorescent lamps
- Lighting controlled by occupants with manual switching
- Light levels generally over illuminated
- No daylight harvesting strategies in effect

Proposed Upgrades:
Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

Table 7: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Replace 32W T8 Lamps with 25W T8 Lamps	**5,956 (8.7%)**	**NA**	**$ 661**	**NA**	**$ 3,192**	**4.8**

Assumptions:

- $30 material and installation cost per lamp fixture with new ballast.

HVAC Efficiency Measures

Implement Night Time Thermostat Setback

Category: HVAC Controls

Existing Condition:

With the exception of one classroom on the first floor the rooms in the building do not have air conditioning. In the winter the building is heated by hot water fin tube radiators that run along the perimeter of the building. The heat in office spaces is controlled by stand-alone non-programmable thermostats. The occupants in the space set the temperature. When the space does not meet the set point the thermostat sends a signal to a control valve that opens to supply hot water to the fin tube radiators supplying the space.

Proposed Upgrades:

During the night time, when the building is unoccupied, the building temperature only needs to be warm enough in the winter to prevent freezing. When the thermostats in the building can be set centrally through the building automation system, implementing a night time setback will save energy without impacting occupant comfort.

This efficiency measure proposes to install controls to set back the building temperature, by shutting off the hot water distribution pump, during unoccupied hours and weekends.

Table 8: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Implement Night Time Thermostat Setback	**4,411 (6.4%)**	**310 (26.3%)**	**$ 490**	**$ 2,390**	**$ 5,000**	**1.7**

Assumptions:

- The combined labor and installation cost is estimated to be $5,000 to install a time clock and tie into motor relay to enable and disable motor on a schedule.

Plug Loads Conservation Measures

Reduce Electric Equipment Loads

Category: Electric Equipment

Existing Condition:

Appliances plugged into an electrical outlet such as computers, monitors, task lights, printers, and cell phone chargers, consume 20% to 60% of all electricity in offices and are the fastest growing segment of electrical demand. These devices consume electricity during active use, as well as in standby mode. Installation of a plug load management system will reduce plug load energy consumption.

Proposed Upgrades:

This ECM proposes to install a plug load management system.

Plug load management systems have the capability to:

- Measure, control and manage electrical plug loads to prevent the waste of electricity.
- Provide device level monitoring to rapidly identify malfunctioning and inefficient devices.
- Generate detailed reports on plug load consumption to aid in tracking progress towards efficiency goals.
- Have the capability to control discretionary plug loads in coordination with demand response events

Table 9: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Reduce Electric Equipment Loads	**7,747 (11.3%)**	**NA**	**$ 860**	**NA**	**$ 7,000**	**8.1**

Assumptions:

- Sixty two office work areas needing a smart power outlet.

Domestic Water Heating Energy Efficiency Measures

Install Aerators on Faucets to Reduce Water Flow Rate

Category: Water Conservation

Existing Condition:

The existing restroom lavatory sinks consume 2.5 gallons per minute (gpm). The hot water at the sinks is heated by instantaneous electric hot water heaters.

Proposed Upgrades:

Johnson Controls suggests installing 1/2 gpm, spray type, pressure compensating flow moderators on these existing faucets. These moderators successfully regulate the flow rate between water pressures of 20 to 80 psi. These moderators provide adequate water flow to complete the tasks performed in these sinks and deliver an average 30% savings over the existing aerators.

Table 10: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Install Aerators on Faucets to Reduce Water Flow Rate	**1,036 (1.5%)**	**NA**	**$ 115**	**NA**	**$ 40**	**0.3**

Assumptions:

- $20 material and installation cost per aerator.

Retrocommission Building Steam Supply

Category: Retrocommissioning

Existing Condition:

During the Audit it was discovered that the supply steam to the hot water heat exchanger is not being shut off when the hot water system reaches set point temperature. The excess supply steam causes the water in the hot water loop to boil. The boiling water in the hot water loop creates steam, the steam over pressurizes the system, which then causes the relief valve to dump water to the drain until the system is below the pressure relief set point. When the hot water relief valve closes the hot water system is filled with cold make up water. Once the hot water loop is heated up again the cycle repeats itself. The flow rate at which the system dumps water was not measured but was estimated to be about 3 gpm. The entire cycle takes about 5 minutes. Three minutes of the system being filled with water and heating up and 1 minute and 25 seconds of the relief valve opening up and dumping water to the drain. The temperature valve read between 214 ºF and 203 ºF when water was being released to the drain.

Proposed Upgrades:

This ECM proposes to retrocommission the existing building steam supply system and find and repair the root cause of the water being released to the drain.

Table 11: ECM Summaries

ECM	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (MMBtu)	Annual Cost Savings kWh ($)	Annual Cost Savings Dist. Heat ($)	Install Cost ($)	Simple Payback Period (yrs)
Retrocommission Building Steam Supply	**NA**	**92 (7.8%)**	**NA**	**$ 711**	**$ 3,000**	**2.7**
Note: Retro commissioning of building steam includes water savings of $384 per year.						

Assumptions:

- Two days technician time.

Appendix I – Notes

Title: Hot/cold spots in building

Title: Split PC AC

Text: For lower classroom

Title: Building recommission

Text: Control valves likely switched in several spaces

Title: Hot water pumps

Title: Condensate return pump

Title:ECM: insulate 20 ' of 2" pipe @ 200f

Title: Building facade

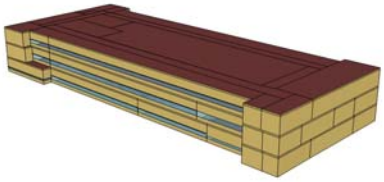
Appendix II – Building Information

Address	Latitude	Longitude
Monterey, CA 93943, USA	36.598867826439	-121.87411311554

Building 330 Ingersoll Hall

Energy Audit Report

401-499 Sloat Avenue, Monterey, CA 93940, USA



September 26, 2014

Prepared By:
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EXECUTIVE SUMMARY

The following report summarizes the results from the Energy Efficiency and Renewable Energy Site Assessment of building 330 Ingersoll Hall building located 401-499 Sloat Avenue, Monterey, CA 93940, USA. During the site visit on February 20th, 2014 the team identified five energy conservation measures with payback periods ranging from 1.4 to 8.1 years. The combined measures have a simple payback of 3.7 years. Installation of these five measures will reduce the building electrical energy consumption by 10.1 % and save $19,789 per year. The estimated cost of implementation of the project is $74,199. The estimate does not include contractor mark up.

SITE OVERVIEW

Building 330 Ingersoll Hall, was constructed in 1969, is a 75,069.91 ft^2 structure with 3 floors with operable windows. The building serves primarily as classroom education and contains classrooms, offices, an auditorium and data centers.

The office spaces around the perimeter of the building do not have air conditioning. The classrooms in the core of the building have fan coil units. An air handling unit on the roof, with a hot water coil only, provides outside air to the building. The server rooms have dedicated cooling systems. Fin tube radiation around the perimeter of the building provides heat.

ENERGY USAGE OVERVIEW

The electricity consumption was reported to be 1,765,107 kWh per year at a cost of $195,943. District heating steam enters the building main mechanical room. The steam is used to heat the building hot water loop. Building steam use data was not available so the modeled building consumption was used as the baseline. The annual water consumption was reported to be 196,551 thousand gallons per year.

Table 1: Monthly Energy and Cost Summary

	Electricity Use (kWh)	Electricity Cost ($)
Feb-13	171,165	21,411
Mar-13	158,075	19,773.6
Apr-13	154,560	19,333.9
May-13	143,520	17,952.9
Jun-13	172,240	21,545.5
Jul-13	147,680	18,473.3
Aug-13	170,080	21,275.3
Sep-13	118,040	14,765.6
Oct-13	155,720	19,479.0
Nov-13	139,640	17,467.6
Dec-13	152,360	19,058.7
Jan-14	117,560	14,705.6

Table 2: Baseline

Design Alternative Name	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kW)	Electricity (kWh)	District Heating (MBTU)	Annual Utility Cost (electricity)
Baseline	**289**	**271**	**1,765,107**	**2,632**	**$195,943**

ENERGY CONSERVATION MEASURES

The following tables summarize the quantified energy savings by conservation measure. The tables provide an annotated list of measures, estimated economic impact, and implementation cost for each energy conservation measure. Details of the calculations and assumptions for each ECM are presented in later sections of this report.

Table 3: Energy Conservation Measures – All Measures Combined Impact

ECM	Annual Electricity Savings(kWh)	Annual District Heating Savings (MMBtu)	Annual Cost Savings ($)	Installation Cost ($)	Simple Payback Period (yrs)
All Measures	**178,276 (10.1%)**	**0.00 (0.0%)**	**$19,789**	**$74,199**	**3.7**

Table 4: Lighting Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Add Occupancy Sensors to Lights	43,431 (2.5%)	0.00 (0.0%)	$ 4,822	$ 6,820	1.4
Replace 32W T8 Lamps with 25W T8 Lamps	59,681 (3.4%)	0.00 (0.0%)	$ 6,625	$ 14,704	2.2

Table 5: HVAC Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Constant Speed to Variable Speed Pump – Hot Water System	24,628 (1.4%)	0.00 (0.0%)	$ 2,734	$ 10,500	3.8

Table 6: Plug Load Energy Efficiency Measures – Summary

ECM Name	Annual Electricity Savings (kWh/yr)	Annual Gas Savings (MMBtu/yr)	Total Annual Savings ($/yr)	Total Installed Cost ($)	Simple Payback Period (yrs)
Reduce Night Time Electric Equipment Loads -- Computers	7,683 (0.4%)	0.00 (0.0%)	$ 853	$ 2,175	2.5

Reduce Electric Equipment Loads - Install High Efficiency Uninterruptible Power Supply	**42,853 (2.4%)**	**0.00 (0.0%)**	**$ 4,757**	**$ 40,000**	**8.4**

INTRODUCTION

CLIMATE DATA

Building 330 Ingersoll Hall is located at 401-499 Sloat Avenue, Monterey, CA 93940, USA with a latitude and longitude of approximately 36.59, and -121.87, respectively.

Figure 22: Aerial view of Building 330 Ingersoll Hall taken from Google Earth

The table below shows the monthly average climate conditions for Monterey, California.

Table 7: Monthly weather averages for Monterey, California.

Average Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	55.3	49.8	51.3	52.3	53.9	56	58.3	60	60.9	60.2	57.7	53.7	49.7

Average High Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62.4	57.8	58.5	59.2	60.5	62.2	64.6	66.1	67.3	67.3	65.5	61.7	57.6

Average Low Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48.3	41.8	44.1	45.4	47.3	49.7	52	53.9	54.4	53.1	49.8	45.7	41.8

Average Precipitation — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	17.8	3.8	3.6	3	1.2	0.5	0.1	---	0.1	0.2	0.9	1.9	2.6

Average Number of Days With Precipitation — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	74.2	11.7	12.5	9.1	7.1	3.9	2	1.2	1.8	1.6	4.1	7.9	11.3

Highest Recorded Temperature — Years on Record: 41

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	104	84	85	85	93	95	101	98	95	101	104	95	89

Lowest Recorded Temperature — Years on Record: 41

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	20	22	26	32	35	38	42	43	45	43	35	35	20

Average Length of Day — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hours	12.6	10.5	11.3	12.4	13.6	14.6	15.1	14.9	13.9	12.8	11.7	10.7	10.2

Average Number of Days Above 90F/32C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	0.2	---	---	---	---	0.1	0.1	---	---	---	0.1	---	---

Average Number of Days Below 32F/0C — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	1.6	0.7	---	---	---	---	---	---	---	---	---	---	0.9

Most Rain Reported in a Month — Years on Record: 41

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	37.7	10	7.3	9.6	7.1	2.4	1.6	0.7	1	3.1	2.5	6.5	9.8

ENERGY USE AND UTILITY DATA

Table 6: Utility Costs

Utility	Cost	Units
Electricity	0.111	$/kWh
Water	5.36	$/kgallon
Natural Gas	5.79	$/MMBtu
Steam	7.72	$/MMBtu

Note: District heating cost was calculated by using a boiler and steam distribution efficiency of 75%.

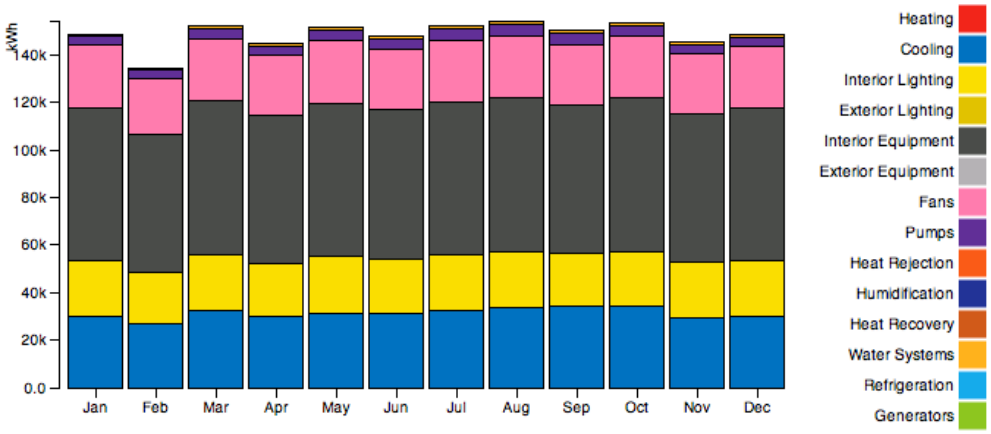


Figure 2: Bldg 330 modeled monthly electricity consumption breakdown by end use

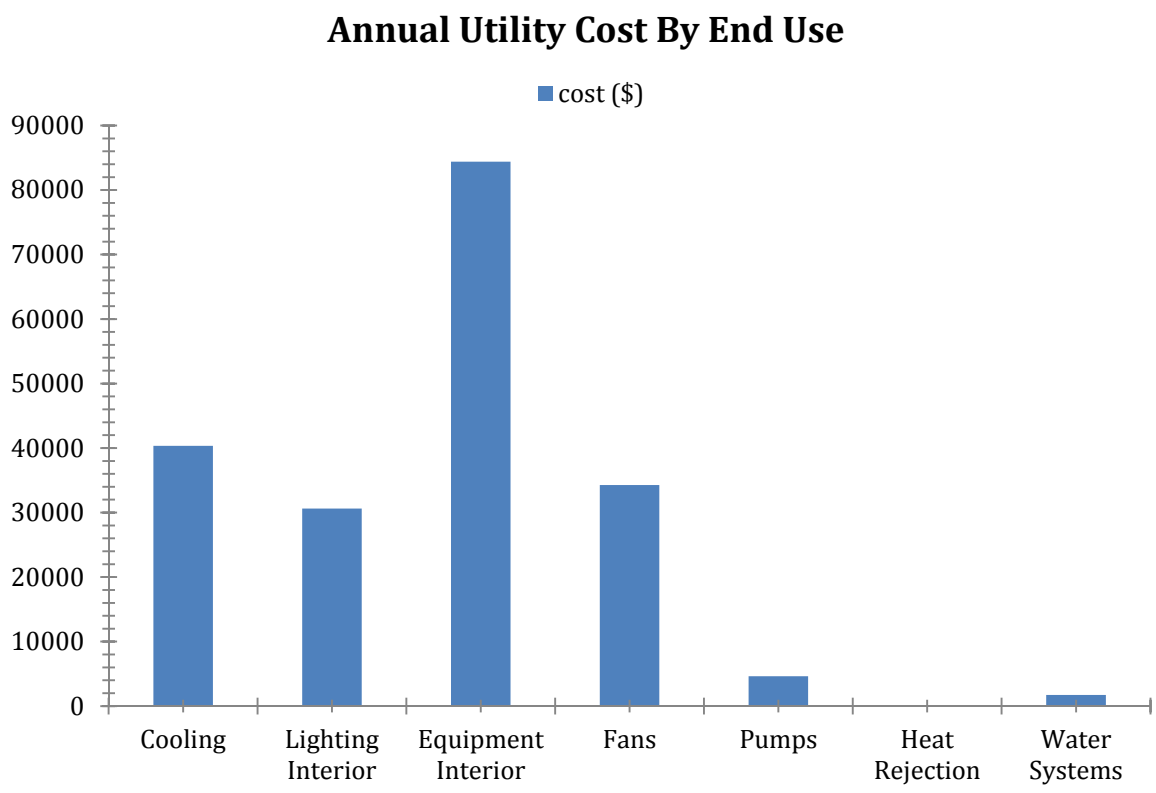


Figure 3: Building 330 Ingersoll Hall annual energy cost breakdown by end use

Energy Conservation Measures

CALCULATION METHODS

Building energy modeling was used to calculate energy and energy cost savings from various energy conservation measures (ECMs) analyzed for the project. OpenStudio was selected as the building simulation software tool to perform the energy modeling of this site. OpenStudio is a free, open-source, commercially available interface for the EnergyPlus hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. OpenStudio uses a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rates to perform analysis. The major benefit of OpenStudio is that interactions between ECMs is accurately accounted for, which can make a big difference in the viability of the ECMs.

OpenStudio energy models were created for the Building 330 Ingersoll Hall building. The existing operating condition of HVAC systems was modeled, including current operating schedules and, to the furthest extent possible, equipment operational characteristics determined from discussion with the facilities team. Graphical representations of the building energy models developed in OpenStudio are given below. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

Figure 4: Model Zones

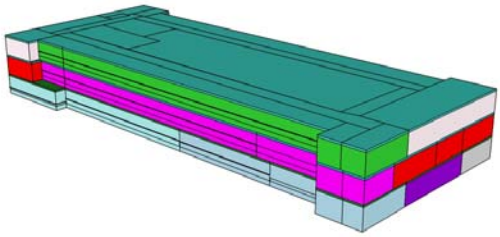
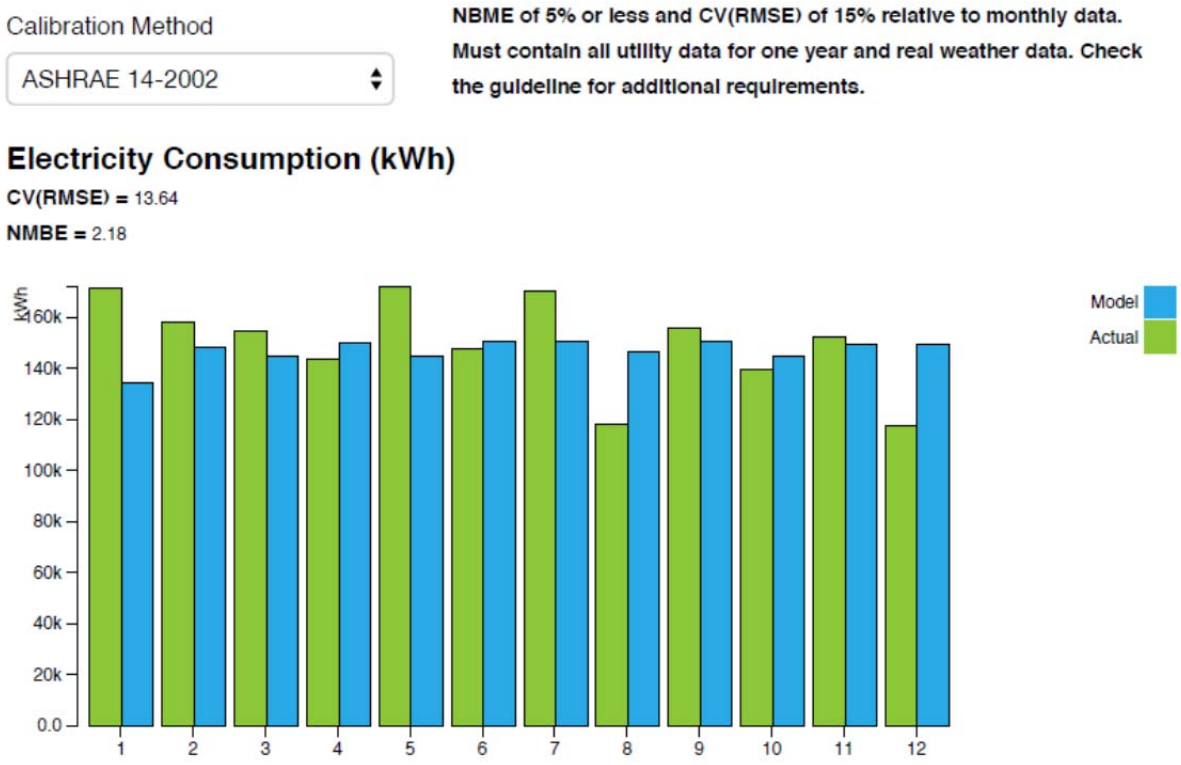


Figure 5: OpenStudio calibration of monthly energy consumption versus actual utility data



ENERGY CONSERVATION MEASURE DESCRIPTIONS

Lighting Energy Efficiency Measures

Add Occupancy Sensors to Lights Alternative

Category: Electric Lighting Controls

Existing Condition:

This audit collected information on the predominant types of lighting present, the type of fixtures used, and the general condition of the lighting systems; it also included a comprehensive fixture count. Interviews with people occupying the space and maintenance employees provided the operating hours of the lighting systems.

We found the following conditions:

- T8 32 watt fluorescent lamps in offices and classrooms
- LED lamps in hallways
- Lighting controlled by occupants with manual switching
- Many of the occupants in perimeter offices take advantage of natural daylighting and turn of the lights in their offices

Proposed Upgrades:
Occupancy sensors save energy by turning off lights when not needed and/or when spaces are left unoccupied. Install a passive electronic sensor to automatically activate and deactivate lighting circuits based on occupancy. There are two commonly used sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat patterns as people move, while ultrasonic sensors detect physical movement. The type and location of each sensor must be carefully selected for each individual room layout and expected activity. In many instances, a simple wall switch replacement is adequate. In other cases, a ceiling-mount sensor or alternatively placed wall-mount sensor may provide better coverage. In rooms with multiple lighting circuits or devices, multi-pole power packs and auxiliary relays can be configured to operate from a single sensor head. In larger spaces, multiple sensors can be wired in parallel to keep all lights on if any one sensor is triggered.

Assumptions:

- The combined labor and installation cost is $110 per sensor.

Replace 32W T8 Lamps with 25W T8 Lamps Alternative

Category: Lighting Equipment

Existing Conditions:

This audit collected information on the predominant types of lighting present, the type of fixtures used, and the general condition of the lighting systems; it also included a comprehensive fixture count. Interviews with people occupying the space and maintenance employees provided the operating hours of the lighting systems.

We found the following conditions:

- T8 32 watt fluorescent lamps in offices and classrooms
- LED lamps in hallways
- Lighting controlled by occupants with manual switching
- Many of the occupants in perimeter offices take advantage of natural daylighting and turn of the lights in their offices

Proposed Upgrades: Retrofit all of the standard T-8 lamps with low-wattage T-8 lamps. The low-wattage T-8 lamps should be specified a 25W, with a color temperature of 3,500 - 4,100 Kelvin. If the ballasts need to be replaced, electronic ballasts should be specified as program start ballasts, so that they can accommodate occupancy sensor controls. The ballasts should be specified with a ballast factor of 0.88, and a power factor above 95%. The total system Color Rendering Index (CRI) should be designed to be greater than 85%. The electronic ballasts are designed to provide the appropriate starting and operating electricity to the lamps. Electronic ballasts operate at a higher frequency, eliminating flicker, and have a higher efficiency than magnetic ballasts.

Assumptions:

- $30 material and installation cost per lamp fixture with new ballast.

HVAC Efficiency Measures

Constant Speed to Variable Speed Pump HW

Category: HVAC Distribution

Existing Condition:

Building heating hot water is supplied by hot water pumps to fin tube radiaters that run along the perimeter of the building. The hot water pumps run at a constant speed regardless of the hot water demand.

Proposed Upgrades:

The ECM proposes to add variable frequency drives to constant speed pump motors to reduce motor power consumption and more closely match the required load.

Assumptions:

- The combined labor and installation cost for (1) variable speed drive is estimated to be $3,500.

Plug Loads Conservation Measures

Reduce Night Time Electric Equipment Loads – Computers

Category: Equipment Controls

Existing Conditions:

Appliances plugged into an electrical outlet such as computers, monitors, task lights, printers, and cell phone chargers, consume 20% to 60% of all electricity in offices and are the fastest growing segment of electrical demand. These devices consume electricity during active use, as well as in standby mode. Installation of a plug load management system will reduce plug load energy consumption.

Proposed Upgrades:

This ECM proposes to install a plug load management system.

Plug load management system have the capability to:

- Measure, control and manage electrical plug loads to prevent the waste of electricity.
- Provide device level monitoring to rapidly identify malfunctioning and inefficient devices.
- Generate detailed reports on plug load consumption to aid in tracking progress towards efficiency goals.
- Have the capability to control discretionary plug loads in coordination with demand response events

Assumptions:

- $75 material and installation cost per computer work station area.

Reduce Electric Equipment Loads by Percentage HE UPS

Category: Electric Equipment

Existing Conditions:

Uninterruptible power supply (UPS) units provides emergency power to data center equipment when the main power source fails. The system provides close to instantaneous

protection from input power interruptions to protect hardware and prevent disruptions to business or data loss.

Proposed Upgrades:

This ECM proposes to replace existing UPS systems with higher efficiency units.

Assumptions:

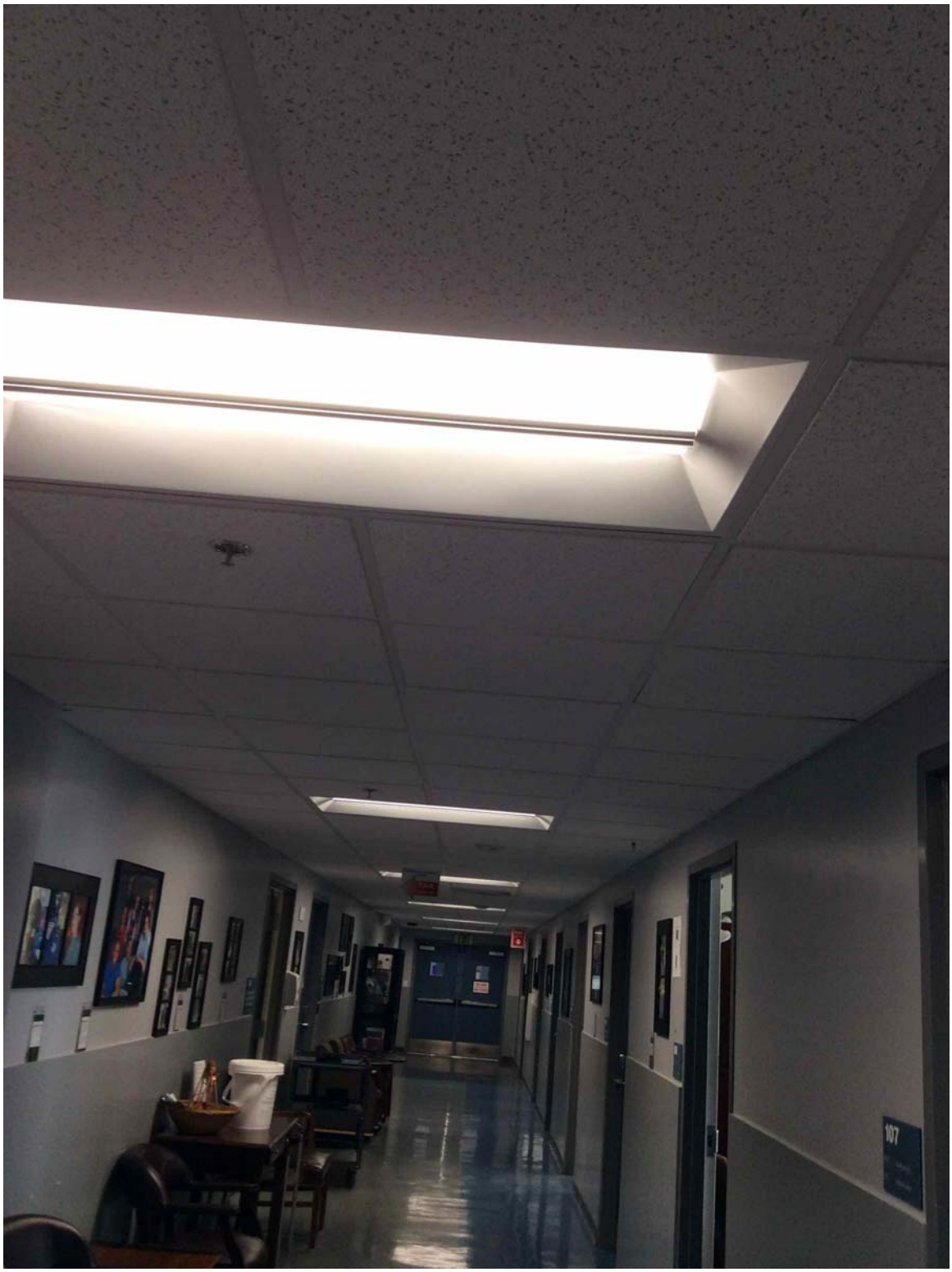
- $40,000 labor and installation to install new UPS.

Appendix I – Notes

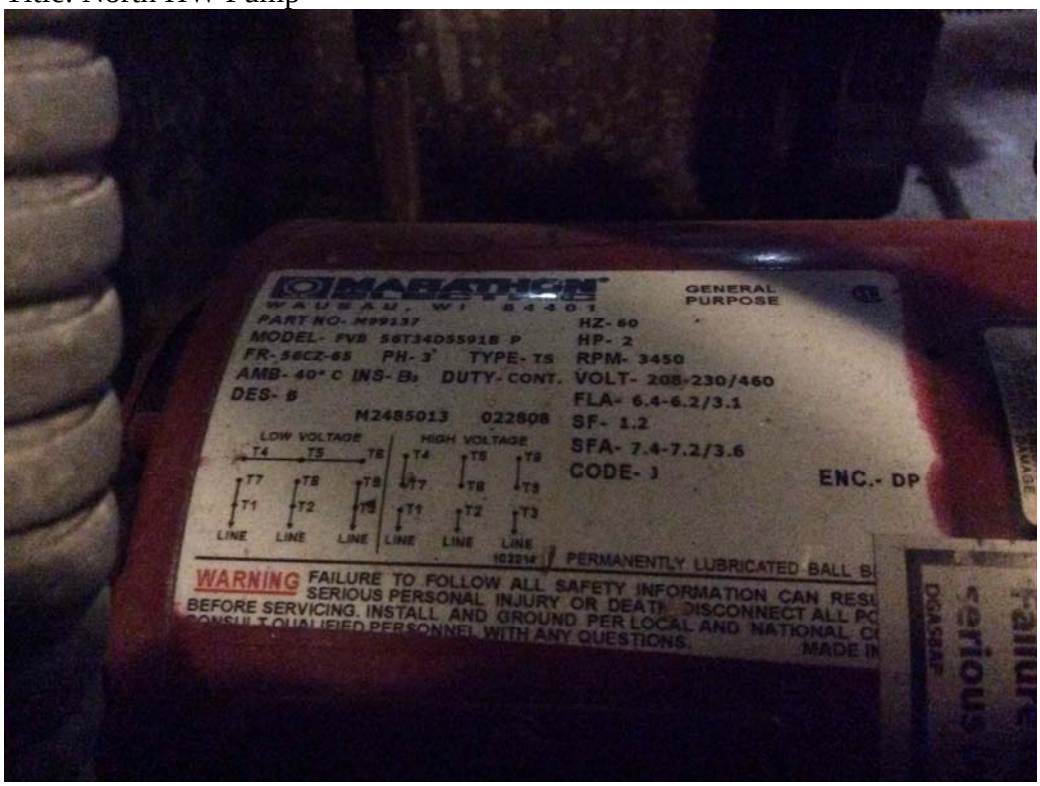
Title: Exterior

INGERSOLL HALL

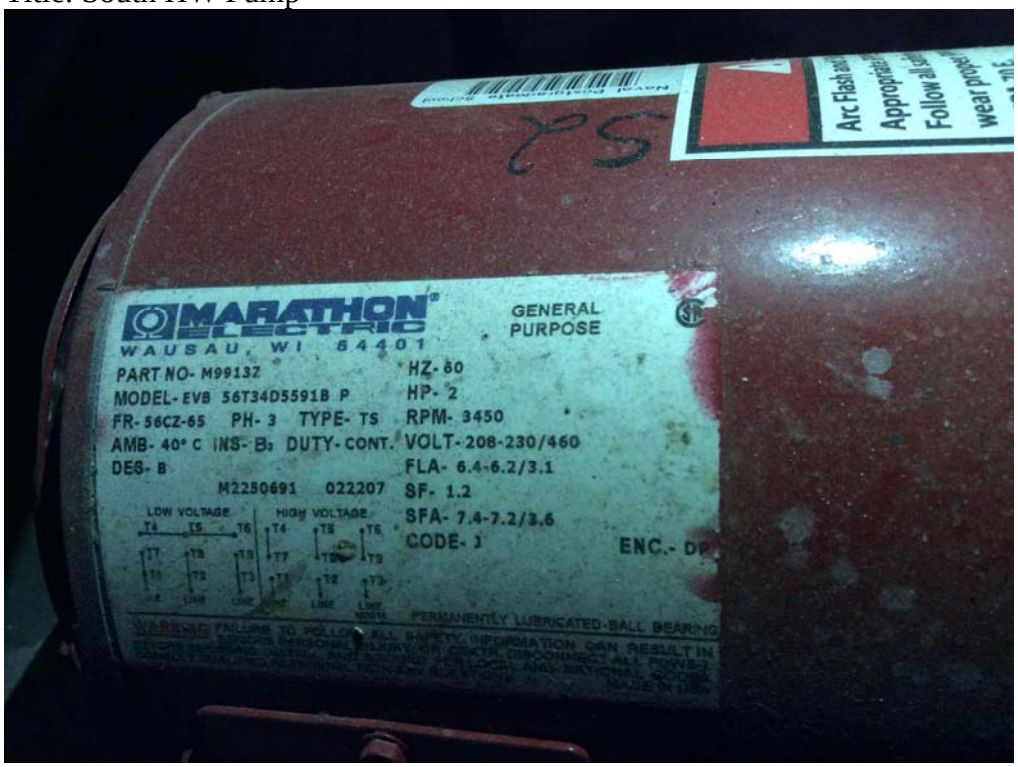
Title: Hall lights
Text: LEDs on occ sensors



Title: North HW Pump



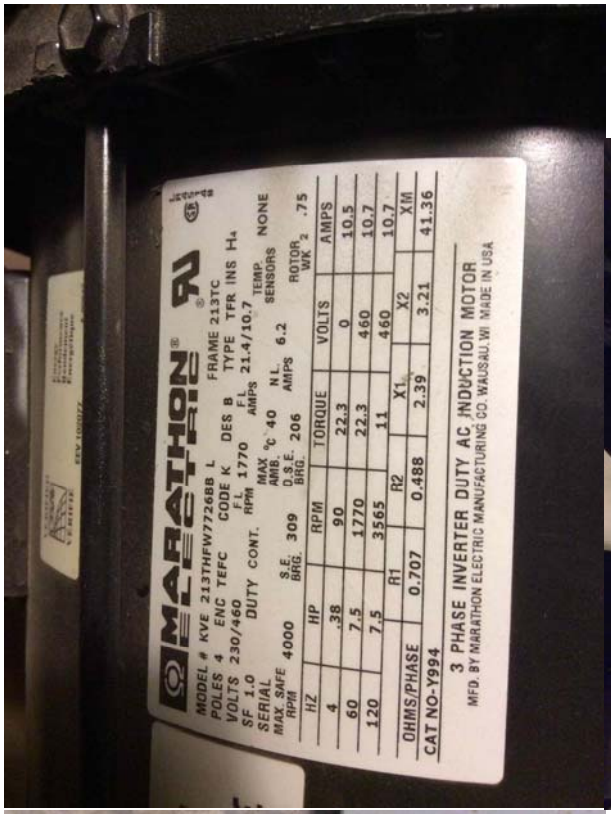
Title: South HW Pump



Title: Upstairs HW Pump

Title: Condensate Pump

Title: Supply Fan with VFD



Title: Exhaust Fan

Title: Condenser Pumps

Title: Chilled water pumps for data center chiller

Title: Data Center Chiller

Carrier

A United Technologies Company

MODEL 30HK-050-D-510--

	QTY	VOLTS AC	PH	HZ	RLA
COMP	1	208/230	3	60	83.0
COMP	1	208/230	3	60	57.0

FAN MOTORS	QTY	VOLTS AC	PH	HZ
OUTDOOR				
OUTDOOR				

Title: Exhaust fan common area ahu

Title: Supply air fan common area ahu

Title: Air cooled chiller 70 ton
Text: 4 users old 2 chillers

Appendix II – Building Information

Address	Latitude	Longitude
401-499 Sloat Avenue, Monterey, CA 93940, USA	36.596667476599	-121.87726307627

Traditional Audit Team Report for Buildings 259 and 330 of the Naval Postgraduate School

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Introduction

This report summarizes the results from site assessment of Buildings 259 and 330 of the Naval Postgraduate School campus. NAME REDACTED conducted the assessment on Mar-3-5, 2014. Several possible energy and water conservation measures were identified during the site visit.

Building Overview

Buildings 259 and 330 (Ingersoll Hall) are both part of the Naval Postgraduate School campus, located in Monterey, CA, very close to the coast line. The campus has approximately 1.4 million square feet of buildings. Building 259 has a total of 18,242 square feet (ft^2), which represents only 1.3% of the total square footage of the campus. Building 330 has a total of 78,087 square feet (ft^2), which represents 5.5% of the total square footage of the campus.

Building 259

The building is a 2-story building that was originally built in 1955 and has a total of 18,242 square feet (ft^2). This building was scheduled for demolition years ago (used to be barracks), but was renovated 4 years ago and converted in its entirety to office space. Figure 1 shows a photo of Building 259

Figure 1. Building 259. *Photo by* NAME REDACTED

Building 330

The building is a 3-story building that was originally built in 1968 and has a total of 78,087 square feet (ft^2). This building has a mixed use of administrative office (50,039 sqft), classrooms (17,869 sqft), data center (5,080 sqft), auditorium (2,360 sqft), and applied instruction space (2,739 sqft). Figure 2 shows a photo of Building 330

Figure 2. Building 330. *Photo by* NAME REDACTED

Climate Data

The Naval Postgraduate School campus is located in the city of Monterey, CA. The city is at an elevation of 50 feet above sea level, and its latitude and longitude are approximately 36.36°N, 121.51°W, respectively. The climate is coastal and with very moderate variations in temperature from season to season. As a coastal climate, the summer months tend to have very mild weather.

Table 1. Historic Weather Summary

Average Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	55.3	49.8	51.3	52.3	53.9	56	58.3	60	60.9	60.2	57.7	53.7	49.7

Average High Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	62.4	57.8	58.5	59.2	60.5	62.2	64.6	66.1	67.3	67.3	65.5	61.7	57.6

Average Low Temperature — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48.3	41.8	44.1	45.4	47.3	49.7	52	53.9	54.4	53.1	49.8	45.7	41.8

Average Precipitation — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	17.8	3.8	3.6	3	1.2	0.5	0.1	---	0.1	0.2	0.9	1.9	2.6

Average Number of Days With Precipitation — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	74.2	11.7	12.5	9.1	7.1	3.9	2	1.2	1.8	1.6	4.1	7.9	11.3

Heating Degree Days — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	3561	471	384	394	335	283	204	157	134	152	233	340	474

Cooling Degree Days — Years on Record: 30

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	30	---	---	---	2	3	3	2	5	8	6	1	---

Source: Weatherbase. Accessed March 11, 2014: http://www.weatherbase.com.

Utility Data

The electric and gas provider for distribution for the Naval Postgraduate School is Pacific Gas & Electric (PG&E). California American Water is the water provider. The campus has several utility accounts that serve multiple buildings on campus. New electric submeters were installed in the buildings in question in recent years. Building 330 even has an additional submeter dedicated to the data center.

Most buildings on campus have steam from the central steam boiler plant as their main heating fuel, and there was no steam submeters data available, therefore, it was not possible to determine the allocated usage of natural gas to Buildings 259 and 330. Similarly, no submeters for water exist and thus it was not possible to determine the water usage for the buildings either.

The main electric meter serving the campus had a total consumption for FY12 of 15,476,048 kWh and a total cost of $1,843,331 (this includes transmission and distribution charges from PG&E as well as generation charges from WAPA). Similarly, the main gas meter serving the steam boiler plant on campus had a total consumption for FY12 of 604,487 Therms and a total cost of $383,630 (this includes distribution charges from PG&E as well as commodity charges from DESC). Finally, the main water meter serving the campus had a total consumption of 17,683 kgals and a total cost of $72,874. No data was available for more recent years.

The table below shows the monthly electric use for Feb 2013 to Jan 2014 from each of the submeters installed at each of the two buildings in question.

Table 2. Annual Electricity Use at Buildings 259 & 330

Month	Read Start	Read End	# of Days	Electric Consumption (kWh)		
				Meter #1	Meter #2	Meter #3
Feb	2/4/13	3/4/13	28	7,496	15,165	210,000
Mar	3/4/13	4/1/13	28	7,707	20,675	137,400
Apr	4/1/13	4/29/13	28	7,040	15,360	139,200
May	4/29/13	6/3/13	35	6,240	13,920	129,600
Jun	6/3/13	7/1/13	28	6,720	16,240	156,000
Jul	7/1/13	8/5/13	35	5,600	14,480	133,200
Aug	8/5/13	9/3/13	29	6,240	15,280	154,800
Sep	9/3/13	9/30/13	27	4,800	10,640	107,400
Oct	9/30/13	11/4/13	35	7,680	14,720	141,000
Nov	11/4/13	12/2/13	28	7,200	14,240	125,400
Dec	12/2/13	1/6/14	35	8,640	12,560	139,800
Jan	1/6/14	2/6/14	31	5,920	10,160	107,400
			367	**81,283**	**173,440**	**1,681,200**

Notes:
Meter #1: Building 259
Meter #2: Ingersoll Hall (Building 330)
Meter #3: Data Center (Building 330)

The monthly electricity use can also be seen in graphic format in Figure 3, Figure 4 and Figure 5.

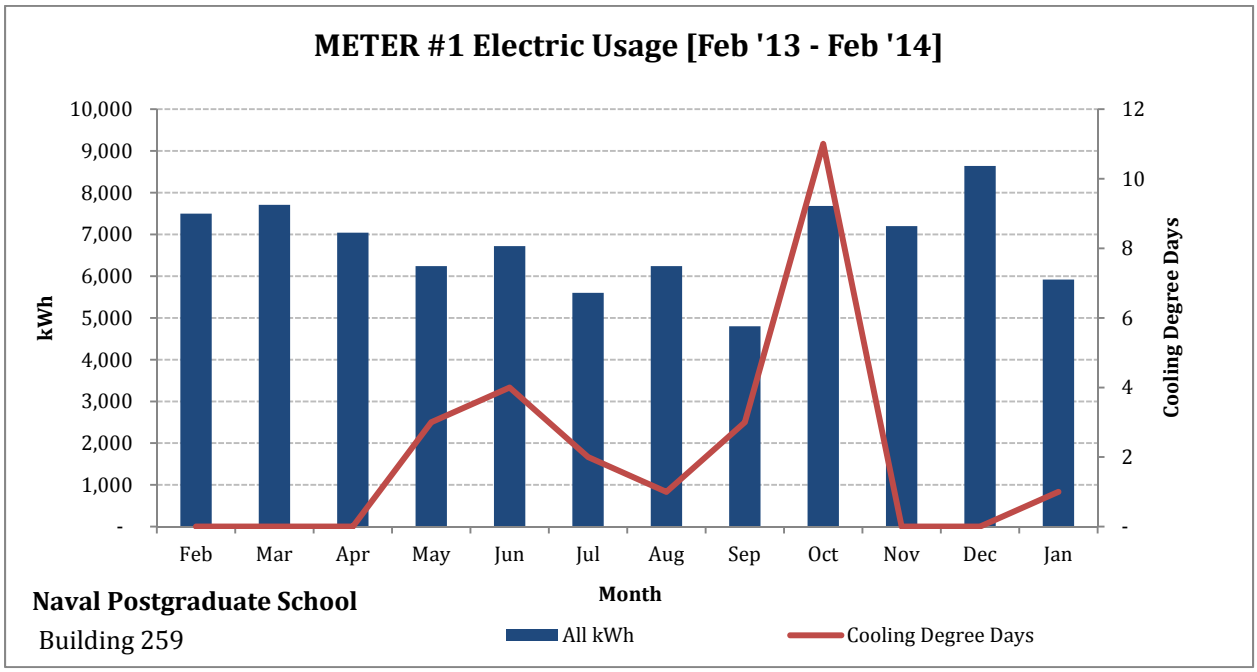

Figure 3. Building 259 monthly electricity use for Feb '13 to Jan '14

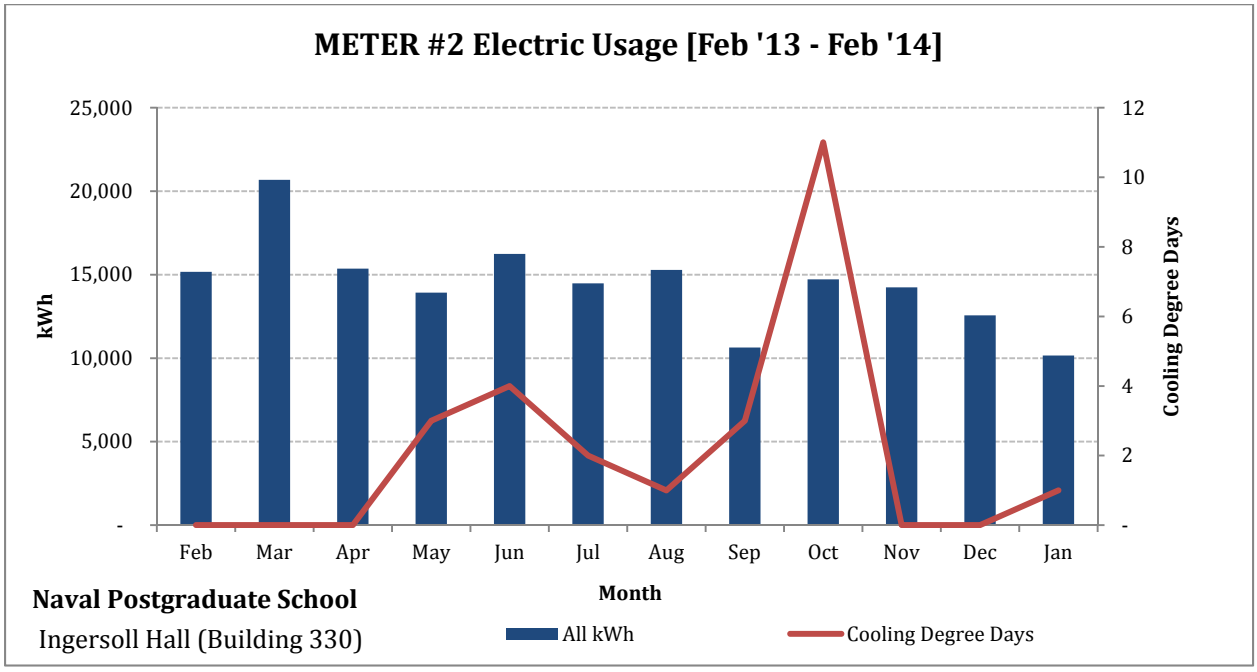

Figure 4. Ingersoll Hall (Building 330) monthly electricity use for Feb '13 to Jan '14

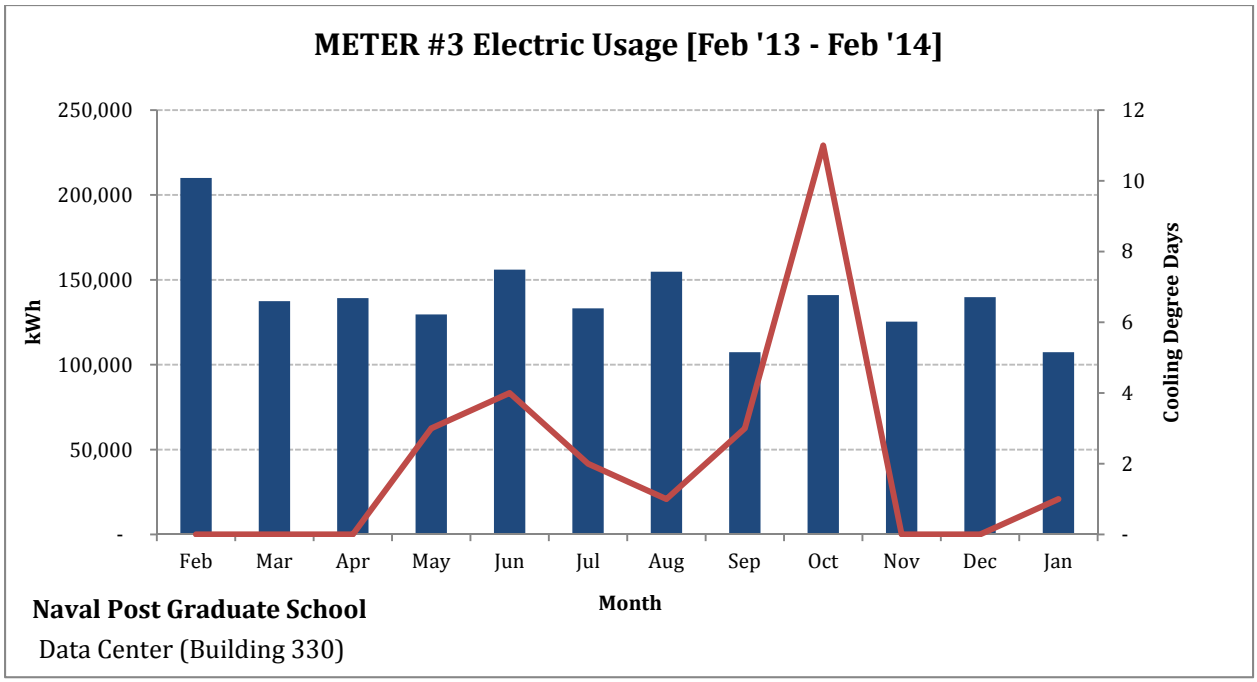

Figure 5. Data Center (Building 330) monthly electricity use for Feb '13 to Jan '14

Figures 3, 4 and 5 show, as can be expected given the very mild coastal weather in the summer months with very few cooling degree days, that there is no correlation between the electricity use and the weather.

The totals for each of these meters represent approximately 0.5% (Building 259), 1.1% (Building 330) and 10.8% (Data Center –Building 330) of the total consumption for the entire campus. As would be expected, despite the fact that the data center, and Building 330 in its entirety, only a small percentage of the total square footage of the campus (5.5%), it accounts for a little over 10% of the total energy consumption.

Even though costs were provided for the utilities for FY12 for the main campus, and therefore average utility rates can be calculated from those values, the following are the rates that NAME REDACTED were provided to be used in any energy projects for FY14:

NAVFAC SW Electricity Purchase Rate:	$111.00/Mwh
NAVFAC SW Natural Gas Purchase Rate:	$5.79/MBtu
NAVFAC SW Water Purchase Rate:	$5.36/kGal

Building Description

Occupancy

Buildings 259 and 330 both have typical office hours, and it is relatively constant between 7:00 am and 5:00 pm, Monday through Friday. Both buildings are primarily unoccupied during weekends. Note that the occupancy schedule is "people occupancy," which is related to the heating, ventilation, and air-conditioning (HVAC) schedule, but is not the same as the HVAC schedule.

Building Envelope

Building 259

The exterior walls are precast concrete panels. The roof is a flat roof, but was not accessible at the time of the site survey. The windows are operable double pane with thermally broken frames.

Building 330

The exterior walls are precast concrete panels. The roof is a built-up flat roof with a rock ballast. The windows are typically floor to ceiling single pane with dark glass on the bottom pane, and an operable pane as well.

Heating, Ventilation, and Air Conditioning

Building 259

The HVAC system consists simply of fin-tubed hot water radiators with standalone manual thermostatically controlled valves in each room. There is no cooling in the building and the occupants rely on the operable windows for cooling and ventilation in the rare occasions that the temperature gets too high. The room temperatures and setpoints are controlled by the occupants through the manual heating valves, although most occupants do not mess with the settings on these valves.

Building 330

The HVAC system consists of fin-tubed hot water radiators with standalone manual thermostatically controlled valves for most of the offices, classrooms or conference rooms located along the perimeter of the building. There is no cooling in these areas and the occupants rely on the operable windows for cooling and ventilation in the rare occasions that the temperature gets too high.

There is also one large variable air volume (VAV) Supply Fan (SF-1) and Exhaust Fan (EF-1) located in the penthouse that serves primarily the interior zones of all three floors (core areas). The exhaust fan has a premium efficiency 20 HP motor and the supply fan motor was not accessible. The fans have Variable Frequency Drives (VFDs) and the speeds are controlled to maintain a certain building pressure setpoint. The supply fan has one hot water reheat coil for each floor of the building and has no cooling coils. They are scheduled to operate between 5:00 am and 5:00 pm on weekdays, and scheduled to be off at night and during weekends and

holidays. The heating temperature setpoint is 68°F .There is an economizer that is enabled whenever the outside air temperature is between 65°F and 75°F. There is also a supply fan speed and outside air damper position control based on CO_2 levels in the return air.

There is one variable air volume (VAV) Air Handling Unit (AHU-1) that serves the Auditorium, located in the basement. The supply fan has a new 7.5 HP motor and a 2 HP exhaust fan motor with Variable Frequency Drives (VFDs) that were installed in 2013. The unit is scheduled to operate between 5:00 am and 5:00 pm on weekdays. It is scheduled to be off at night and during weekends and holidays. The heating temperature setpoint is 68°F, and the cooling temperature setpoint is 74°F. There is an economizer that economizes based on the outside air temperature. There is also a supply fan speed control and outside air damper position based CO_2 levels in the Auditorium. Both motors were replaced about one year ago.

There is one constant volume (CV) Supply Fan (SF-2) and Exhaust Fan (EF-2) also located in the penthouse that serves the Data Center. The supply fan has a premium efficiency 15 HP motor (exhaust fan was not accessible) and the unit has one chilled water coil and no heating coil. They are scheduled to operate 24 hours/day 7 days/week. The cooling temperature setpoint is 74°F. There is an economizer that economizes based on the outside air enthalpy. This unit supplies the raised floor of the Data Center.

There are three constant volume (CV) Liebert CRAC units located within the Data Center. These are also scheduled to operate 24 hours/day 7 days/week. The cooling temperature setpoint was 68°F and 50% RH. One of these units had a chilled water coil and the other two were water-cooled DX cooling (compressors) units. Two of the units were installed about 3 years ago, and the third one was about 7 years old.

There is one constant volume (CV) Air Handling Unit (AHU-2) that serves the UPS room in the first floor, located in the room next to it. The unit has a premium efficiency motor (motor nameplate was unaccessible). This unit only has a chilled water coil and not heating coil. It is scheduled to operate 24 hours/day 7 days/week. The cooling temperature setpoint is 70°F.

Finally, there are twenty Fan Coil Units (FCU) that serve primarily larger classrooms, offices, lecture halls and conference rooms that are located above the ceiling within the core of the building. These fan coil units only have a chilled water coil and no heating coil. They are scheduled to operate between 5:00 am and 5:00 pm on weekdays, and scheduled to be off at night and during weekends and holidays. The cooling temperature setpoint in the majority of them is 75°F. There is also CO_2 monitoring in nine of those classrooms where the fan coils were installed. These fan coil units were all installed as part of a renovation that was finalized in 2009.

Cooling Plant

Building 259

There is no cooling in this building.

Building 330

The building has one 50-ton water-cooled reciprocating chiller manufactured by Carrier located on the first floor. This chiller was installed around 9 years ago and it primarily serves the CRAC

unit in the Data Center that has a chilled water coil plus AHU-2 serving the UPS room. There is a constant volume set of two 2 HP chilled water pumps (lead/lag control) for this chiller.

There is a fluid cooler with two sets of two 3 HP constant volume condenser water pumps (lead/lag control), one serves the chiller mentioned above and the other serves the two water-cooled CRAC units in the Data Center. The fluid cooler has multiple fans that are controlled to maintain the condenser water setpoint.

There are also two 75-ton air-cooled rotary scroll chillers manufactured by Carrier, located on the roof. These chillers supply chilled water to the FCUs and the chilled water coil in SF-2 (serving the building core), as well as AHU-1 (which serves the auditorium). There is a set of two 7.5 HP variable volume chilled water pumps (lead/lag control) for these chillers. These chillers and pumps were installed as part of the renovation that took place in 2009.

Both chiller loops are interconnected to provide backup for the Data Center, in case the chiller serving the Data Center fails.

Heating Plant

Building 259

The building uses steam from the central boiler plant on campus as the main heating fuel. The central plant provides 50 psi steam that is then reduced down to 10 psi through a Pressure Reducing Valve. The low pressure steam is used to produce hot water in a Heat Exchanger (steam to hot water converter), and then distributed through a 1 HP constant flow Hot Water Pump to all the fin-tube radiators throughout the building. There is also a condensate receiver and condensate pumps that are used to pump the condensate back to the central boiler plant.

The hot water supply setpoint for the steam-to-hot-water converter is 180°F when the Outside Air Temperature is 35°F of lower, and then reset linearly down to 75°F as the Outside Air Temperature rises up to 75°F.

The hot water pump is scheduled to operate between 5:00 am and 4:30 pm on weekdays, and disabled at nights, weekends and holidays. However, there is a heating lockout to disable the hot water pumps whenever the outside air temperatures rises above 65°F.

Building 330

The building uses steam from the central boiler plant on campus as the main heating fuel. The central plant provides 50 psi steam that is then reduced down to 10 psi through a Pressure Reducing Valve. The low pressure steam is used to produce hot water in a Heat Exchanger (steam to hot water converter), and then distributed through three different loops in the building. One loop has a three-way hot water valve and 2 HP constant flow hot water pump and serves the fin-tube radiators in the southeast part of the building. An identical configuration is used for the fin-tube radiator loop in the northwest part of the building. And finally there is a 5 HP constant flow hot water pump serving the heating coils in the air handlers (no control valve). There is also a condensate receiver and condensate pumps that are used to pump the condensate back to the central boiler plant.

The hot water supply setpoint for the fin-tube radiator loops is 180°F when the Outside Air Temperature is 55°F of lower, and then reset linearly down to 150°F as the Outside Air Temperature rises up to 70°F. The hot water supply setpoint for the steam-to-hot-water converter is a constant 175°F.

The hot water pump serving the fin-tube radiators is scheduled to operate between 5:00 am and 5:00 pm on weekdays, and disabled at nights, weekends and holidays. The hot water pump serving the air handlers is scheduled to operate between 4:00 am and 5:00 pm on weekdays, and disabled at nights, weekends and holidays. There is a heating lockout that disables all hot water pumps and close the steam valve in the main heat exchanger whenever the outside air temperature rises above 68°F.

Domestic Hot Water

Domestic hot water (DHW) is supplied by instantaneous electric heaters installed under the sink in each bathroom.

Building Automation System

The HVAC systems, including air-handling units (AHUs) and pumps, are controlled by a new DDC Automated Logic building automation system (BAS) that was installed or updated around 4 years ago. Lighting controls are currently not included in the BAS..

Lighting

A majority of the lighting fixtures use T-8 fluorescent lamps and electronic ballasts with 2 or 3 32 Watt lamps. The lighting systems are controlled by manual wall switches in a majority of the spaces, and there are very few rooms that have occupancy sensors.

Building 330 had all the lighting fixtures in hallways and stairways replaced in Nov ’13 with new LED fixtures, and the LED fixtures in the stairways have bi-level controls with occupancy sensors.

The auditorium in Building 330 had incandescent light bulbs.

Plug Loads

The office equipment accounts for the primary electrical plug load in the facility. The main office equipment loads are associated with the laptop and desktop computer workstations, as well as several vending machines, copy machines and printers. All (except three) of the vending machines were observed to have vending misers occupancy controllers already installed.

Building 330 has a 5,000 sqft Data Center, which is a major user of energy.

Domestic Water Fixtures

All public restrooms were observed to have waterless urinals and low-flow (1.6 gpf) toilets. Building 259 had low-flow faucets (0.5 gpm) with automatic shut off sensors. Building 330 had mostly regular manual faucets (1.5 gpm) without any sensors.

Current Energy Efficiency Best Practices and Observations

Numerous energy conservation measures (ECMs) and best practices have been implemented as part of various renovation projects. The following is a list of current energy efficiency projects and practices that were identified:

- Knowledgeable, proactive, enthusiastic, and competent facilities staff
- Good preventative maintenance schedules
- ALC central building automation system with scheduling for HVAC
- Variable speed drives on all major pump and fan motors
- Air-side economizer based on outdoor air temperature or enthalpy
- Hot water temperature reset
- Demand control ventilation based on CO_2 in the return duct of the AHU serving all floors of Building 330 [1000 parts per million (ppm) limit], as well as in the AHU serving the Auditorium [800 parts per million (ppm) limit]
- Premium efficiency motors for the bigger chilled water, and hot water pumps and fans
- Cooling tower sequencing to minimize fan energy
- T-8 fluorescent and CFL lighting
- Light-emitting diode (LED) lighting in hallways and stairways of Building 330
- Bi-level light fixtures in stairwells with occupancy sensors in Building 330
- Waterless urinals and low-flow toilets
- Advanced metering on electricity only

Energy Conservation and Water Conservation Measures

The following sections contain the HVAC, lighting, plug loads, envelope, and water measures that were analyzed.

1 HVAC Measures

The following sections contain the HVAC energy efficiency measures that were analyzed.

1.1 Pipe Insulation

Current Condition: Currently, there are about 30 linear feet of bare (uninsulated) hot water supply and condensate return piping in Building 259. Similarly there are about 10 linear feet of bare hot water piping in the basement of Building 330 (See Figures 6 and 7). The insulation on some of the old piping was probably damaged due to age or repairs, and was never reinstalled, and some of the new piping was never insulated.

Figure 6. Building 330 Basement – Uninsulated hot water piping. *Photos by* NAME REDACTED

Figure 7. Bldg 259 Basement –Uninsulated condensate return piping. *Photos by* NAME REDACTED

Recommended Action: Reinsulate the bare piping to prevent unnecessary heat loss. Below are the calculated energy and cost savings, and simple payback for implementing this measure. Calculation assumptions are also given below.

Cost per linear foot of insulation =	$24/ft
Total Cost (40 ft x $24) =	$960
Expected Simple Payback =	16 years
Estimated Savings (@ $5.79/MBtu) =	$60/yr

Assumptions:

- The Spread sheet calcs were used to calculate the energy and cost savings from implementing a pipe insulation on non-insulated piping.
- The cost for install of insulation was assumed to be $24/Linear Foot

1.2 Insulation Blankets

Current Condition: Currently, the steam Pressure Reducing Valves located in the basement of Buildings 259 and 330 are uninsulated (see Figure 8). PRVs and other valves and fittings are very commonly left uninsulated because they require maintenance and/or have moving parts. The temperature of these uninsulated steam valves was measured between 250°F and 300°F.

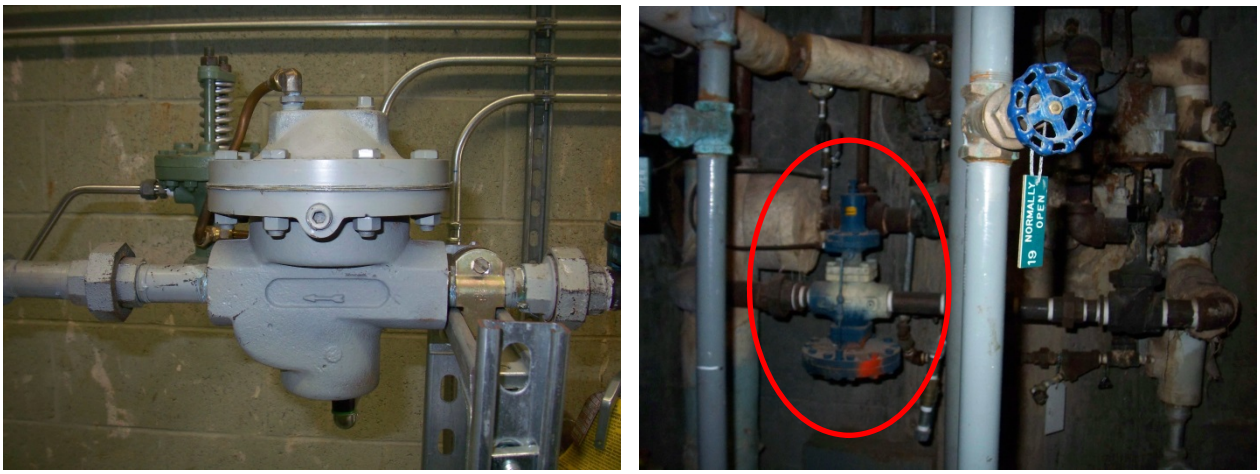

Figure 8. Uninsulated PRV in Blg 259 (left) and Blg 330 (right). *Photos by* NAME REDACTED

Recommended Action: Install removable insulation blankets. These blankets can be used to cover valves, joints, strainers, flanges, PRVs, and other equipment that needs to be accessed for maintenance or other reasons from time to time. The blankets can be installed and removed quickly in minutes, with no need for additional tools or materials. The blankets have 1" of insulation, are custom-fit to the piece of equipment that will be covered, and will significantly reduce the heat loss. Below are the calculated energy and cost savings, and simple payback for implementing this measure. Calculation assumptions are also given below.

Cost per Blanket for a 2" PRV valve =	$320
Total Cost (2 x $320) =	$640
Expected Simple Payback =	1.4 years
Estimated Savings (@ $5.79/MBtu) =	$450/yr

Assumptions:

- Spread sheet calcs were used to calculate the energy and cost savings from implementing insulation blankets on uninsulated PRVs.

1.3 Motor Replacements

Current Condition: Currently, the motors installed on the 2 HP chilled water pumps that serve the 50-ton chiller dedicated to the Data Center on the first floor, as well as the 3 HP condenser water pumps located in the same mechanical room on the first floor, are not premium efficiency pumps (see Figure 9 for nameplate of these pumps). The 2 HP motor has an efficiency of 82.9% and the 3 HP motor has an efficiency of 89.5%. These motors and pumps operate 24 hrs/day since the Data Center operates and requires cooling continuously.

Figure 9. Nameplate for chilled water pump motor (left) condenser water pump motor (right).
***Photos by* NAME REDACTED**

Recommended Action: Given the long run hours of these motors, they should be replaced with premium efficiency motors (89.5% for 3 HP motor and 86.5% for 2 HP motors). However, since these are three different sets of motors and are operated as lead/lag, then only one motor should be replaced on each set and eliminate the use of the lead/lag control. The other pump will remain as backup for emergency and/or maintenance and the one with the new motor will operate continuously. Below are the calculated energy and cost savings, and simple payback for implementing this measure. Calculation assumptions are also given below.

Cost to Replace a 2 HP motor with a NEMA Premium Efficiency motor=	$944
Cost to Replace a 3 HP motor with a NEMA Premium Efficiency motor=	$1,118
Total Cost (1 x $944 + 2 x $1,118) =	$3,180
Expected Simple Payback =	75 years
Estimated Savings =	$42/yr

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from replacement of motors

1.4 HVAC Scheduling

Current Condition: Currently, the majority of the HVAC systems are scheduled to operate for 12 hours per weekday and to not operate during the weekends. The scheduled operation for the HVAC systems is typically between 5:00 a.m. and 5:00 p.m. on the weekdays (see Figure 10 for screenshot of typical HVAC schedule from ALC BAS).

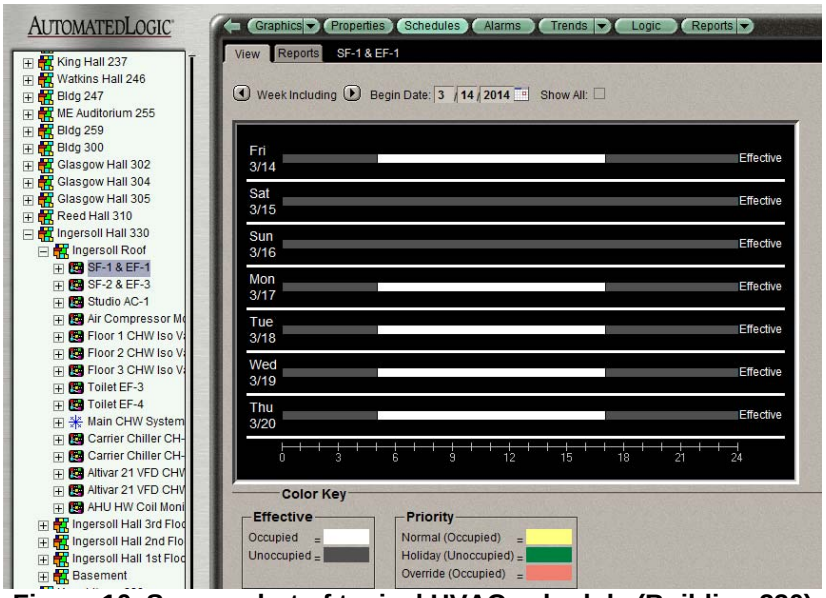

Figure 10. Screen shot of typical HVAC schedule (Building 330)

Recommended Action: Consider operating the HVAC system for 10 hours a day during swing seasons when the weather conditions are very mild and the space conditioning loads are moderate and the HVAC could be operated from 6:30 am to 4:30 pm. Maintain the current HVAC schedule during the summer and winter months. Below are the calculated energy and cost savings and simple payback for HVAC scheduling. Calculation assumptions are also given below.

Cost to Reprogram ALC Controls =	$50/ hr
Total Cost (50 hr/yr x $50/hr) =	$250
Expected Simple Payback =	0.4 years
Estimated Savings =	$669/yr

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from scheduling the HVAC to operate 10 hours a day during the swing seasons
- The implementation cost was assumed to be two hours for a technician to reprogram the building automation system with the new temperature setpoints at a labor rate of $50/hour

1.5 Reduce Ventilation Rates to ASHRAE 62.1-2007 Levels

Current Condition: Given the age of the Building 330, it is quite possible that it was originally designed for ventilation rates that are set to 20 cubic feet per minute (cfm)/person or higher. The current ventilation requirement for offices as specified by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 62.1-20076 is 17 cfm/person. Therefore, the percent outside air required by ASHRAE is approximately 15% lower than the current ventilation rates.

Recommended Action: Reduce ventilation airflow rates to ASHRAE 62.1-2007 required levels. It will be necessary to carry out a more detailed engineering analysis to determine required rates for main AHU in Building 330 supplying all three floors using the ASHRAE ventilation rate procedure. Complying with ASHRAE 62.1-2007 should reduce ventilation airflow rates in the building by approximately 15%.

Implementing this ECM includes:

- Carrying out detailed ventilation rate calculations or measurements for the main AHU in Building 330 using the ventilation rate procedure in ASHRAE 62.1-2007
- Rebalancing outside airflow dampers at the air handler.

Below are the calculated energy and cost savings and simple payback for reducing the ventilation rates. Calculation assumptions are also given below.

Assumptions:

- The eQUEST energy model was used to estimate the savings from reducing the ventilation rates to ASHRAE 62.1-2007 levels
- The ventilation rate was assumed to be reduced by 15%
- The design of the ventilation rates was assumed to be 40 hours x $200/hr, which totals $8,000
- The labor time to implement reducing the ventilation rates to ASHRAE 62.1-2007 levels was assumed to take eight hours per AHU x $50/hr, which totals $6,400 for the 16 AHUs with a minimum outside air setpoint
- Commissioning the AHUs was assumed to take 40 hours x $100/hr, which totals $4,000
- No savings were identified for this ECM

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[6] American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). *ASHRAE Standard 62.1-2007: Ventilation for Acceptable Air Quality.* Atlanta, Georgia, 2010. http://openpub.realread.com/rrserver/browser?title=/ASHRAE_1/ashrae_62_1_2010_1024.

2 Lighting Measures

The following sections contain the lighting efficiency measures that were analyzed.

2.1 Replace 32 Watt T8 Lamps with 25 Watt T8 Lamps

Current Condition: The most widely used fluorescent lighting fixtures in offices and classrooms in Building 259 and Building 330 include 2, 3 or 4 32-Watt T8 Lamps. Building 259 has typically surface mounted lighting fixtures and Building 330 has typically lay-in fixtures (See Figure 11 for typical lighting fixtures). There are an estimated total of 827 fixtures within both buildings, and assuming there is an average of 3 lamps per fixture, this represents a total load of roughly 79 kW. The estimated runtime of these lamps is approximately 2,920 hours per year, assuming the typical ASHRAE lighting schedule.

Figure 11. Typical surface mounted fixture in Bldg 259 (left) and lay-in fixture in Blg 330 (right).
***Photos by* NAME REDACTED**

Recommended Action: To insure compatibility of the lamps and ballasts and to provide consistency in lamp color and maintain current light levels, it is better to perform all the lighting retrofits at once. However, if it is not possible, then it is recommended that all of the 32 Watt lamps and ballasts in each lighting fixture be retrofitted incrementally, as lamps fail, with low-wattage lamps. The low-wattage lamps should be specified at 25 W, with a color temperature matching that of the existing lamps.

Below are the calculated energy and cost savings, and simple payback for replacing standard T-8s with low-wattage T-8s. Calculation assumptions are also given below.

Cost to Retrofit a 3-Lamp 32 W fixture with new 25 W lamps and ballast=	$55
Total Cost (827 fixtures x $55/fixt) =	$45,485
Expected Simple Payback =	5 years

Estimated Savings = $9,033/yr

Assumptions:

- Labor and material to retrofit a 3-Lamp 32 W fixture with new T8 Technology will cost $55/Fixture x 827 fixtures
- Energy savings take into account interactions with the heating and cooling systems
- A 30% contingency was added to the overall cost.

2.2 Replace Incandescent Lamps in the Auditorium with LED Lamps

Current Condition: There were a total of 31 one-lamp fixtures with incandescent lamps rated at 200 W each (see Figure 12 for lamps in the Auditorium of Building 330), with a peak load of 6.2 kW. The estimated runtime of these lamps is four hours per day, five days per week, for a total of 1,043 hours per year.

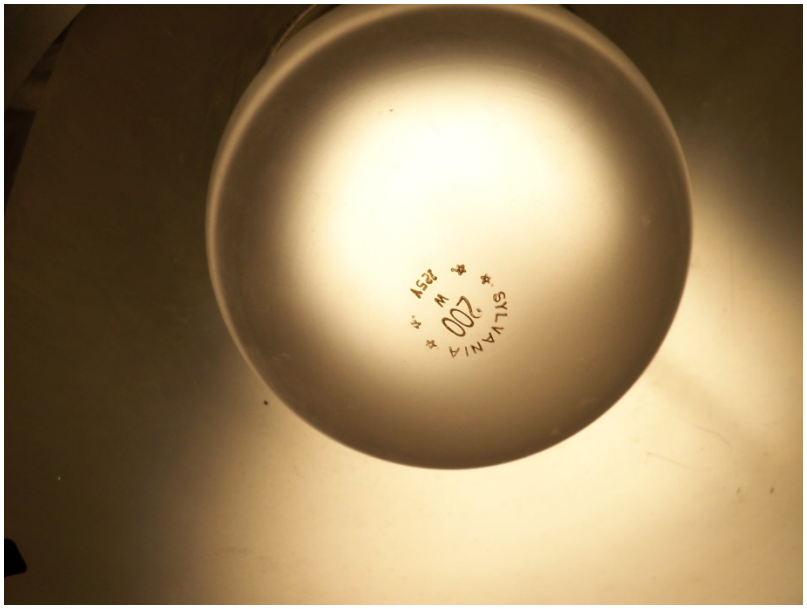

Figure 12. 200-Watt incandescent lamps used in Auditorium (Blg 330). *Photo by* NAME REDACTED

Recommended Action: Replace all of the incandescent lamps with LED lamps with dimming capabilities. LED lamps should be specified to have the same base configuration and same aesthetic effect as the current lamp, producing close to the same amount of light while consuming less energy. Equivalent LED lamps are estimated to have a power rating of 35 W per lamp. In addition, LED lamps have a rated lifetime of 25,000 hours compared to 750 hours with incandescent lamps. Therefore, over a 25-year project lifetime, the incandescent lamps will go through 34.8 replacement cycles compared to 1.0 with LED lamps, resulting in significant O&M savings in addition to the energy cost savings. Below are the calculated energy and cost savings and simple payback for replacing incandescent lamps with LEDs in the Auditorium. Calculation assumptions are also given below.

Cost to Retrofit a 200 W incandescent lamp with a 34 W LED =	$30
Total Cost (31 lamps x $30/fixt) =	$930
Expected Simple Payback =	1.5 years
Estimated Savings =	$593/yr

Assumptions:

- Labor costs were estimated to be 12 min/fixture x $50/hr x 31 fixtures
- Lamp costs were estimated at $20/lamp x 31 lamps

3 Plug Load Measures

The following sections contain the plug load efficiency measures that were analyzed.

3.1 Install Vending Machine Misers and De-Lamp Advertisement Lighting

Current Condition: There was one refrigerated vending machine in Building 259, as well as one refrigerated vending machine in Building 330 that did not have any occupancy controls. The rest of the vending machines in Building 330 did have occupancy controllers already installed. The refrigerated vending machines were rated at 400 W each (estimated) with two 25 W linear fluorescent lamps. The estimated run time for these vending machines is 8,760 hours per year.

Figure 13. Vending Machines without occupancy controls in Bldg 259 (left), and Blg 330 (middle) and vending machines with occupancy controls in Blg 330 (right). *Photos by* NAME REDACTED

Recommended Action: Install vending machine misers on all refrigerated vending machines that did not have them already installed. Vending machine misers are small, easy-to-use devices that can reduce the energy consumed in refrigerated vending machines by up to 46%. The controller uses an infrared occupancy sensor to power down the unit when no occupants are present and has some intelligent control; it will record the time intervals when the building is not occupied and power down the machine during these periods. The refrigerated vending machine misers keep the beverages cold, while simultaneously reducing the energy consumption of the machine.

In addition, review the vendor contract for the vending machine to determine if the advertising lighting can be removed from all of the cold-drink vending machines. De-lamping will result in electrical savings and reduce the cooling load within the vending machine. Below are the calculated energy and cost savings, and simple payback for installing vending machine misers. Calculation assumptions are also given below.

Cost to install a Vendingmiser =	$250
Total Cost (2 x $250) =	$500
Expected Simple Payback =	1.4 years
Estimated Savings (@ $0.111/kWh) =	$358/yr

Assumptions:

- Assumed average load is reduced to 240 W with a capacity factor of 100%
- Labor costs were estimated at $50/hr x 2 hrs/machine x 2 machines
- Miser costs were estimated at $150/miser x 2 misers

4 Water Conservation Measures

The following sections contain the water efficiency measures that were analyzed.

4.1 Install Low-Flow Aerators on Faucets

Current Condition: There were a total of 28 standard efficiency faucets in Building 330 (see Figure 14). The baseline water use characteristics were calculated assuming each male occupant washes their hands three times a day and each female occupant washes their hands four times a day. The faucets are standard water faucets with a rated flow rate of 1.5 gpm.

Figure 14. Typical 1.5-gpm faucet installed in all restrooms in Blg 330. *Photo by* NAME REDACTED

Recommended Action: Install low-flow aerators on all of the existing standard faucets. The savings calculation was based on replacing 28 faucets with 0.5 gpm faucet aerators. Below are the calculated energy and cost savings and simple payback for installing low-flow aerators on faucets. Calculation assumptions are also given below.

Cost to install a faucet aerator =	$25/unit
Total Cost (28 x $25) =	$700
Expected Simple Payback =	1.1 years
Estimated Savings (@ $5.36/kgal) =	$616/yr

Assumptions:

- Assumed 125 male occupants and 125 female occupants
- Assumed a wash duration of 1.0 minutes/wash
- Faucets are used 250 days per year
- Labor costs were estimated at $50/hr x 0.25 hours
- Aerator costs were estimated at $12/faucet

5 Data Center Conservation Measures

As the largest energy user in the building, there may be Energy Conservation Measures in the Data Center in Building 330 that are worth exploring. Some of the mechanical and electrical infrastructure, equipment age and operational characteristics may not be up to date. The air management within the raised floor area may be suffering from high levels of air recirculation and short circuiting "bypass." Recirculation is the air discharged from servers that returns and mixes with air entering the servers to cool them, thus resulting in hot spots. Bypass is the air that leaves the floor grills and returns directly to the Computer Room Air Conditioning (CRAC) unit without cooling servers, thus wasting fan energy.

Outlining and identifying energy efficiency and/or invoking energy savings measures can typically reduce a data center's operational costs by 20-60%, based on the ability to optimize and/or consolidate IT infrastructure footprints. There is a direct correlation between physical IT deployments within the data center raised floor space and the amount of power required to operate, as well the amount of power required to support and run mechanical and electrical systems. The metric that is widely utilized today to understand and calculate energy efficiency for data center facilities is PUE (Power Usage Effectiveness), which is defined as the total data center power divided by the Information Technology (IT) equipment power. Lower PUE values translate into more energy-efficient data centers.

NAME REDACTED has a partnership with NAME REDACTED, a company that is nationally recognized as the leader in the planning, design, assurance and construction of high-performance, high-reliability and high-security data centers. Through this partnership NAME REDACTED can measure and benchmark the data center PUE values against U.S. Department of Energy (DOE) Lawrence Berkeley National Laboratory (LBNL) benchmarking data to determine if there is an opportunity for optimization.

Below are some specific examples of the energy conservation measures (ECMs) that can be explored within the data center but that will require a more detailed analysis as well as inputs from the IT Department. Without this more detailed analysis, the costs and savings from these measures cannot be easily estimated.

5.1 CRAC Unit Replacement

Replacement of the oldest Computer Room Air Conditioning (CRAC) water-cooled unit with state of the art unit with variable air flow. New units would be in cooling mode only, with no electric heat and no humidification elements. With older units, it means that one cooling unit could be cooling, while the other one is heating – or one cooling unit is humidifying while another is dehumidifying. New units also contain environmentally friendly refrigerant.

5.2 Centralized Humidification System

Installation of a Centralized Ultrasonic Humidification System as a replacement to the existing CRAC-based Infrared Humidifiers (IR).Ultrasonic humidifiers use up to 90% less electrical energy than electrode boilers or IR humidifiers. Water is not heated and wasted, as with typical humidification flush cycles.

5.3 Data Center Air Management Optimization

Data center Air Management Optimization (airflow, layout, pressurization optimization). Reduction of bypass and air recirculation is achieved by properly sealing the entire raised floor area using cable skirts or brushes; installing blanking panels in all racks where servers are not present; installing extension return ducts on all newly replaced CRACs and routing cool air to cold aisles only. This could also entail increasing the cooling setpoints in CRAC units in the Data Center up to 70°F or 72°F, and only running them (and the associated chiller and chilled water/condenser water pumps) whenever the main air handling unit located on the roof cannot maintain those sepoints.

5.4 Data Center Controls Optimization.

Optimize the air temperature and relative humidity control set points and dead bands to improve energy efficiency, yet also meet the ASHRAE 2008 recommended range. This also includes eliminating the reheat and humidification elements from all remaining CRAC units that were not replaced.

5.5 Data Center IT Modernization, Optimization and/or Consolidation.

In order to reduce the overall IT infrastructure footprint and reduce overall power consumption and energy efficiency, two aspects are evaluated: (1) Wintel and UNIX Systems (virtualization and blade server systems); and (2) Storage systems (newer disk storage systems offer much higher disk capacities, as well as much smaller rack-mount footprints that no longer require standalone cabinets that occupy critical raised floor space and consume higher levels of energy). Each of these strategies can yield 10-50% physical IT infrastructure reductions and similar power consumption reductions.

Appendix D: DoD Audit Score Sheets

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Thomas H. Hykes**

Audit Report Identifier: **USAFA, Building 8116 and 8120**

Question 1:

Criteria	Observations
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. ~~are~~ is Score: _8_/10	"The utility use for the buildings ~~are~~ is given in the tables below" (page 2). AFA should be upper case (page 9). Verb should be singular or noun plural "can save" has an extra space (page 13). "higher than" has an extra space (page 15). The word "investmen~~-~~t" has an extra space for ECM #9 (page 15). These are difficult to notice when using proportional spacing. Hyphenate the word "non critical" (page 17) The name "Hewlet-Packard" has two t's (tt).
	Duplicate information regarding OpenStudio and ECMs in the "Calculations Method" paragraphs in each report.

Question 2:

Criteria	Observations
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: _8_/10	USAFA inputs the base case and alternatives in BLCC 5.13, so just a summary of ECM results is not adequate. The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Question 3:

Criteria	Observations
Report is concise, easy to read, and easy to navigate. Score: _9_/10	The Bar Charts are difficult to read. Suggest the sequence in each bar match the sequence in the legend. Suggest the legend be limited to only the data used in making each bar (14 items in the legend and only 5 used in the bar).

Question 4:

Criteria	Observations

Existing conditions are explained well, and recommendations are detailed and clear. Score: _5_/10	All spaces in Bldg 8120 and the office areas of Bldg 8116 have occupancy sensors (see first paragraphs on page 13). The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Quantity and location of items would be helpful.

Question 5:

Criteria	Observations
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _5_/10	Assumptions are missing. Recommendations, e.g. "Install low-wattage T8 lighting" and "Replace the lighting system with a newer, more efficient lighting technology," are too ambiguous. O&M costs are missing

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: _10_/10	

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _5_/10	It would be useful to have the Executive Summary include cost of utilities used by the buildings. Most reading it understand dollars and not energy units. Annual totals would be useful. Did not find any links to outside resources and assumption supporting documentation.

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _2_/10	Only a summary of ECM results was provided. The existing equipment data is needed, number of units, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Other Misc. Comments:

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Thomas H. Hykes**

Audit Report Identifier: **USAFA, Building 6202**

Question 1:

Criteria	**Observations**
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _9_/10	The name "Hewlet-Packard" has two t's (tt). Duplicate information regarding OpenStudio and ECMs in the "Calculations Method" paragraphs in each report.

Question 2:

Criteria	**Observations**
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: _8_/10	USAFA inputs the base case and alternatives in BLCC 5.13, so just a summary of ECM results is not adequate. The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Question 3:

Criteria	**Observations**
Report is concise, easy to read, and easy to navigate. Score: _9_/10	The Bar Charts are difficult to read. Suggest the sequence in each bar match the sequence in the legend. Suggest the legend be limited to only the data used in making each bar (14 items in the legend and only 5 used in the bar).

Question 4:

Criteria	**Observations**
Existing conditions are explained well, and recommendations are detailed and clear. Score: _6_/10	The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Quantity and location of items would be helpful.

Question 5:

Criteria	Observations
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _5_/10	Assumptions are missing. Recommendations, e.g. "Install low-wattage T8 lighting" and "Replace the lighting system with a newer, more efficient lighting technology," are too ambiguous. O&M costs are missing

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: _10_/10	

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _5_/10	It would be useful to have the Executive Summary include cost of utilities used by the building. Most reading it understand dollars and not energy units. Annual totals would be useful. Did not find any links to outside resources and assumption supporting documentation.

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _2_/10	Only a summary of ECM results was provided. The existing equipment data is needed, number of units, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Other Misc. Comments:

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Thomas H. Hykes**

Audit Report Identifier: **USAFA, Building 4198**

Question 1:

Criteria	**Observations**
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _9_/10	The name "Hewlet-Packard" has two t's (tt). Duplicate information regarding OpenStudio and ECMs in the "Calculations Method" paragraphs in each report.

Question 2:

Criteria	**Observations**
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: _8_/10	USAFA inputs the base case and alternatives in BLCC 5.13, so just a summary of ECM results is not adequate. The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Question 3:

Criteria	**Observations**
Report is concise, easy to read, and easy to navigate. Score: _9_/10	The Bar Charts are difficult to read. Suggest the sequence in each bar match the sequence in the legend. Suggest the legend be limited to only the data used in making each bar (14 items in the legend and only 5 used in the bar).

Question 4:

Criteria	**Observations**
Existing conditions are explained well, and recommendations are detailed and clear. Score: _6_/10	The existing equipment data is needed, number operating hours, assumptions, etc. is needed. Quantity and location of items would be helpful.

Question 5:

Criteria	Observations
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _5_/10	Assumptions are missing. Recommendations, e.g. "Install low-wattage T8 lighting" and "Replace the lighting system with a newer, more efficient lighting technology," are too ambiguous. O&M costs are missing

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: _10_/10	

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _5_/10	It would be useful to have the Executive Summary include cost of utilities used by the building. Most reading it understand dollars and not energy units. Annual totals would be useful. Did not find any links to outside resources and assumption supporting documentation.

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _2_/10	Only a summary of ECM results was provided. The existing equipment data is needed, number of units, number operating hours, assumptions, etc. is needed. Manufacturer's data of replacement equipment is also needed.

Other Misc. Comments:

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Don Vincent (who is answering the questions) did "not" participate. Don Vincent = Energy Mgr Fort Bliss TX**

Audit Report Identifier: **Building COF 20105**

Question 1:

Criteria	Observations
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 5 / 10	**See Dennis Wike's direct comments on the Report.**

Question 2:

Criteria	Observations
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: 1/10	**See attached Comment Sheet, titled:** **Fort Bliss Simuwatt Comments with** **CONTROL #: 8K3T?9B&**

Question 3:

Criteria	Observations
Report is concise, easy to read, and easy to navigate. Score: 8/10	**See Dennis Wike's direct comments on the Report.**

Question 4:

Criteria	Observations
Existing conditions are explained well, and recommendations are detailed and clear. Score: 4/10	**See attached Comment Sheet, titled:** **Fort Bliss Simuwatt Comments with** **CONTROL #: 8K3T?9B&**

Question 5:

Criteria	Observations

Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: 0/10	**See Dennis Wike's direct comments on the Report.** **See attached Comment Sheet, titled:** **Fort Bliss Simuwatt Comments with** **CONTROL #: 8K3T?9B&**

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: 7 / 10	**Don Vincent did not participate.** *Score of 7 established via email after receipt of scorecard.*

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: 2 /10	**See Dennis Wike's direct comments.** *Score of 2 established via email after receipt of scorecard.*

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: 1 / 10	**Zero back up as to how the Costs and Savings were derived. Also, the "advanced" meter data should be "verified" before being used in calculations. Also, Fort Bliss is now in the Interruptible Tariff Agreement with the El Paso Electric CO. Difficult to calculate the electrical Energy Costs.**

Other Misc. Comments: Critical one reads the attached.
Fort Bliss Simuwatt Comments with CONTROL #: 8K3T?9B&

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Andrew Carmean**

Audit Report Identifier: _____

Question 1:

Criteria	**Observations**
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _10__/10	

Question 2:

Criteria	**Observations**
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: __9_/10	**In order for it to be copied into a 1391 easily, one should add sections that describe the "Current Situation", and "Impact if not provided"**

Question 3:

Criteria	**Observations**
Report is concise, easy to read, and easy to navigate. Score: __10_/10	**I can find the relevant information easily.**

Question 4:

Criteria	**Observations**
Existing conditions are explained well, and recommendations are detailed and clear. Score: _10_/10	**I see the existing conditions, current consumption and operating conditions.**

Question 5:

Criteria	**Observations**
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included.	

Score: _10_/10	

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: _10__/10	**I don't recall eliminating any recommendations.**

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _10_/10	**The only things that help gain support are the energy savings and payback period.**

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _10__/10	**MMBtu column isn't populated in the draft.**

Other Misc. Comments:

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Jonathan Caldwell**

Audit Report Identifier: **Bldg 662 and 1060 Audits, Tyndall AFB**

Question 1:

Criteria	**Observations**
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: __10_/10	**Professional, concise and error free.**

Question 2:

Criteria	**Observations**
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: __9_/10	

Question 3:

Criteria	**Observations**
Report is concise, easy to read, and easy to navigate. Score: __9_/10	

Question 4:

Criteria	**Observations**
Existing conditions are explained well, and recommendations are detailed and clear. Score: _10_/10	

Question 5:

Criteria	**Observations**
Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included.	

Score: _9_/10	

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: _10_/10	

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: ___/10	**N/A**

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _9__/10	

Other Misc. Comments:

Very well done. One of the better audit reports I've seen because the ECMs are based on actual modeling. Consider the model more accurate than most because actual consumption data factors into model.
Tables and charts are effective and understandable. Excellent job capturing true cost/payback of ECMs.

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Doug Taber, NSA Monterey Energy Manager, Comments @09-22-2014**

Audit Report Identifier: **Third Party simuwatt audit tool, Building 259 Audit**

Question 1:

Criteria	Observations
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _8__/10	**Document not as polished as the conventional audit is, but just needs final formatting and margins, etc., as well as a final technical edit. No big thing – just seems a little earlier in the document-production process.**

Question 2:

Criteria	Observations
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: __8_/10	**Data are very useable for preparing Forms 1391 and preparing energy projects for submittal. Might need an appendix with backup calculations in more detail for project funding submittal. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor. We will definitely be able to use this audit for "EISA 2007" legislation compliance reporting.**

Question 3:

Criteria	Observations
Report is concise, easy to read, and easy to navigate. Score: _9__/10	**Would like to have ECMs numbered in executive summary and in main body of report – for easy reference.**

Question 4:

Criteria	Observations
Existing conditions are explained well, and recommendations are detailed and clear. Score: _10__/10	**Appreciate the discussion of hot and cold spots in B-259, and also the simple ECM of thermostat controls. The identification and discussion of the steam valve issues is very highly appreciated.**

Question 5:

Criteria	Observations

Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _8__/10	**Might need an appendix with calculations in more detail to backup project submittal for funding. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor. We will definitely be able to use this audit for "EISA 2007" legislation compliance reporting.**

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: ___/10	**N/A – I wasn't here at the time of the site visit.**

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _8__/10	**No list of outreach materials – but not really necessary for such a straightforward audit.**

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _10_/10	**Needs appendix with full calculations/computer printouts in final version of report.**

Other Misc. Comments:

Fluorescent lamp ECM:
Audit may have been conducted during Navy's partial prohibition on LED tube replacements, but better and more cost-effect LEDs are around now. CREE as an example, $31.50 each at Amazon. Generally fluorescent lighting is "old technology" that LEDs can replace with longer-life bulbs, less bulb-changing labor, and without mercury disposal requirements (though LEDs are still considered as e-waste).

Aerator ECM:

ECM in progress, and expect that audit team was not made aware of the base's gradual program to change all aerators out for low-flow units.

Reviewer finds it highly significant that the SimuWatt team was able to identify steam system issues that the conventional audit missed. Excellent observations that are much appreciated.

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Doug Taber, NSA Monterey Energy Manager, Comments @09-22-2014**

Audit Report Identifier: **Third Party simuwatt audit tool, Building 330 Audit**

Question 1:

Criteria	Observations
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _8__/10	**Document not as polished as the conventional audit is, but just needs final formatting and margins, etc., as well as a final technical edit. No big thing – just seems a little earlier in the document-production process. A few typos.**

Question 2:

Criteria	Observations
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: __8_/10	**Data are very useable for preparing Forms 1391 and preparing energy projects for submittal. Might need an appendix with backup calculations in more detail for project funding submittal. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor. We will definitely be able to use this audit for "EISA 2007" legislation compliance reporting.**

Question 3:

Criteria	Observations
Report is concise, easy to read, and easy to navigate. Score: _9__/10	**Would like to have ECMs numbered in executive summary and in main body of report – for easy reference.**

Question 4:

Criteria	Observations
Existing conditions are explained well, and recommendations are detailed and clear. Score: _10__/10	**Appreciate that data center energy use issues are outside the scope of this audit, but might have been worth mentioning in addition to the power supply ECM. The reviewer is highly familiar with the building, but other readers might not be.**

Question 5:

Criteria	Observations

Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _8__/10	**Might need an appendix with calculations in more detail to backup project submittal for funding. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor. We will definitely be able to use this audit for "EISA 2007" legislation compliance reporting.**

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: ___/10	**N/A – I wasn't here at the time of the site visit.**

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: _8__/10	**No list of outreach materials – but not really necessary for most of the ECMs in this audit. References or links for the UPS system replacement equipment and typical costs might've been nice to have.**

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: _10_/10	**Needs appendix with full calculations/computer printouts in final version of report.**

Other Misc. Comments:

Fluorescent lamp ECM:
Audit may have been conducted during Navy's partial prohibition on LED tube replacements, but better and more cost-effect LEDs are around now. CREE as an example, $31.50 each at Amazon. Generally fluorescent lighting is "old technology" that LEDs can replace with longer-life bulbs, less bulb-changing labor, and without mercury disposal requirements (though LEDs are still considered as e-waste).

Suspect that installed cost for occupancy sensors would be above the listed figure, but that a very good payback would still be achieved.

DOD Personnel – Scorecard for Energy Audit Report

Participant Name: **Doug Taber, NSA Monterey Energy Manager, Comments @09/22/14**

Audit Report Identifier: **Third Party Traditional Audit: Buildings 259 and 330**

Question 1:

Criteria	Observations
Energy audit is free of typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: _9__/10	**A few typos and grammatical errors, but nothing too significant. Report needs a final technical edit and perhaps better definition of acronyms like "WAPA".**

Question 2:

Criteria	Observations
The audit report is in a format which can be used for the easy transcription into a 1391, can be used for compliance reporting, and can be used to put together in a package for financing. Score: _8__/10	**Data are very useable for preparing Forms 1391 and preparing energy projects for submittal. Might need an appendix with backup calculations in more detail for project funding submittal. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor. We will definitely be able to use this audit for "EISA 2007" legislation compliance reporting.**

Question 3:

Criteria	Observations
Report is concise, easy to read, and easy to navigate. Score: _10__/10	**Very clear organization**

Question 4:

Criteria	Observations
Existing conditions are explained well, and recommendations are detailed and clear. Score: _10__/10	**Again, very clear organization**

Question 5:

Criteria	Observations

Assumptions are listed with recommendations, and recommended measures are priced out with payback periods calculated. Operations and maintenance costs are included. Score: _8__/10	**Might need an appendix with backup calculations in more detail, in case we are asked for them. ECM engineering and materials savings both. Generally Navy allows only maintenance material savings – not labor.**

Question 6:

Criteria	Observations
Report does not include recommendations that were eliminated by the site staff during the site visit. Score: ___/10	**Unknown – I wasn't here when site visits occurred**

Question 7:

Criteria	Observations
There are outreach materials in the audit data package that will help gain support for implementing measures including; summary presentation, executive summary document, and links to outside resources. Score: __7_/10	**No executive summary, though almost not needed in such a simple report. A summary page would be good to add, with a summary table of ECMs, costs, savings, and simple-payback periods. Also needs table of utility rates used for ECM calculations.**

Question 8:

Criteria	Observations
Recommended measures have been sufficiently quantified, including number of units, and replacement power rating. Score: __9_/10	**It is realized that quantifying some of the ECMs to 1391-ready status is beyond the scope of this audit (data centers, etc.)**

Other Misc. Comments:
ECM 1.5 Reduce Ventilation Rates (B-330):
This ECM is perhaps outside the scope of the audit due to building modeling required – but it's something that we will follow up on. Hard to imagine that there's no way to capture some fan energy savings there.

ECM 2.1 Replace 32W T-8 with 25W T8:
Audit may have been conducted during Navy's partial prohibition on LED tube replacements, but better and more cost-effect LEDs are around now. CREE as an example, $31.50 each at Amazon. Generally

fluorescent lighting is “old technology” that LEDs can replace with longer-life bulbs, less bulb-changing labor, and without mercury disposal requirements (though LEDs are still considered as e-waste).

ECM 4.1 Aerators on faucets:
ECM in progress, and expect that audit team was not made aware of the base’s gradual program to change all aerators out for low-flow units.

ECMs 5.1 through 5.5:
Appreciate discussion of data center issues.

Appendix E: Energy Audit Expert Audit Score Sheets

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **AFA 8116 8120**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment and then later on in the same paragraph there is mention of water efficiency. Is this a water efficiency assessment too?** **-The Executive Summary states that there are 14 energy efficiency, water efficiency, and renewable energy measures that were analyzed. Results for 14 energy efficiency measures are presented. If water efficiency and renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Do they already have water efficient fixtures and this is why no water efficiency measures are recommended? Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy, water, and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that many of the measures have a simple payback period of 1-10 years. 8 of the 14 measures have paybacks in the 0-10 year range. One of the paybacks is 0.09 years and so you should maybe consider wording it as 0-10 years instead of 1-10 years.** **-Stating that "there are a couple of areas" in the site overview paragraph of the executive summary is not wording commonly found in a technical report. Consider revising.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-On page 2 you use AFA. You should say what this stands for**

	since this is the first time that you use the acronym. **-On page 9 you use Afa. Is this a new acronym or is it the same as AFA. If it is the same as AFA, what does AFA stand for?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.** **-Hewlett-Packard is misspelled in Computer power management measure.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.** **-From the energy calibration charts, the energy model appears to be calibrated to within 10% of the utility data but it would be good to state the actual percentage in the body of the report.** **It seems suspicious that buildings AFA 4198, AFA 6202, AFA 8116 & 8120, Bliss 20105, and Bliss 20107 all have 17 inch Samsung LCD monitors and Hewlett Packard computers (see Replace desktop computers with laptops measure).** **-The replace desktop with laptops measure states that the total connected load for the desktop computer stations is 150 Watts. The computer power management measure states that the computer has a total connected load of 57 Watts. This is a very big discrepancy.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 5/10	**-You state that electricity, natural gas, and water are presented in the utility data but only electricity and natural gas are presented.** **-You state in the first paragraph of the Energy Use and Utility Data section that the utility use for the campus is given. Is this a campus that we're dealing with or a building?**

	-Consider presenting water use and cost for the building. **-Consider presenting 3 years of utility data.** **-Include utility costs in the summary table and not just usage.** **-Include annual totals in the utility chart.** **-Consider having consistent units between the utility bill analysis and the energy savings analysis (e.g., you used CF in the utility bill analysis and MMBtu in the energy savings analysis and therms in the energy model calibration).** **-Define the units….CF for natural gas.** **-Your units are all over the place for natural gas. You use CF, MMBtu, and therms. I would suggest that you pick one and use that one throughout the report.** **-The energy modeling calibration charts are nice but what is CV(RMSE) and NMBE? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	**Observations**
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 2/10	**-The climate data information is very limited. It would be nice to include things like monthly temperatures, humidity, precipitation, wind speed, heating degree days, and cooling degree days.** **-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.**

	-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. For example, I could probably guess that the existing building has 32 watt T-8 lighting and that you would recommend that they install 25 watt T-8 lighting but I have no way of knowing this from the report. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-The cost of air curtains for 10' wide doors is in the range of $2,000 to $3,200, just for the air curtain (i.e., the installation cost is not included). It is stated that there are multiple loading dock doors and therefore the installed cost of $1,200 seems unreasonably low.** **-The convert constant speed pumps to variable speed pumps ECM description is written in a way that makes it seem like the building already has VFDs and focuses on three-way and two-way valves. A better ECM description should be written.** **-ECM #4 has a longer payback than ECM #5 and they are both lighting measures. The prioritization seems to be off here.** **-ECMs #6, 7, and 8 have longer paybacks than ECM #9 and they are all HVAC measures. The prioritization seems to be off here.** **-ECMs #11, 12, and 13 have longer paybacks than ECM #14 and they are all plug loads measures. The prioritization seems to be off here.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.** **-The replace desktop computers with laptops ECM should be done on an incremental cost basis since it has a 76.3 year payback.** **-Consider re-writing this sentence in the install low-wattage T8 lighting measure: The model's initial building lighting power was 57,687 watts, a lighting power density of 1.10 W/ft^2. I don't think this is a sentence.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the number of VFDs and VAV terminals needed for the VAV retrofit are not given. Another example is the setback temperatures are not stated and neither are the hours that the setbacks are implemented. Another example is the number of cogged v-belts is not stated. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., envelope, lighting, HVAC, plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy are mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Put in figure and table numbers.

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

-I would consider adding more headings, especially for the individual ECMs.

- It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **AFA 6202**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment and then later on in the same paragraph there is mention of water efficiency. Is this a water efficiency assessment too?** **-The Executive Summary states that there are 7 energy efficiency, water efficiency, and renewable energy measures that were analyzed. Results for 7 energy efficiency measures are presented. If water efficiency and renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Do they already have water efficient fixtures and this is why no water efficiency measures are recommended? Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy, water, and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that many of the measures have a simple payback period of 1-10 years. 3 of the 7 measures have paybacks in the 0-10 year range. One of the paybacks is 0.3 years and so you should maybe consider wording it as 0-10 years instead of 1-10 years.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?**

Question 2:

Criteria	Observations

Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-Be consistent with the number of significant digits in the energy conservation measures tables.** **-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 5/10	**-You state that electricity, natural gas, and water are presented in the utility data but only electricity and natural gas are presented.** **-Consider presenting water use and cost for the building.** **-Consider presenting 3 years of utility data.** **-Include utility costs in the summary table and not just usage.** **-You go from Sept 2012 to Oct 2011. Maybe put it in as a fiscal year or get all 2012 data.** **-Consider having consistent units between the utility bill analysis and the energy savings analysis (e.g., you used CF in the utility bill analysis and MMBtu in the energy savings analysis and therms in the energy model calibration).** **-Explain why the natural gas use in July is so low compared to June and August.** **-Define the units….ccf and CF for natural gas.** **-Your units are all over the place for natural gas. You use ccf, CF, MMBtu, and therms. I would suggest that you pick one and use that one throughout the report.** **-The energy modeling calibration charts are nice but what is CV(RMSE) and NMBE? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in**

	the energy modeling section and this should just be a utility data section.

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 2/10	**-The climate data information is very limited. It would be nice to include things like monthly temperatures, humidity, precipitation, wind speed, heating degree days, and cooling degree days.** **-There is no description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. For example, I could probably guess that the existing building has 32 watt T-8 lighting and that you would recommend that they install 25 watt T-8 lighting but I have no way of knowing this from the report. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-ECM #4 has a longer payback that ECM #5 and they are both HVAC measures. The prioritization seems to be off here.**

Question 6:

Criteria	Observations

Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.** **-The replace desktop computers with laptops ECM should be done on an incremental cost basis since it has a 223.1 year payback.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the number of VFDs and VAV terminals needed for the VAV retrofit are not given. Another example is the setback temperatures are not stated and neither are the hours that the setbacks are implemented. Another example is the number of cogged v-belts is not stated. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy are mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-Put in figure and table numbers.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

-I would consider adding more headings, especially for the individual ECMs.

-I would consider reformatting the tables to make sure numbers do not wrap in weird ways (ECM #7 table) and to in general make the tables more readable. It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **AFA 4198**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment and then later on in the same paragraph there is mention of water efficiency. Is this a water efficiency assessment too?** **-The Executive Summary states that there are 7 energy efficiency, water efficiency, and renewable energy measures that were analyzed. Results for 7 energy efficiency measures are presented. If water efficiency and renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Do they already have water efficient fixtures and this is why no water efficiency measures are recommended? Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy, water, and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that many of the measures have a simple payback period of 1-10 years. 3 of the 7 measures have paybacks in the 0-10 year range. One of the paybacks is 0.08 years and so you should maybe consider wording it as 0-10 years instead of 1-10 years.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym AFA is used throughout the report but never defined. Define all acronyms the first time you introduce them.** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.**

	-Hewlett-Packard is misspelled in Computer power management measure.

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.** **-From the energy calibration charts, the energy model appears to be calibrated to within 10% of the utility data but it would be good to state the actual percentage in the body of the report.** **It seems suspicious that buildings AFA 4198, AFA 6202, AFA 8116 & 8120, Bliss 20105, and Bliss 20107 all have 17 inch Samsung LCD monitors and Hewlett Packard computers (see Replace desktop computers with laptops measure).** **-The replace desktop with laptops measure states that the total connected load for the desktop computer stations is 150 Watts. The computer power management measure states that the computer has a total connected load of 57 Watts. This is a very big discrepancy.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 5/10	**-You state that electricity, natural gas, and water are presented in the utility data but only electricity and natural gas are presented.** **-You state in the first paragraph of the Energy Use and Utility Data section that the utility use for the campus is given. Is this a campus that we're dealing with or a building?** **-Consider presenting water use and cost for the building.** **-Consider presenting 3 years of utility data.** **-Include utility costs in the summary table and not just usage.**

	-Include annual totals in the utility chart. **-Consider having consistent units between the utility bill analysis and the energy savings analysis (e.g., you used CF in the utility bill analysis and MMBtu in the energy savings analysis and therms in the energy model calibration).** **-Define the units….CF for natural gas.** **-Your units are all over the place for natural gas. You use CF, MMBtu, and therms. I would suggest that you pick one and use that one throughout the report.** **-The energy modeling calibration charts are nice but what is CV(RMSE) and NMBE? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 2/10	**-The climate data information is very limited. It would be nice to include things like monthly temperatures, humidity, precipitation, wind speed, heating degree days, and cooling degree days.** **-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. For example, I could probably guess that the existing building has 32 watt T-8 lighting and that you would recommend that they install 25 watt T-8 lighting but I**

	have no way of knowing this from the report. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.

Other Misc. Comments:

Question 5:

Criteria	**Observations**
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-ECM #6 has a longer payback than ECM #7 and they are both HVAC measures. The prioritization seems to be off here.**

Question 6:

Criteria	**Observations**
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.** **-The replace desktop computers with laptops ECM should be done on an incremental cost basis since it has a 138 year payback.**

Question 7:

Criteria	**Observations**
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	**Observations**

Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the number of VFDs and VAV terminals needed for the VAV retrofit are not given. Another example is the setback temperatures are not stated and neither are the hours that the setbacks are implemented. Another example is the number of cogged v-belts is not stated. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy are mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Put in figure and table numbers.

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

-I would consider adding more headings, especially for the individual ECMs.

- It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

-A general observation that I made reviewing a few of these reports is that the total installed cost is the same for every measure for Buildings 4198 and 6202. This is reasonable for some measures like setbacks, which costs about the same for any building of similar size. The measures that raise concern are measures that include: Low wattage T-8s; Improve Fan Belt Efficiency; CAV to VAV; Constant to variable speed pumping; Replace desktops with laptops; and Computer power management. It is very difficult to understand how the installed costs could be the same in these measures but the energy savings is very different. The other thing that is alarming is that the buildings have a similar building area but the energy use is very different, which implies one building might have bigger HVAC systems or more plug loads or any range of possibilities. It is highly suspicious that the installed costs are the same when you couple that with the fact that no assumptions are given and the energy savings are drastically different in some cases between buildings (e.g., the constant speed to variable speed pumping ECM in Building 4198 saves 858 kWh/yr and costs $5,500 to implement with a 128.8 yr simple payback while Building 6202 saves 4,889 kWh/yr and costs $5,500 to implement with a much shorter simple payback of 21.8 yr).

-Another general observation is that the same ECMs are analyzed in Buildings 4198 and 6202. This raises concern of whether or not all potential ECMs were investigated.

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Fort Bliss 20105**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment and then later on in the same paragraph there is mention of water efficiency. Is this a water efficiency assessment too?** **-The Executive Summary states that there are 7 energy efficiency, water efficiency, and renewable energy measures that were analyzed. Results for 7 energy efficiency measures are presented. If water efficiency and renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Do they already have water efficient fixtures and this is why no water efficiency measures are recommended? Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy, water, and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that many of the measures have a simple payback period of 1-10 years. 3 of the 7 measures have paybacks in the 0-10 year range. One of the paybacks is 0.6 years and so you should maybe consider wording it as 0-10 years instead of 1-10 years.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.** **-Hewlett-Packard is misspelled in Computer power management measure.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.** **-From the energy calibration charts, the energy model appears to be calibrated to within 10% of the utility data but it would be good to state the actual percentage in the body of the report.** **It seems suspicious that buildings AFA 4198, AFA 6202, AFA 8116 & 8120, Bliss 20105, and Bliss 20107 all have 17 inch Samsung LCD monitors and Hewlett Packard computers (see Replace desktop computers with laptops measure).**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 5/10	**-Consider presenting water use and cost for the building.** **-Consider presenting 3 years of utility data.** **-Include utility costs in the summary table and not just usage.** **-Include annual totals in the utility chart.** **-Include natural gas use in the utility chart and include a natural gas energy modeling calibration chart.** **-The energy modeling calibration charts are nice but what is CV(RMSE)? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 2/10	**-Why is there a Google Earth image of the building in the Climate Data section? This seems like it would be more suited to be in the Site Overview section.** **-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. For example, I could probably guess that the existing building has 32 watt T-8 lighting and that you would recommend that they install 25 watt T-8 lighting but I have no way of knowing this from the report. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-The install low-wattage T8 lighting section is written in a way that implies fixtures/ballasts are replaced. If this is the case, the installed cost of $746 is unreasonably low.** **-The implement RTU retrofit kits measure has an unreasonably low installed cost of $17,000 given that it includes CAV to VAV among other things and the building is ~49,000 sq ft (e.g., the CAV to VAV measure for building 4198 costs $70,944 and the building is only ~10,000 sq ft).** **-The re-commission VAV boxes measure is confusing since the previous measure is to convert a CAV to VAV system.** **-ECM #1 has a longer payback than ECM #2 and they are both**

	lighting measures. The prioritization seems to be off here. **-ECM #3 has a longer payback than ECM #4 and they are both HVAC measures. The prioritization seems to be off here.** **-ECM #5 has a longer payback than ECM #6 and they are both plug loads measures. The prioritization seems to be off here.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the number of VFDs and VAV terminals needed for the VAV retrofit are not given. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations

All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy are mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Put in figure and table numbers.

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

- It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Fort Bliss 20107**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment but only energy efficiency measures are presented. Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy efficiency and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that many of the measures have a simple payback period of 1-10 years. 4 of the 10 measures have paybacks in the 0-10 year range. One of the paybacks is 0.4 years and so you should maybe consider wording it as 0-10 years instead of 1-10 years.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.** **-Hewlett-Packard is misspelled in Computer power management measure.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.** **-From the energy calibration charts, the energy model appears to be calibrated to within 10% of the utility data but it would be good to state the actual percentage in the body**

	of the report. **It seems suspicious that buildings AFA 4198, AFA 6202, AFA 8116 & 8120, Bliss 20105, and Bliss 20107 all have 17 inch Samsung LCD monitors and Hewlett Packard computers (see Replace desktop computers with laptops measure).**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 6/10	**-Consider presenting water use and cost for the building.** **-Consider presenting 3 years of utility data.** **-Include utility costs in the summary table and not just usage.** **-Include annual totals in the utility chart.** **-Include natural gas use in the utility chart and include a natural gas energy modeling calibration chart.** **-The energy modeling calibration charts are nice but what is CV(RMSE)? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 3/10	**-Why is there a Google Earth image of the building in the Climate Data section? This seems like it would be more suited to be in the Site Overview section.** **-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the**

	report and make it much more detailed. **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. For example, I could probably guess that the existing building has 32 watt T-8 lighting and that you would recommend that they install 25 watt T-8 lighting but I have no way of knowing this from the report. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-The installed cost for the Re-configure controls for photocells in high bay measure seems unrealistically low.** **-The install low-wattage T8 lighting section is written in a way that implies fixtures/ballasts are replaced. If this is the case, the installed cost of $320 is unreasonably low.** **-The implement RTU retrofit kits measure seems to have an unreasonably low installed cost of $27,000 given that it includes CAV to VAV among other things and the building is ~32,000 sq ft (e.g., the CAV to VAV measure for building 4198 costs $70,944 and the building is only ~10,000 sq ft).** **-The prioritization of the lighting ECMs seems to be incorrect. ECM #1 has a 8.5 year payback, ECM #2 has a 195.1 year payback, ECM #3 has a 0.4 year payback, and ECM #4 has a 12.27 year payback.** **-The prioritization of the plug load ECMs seems to be incorrect. ECM #6 has a 2.64 year payback, ECM #7 has a 48.2 year payback, ECM #8 has a 19.8 year payback, and ECM #9 has a 8.9 year payback.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the number of VFDs and VAV terminals needed for the VAV retrofit are not given. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs, envelope) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy should be addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Put in figure and table numbers.

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

- It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Fort Bliss 20355**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 6/10	**The Executive Summary states that this is an energy efficiency and renewable energy assessment and then later on in the same paragraph there is mention of water efficiency. Is this a water efficiency assessment too?** **-The Executive Summary states that there are 5 energy efficiency, water efficiency, and renewable energy measures that were analyzed. Results for 5 energy efficiency measures are presented. If water efficiency and renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Do they already have water efficient fixtures and this is why no water efficiency measures are recommended? Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy, water, and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that some of the measures have a simple payback period of 1-10 years. You should maybe consider wording it as 0-10 years instead of 1-10 years since the way it is worded now excludes all paybacks that are from 0 to 1 year.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.** **-The following sentence is worded in a way that makes it sound like the lighting systems are overlit and not the mechanical spaces: *The lighting systems in the mechanical***

	***rooms use more power per area than is required and are overlit*. Consider rewording.** **The key card plug load control summary table is missing in the body of the report.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 3/10	**-The calculation assumptions for the energy efficiency measures are not stated. This is a major deficiency. Without knowing the assumptions, it is very difficult to determine if energy savings are overestimated.** **-From the energy calibration charts, the energy model appears to be calibrated to within 10% of the utility data but it would be good to state the actual percentage in the body of the report.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 6/10	**-Consider presenting 3 years of utility data.** **-Include annual totals in the utility chart.** **-Include natural gas use in the utility chart and include a natural gas energy modeling calibration chart.** **-The energy modeling calibration charts are nice but what is CV(RMSE)? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations

Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 2/10	**-Why is there a Google Earth image of the building in the Climate Data section? This seems like it would be more suited to be in the Site Overview section.** **-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description. I should be able to recreate all of the calculations just from the information you provide in the report and I am nowhere close to being able to do this.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 2/10	**-There is no way of knowing if the costs are reasonable because the calculation assumptions are never stated.** **-The prioritization of the lighting ECMs seems to be incorrect. ECM #1 has a 125.0 year payback, ECM #2 has a 8.5 year payback, and ECM #3 has a 11.1 year payback.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 4/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.**

Question 7:

Criteria	Observations

Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 3/10	**-The measures are somewhat described but more detail is needed. In general, the labor time to implement each measure is never stated along with the assumed labor rate.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 4/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs, envelope) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the energy efficiency calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that water efficiency and renewable energy should be addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Put in figure and table numbers.

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

- It might be a good idea to add color or something to make the tables not look so plain.

-The formatting in some of the summary tables has both parenthesis and negative signs for negative numbers. This seems redundant.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Tyndall 1060**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment. Results for 10 energy efficiency measures are presented. If renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy efficiency and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that some of the measures have a simple payback period of 1-10 years. You should maybe consider wording it as 0-10 years instead of 1-10 years since the way it is worded now excludes all paybacks that are from 0 to 1 year.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 8/10	**-In general the assumptions are clearly stated. It would be nice for a little more detail on some of the ECMs. For example, for the replace CRT TVs with LCD TVs, it would be good to know how long the TVs are assumed to be on each day.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 8/10	**-It is unfortunate that you could not obtain monthly electricity data but the monthly natural gas usage and cost is a nice addition.** **-Consider presenting 3 years of utility data.** **-Include annual totals in the utility chart.** **-Figure 3 is a nice addition but consider color coding it similar to the color format of Figure 2.** **-The energy modeling calibration charts are nice but what is CV(RMSE) and NMBE? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section. Just a suggestion.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 3/10	**-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 8/10	**-The costing generally seems reasonable. It would be good to references some of the costs (e.g., cost of the condensing boilers).** **-The prioritization of the HVAC ECMs seems to be incorrect. ECM #2 has a 33.9 year payback, ECM #3 has a 11.1 year payback, ECM #4 has a 40.8 year payback, ECM #5 has a 2.5 year payback, and ECM #6 has a 372.12 year payback.** **-The prioritization of the plug loads ECMs seems to be incorrect. ECM #7 has a 164.0 year payback, and ECM #8 has a 9.3 year payback.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 6/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.** **-The replace refrigerators ECM should be done on an incremental cost basis since it has a 164.0 year payback. You also might consider doing the low wattage T8s, boiler replacement, and CRT TV replacement as an incremental cost.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations

Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 7/10	**-The measures are pretty well described but more detail could be given (e.g., a breakdown of material costs versus labor costs in many measures would be nice to see).**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 7/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs, and DHW) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description is my biggest concern with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-Another major concern is that water efficiency and renewable energy are never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

- It might be a good idea to add color or something to make the tables not look so plain.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Tyndall 662**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 7/10	**-The Executive Summary states that this is an energy efficiency and renewable energy assessment. Results for 10 energy efficiency measures are presented. If renewable energy measures were considered but no opportunities were identified, the report should state that. It would be good if the report stated what the building is already doing well. Is there a PV system already in place and this is why no renewable energy measures are presented? If you state that this is an energy efficiency and renewable energy assessment, you should cover each topic.** **-The Executive Summary states that some of the measures have a simple payback period of 1-10 years. You should maybe consider wording it as 0-10 years instead of 1-10 years since the way it is worded now excludes all paybacks that are from 0 to 1 year.** **-The site overview states that the building is 1 floor but the energy model looks to be a 2-floor building.** **-The building energy model section has a single building in the figure with the graphical representation but the paragraph that describes the energy model says building energy models. Was there more than one building or is this the only model?** **-The acronym HVAC is used throughout the report but never defined. Define all acronyms the first time you introduce them.**

Question 2:

Criteria	Observations

Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 8/10	**-In general the assumptions are clearly stated. It would be nice for a little more detail on some of the ECMs. For example, for the CAV to VAV measure, it would be good to know how many VAV boxes are needed.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 8/10	**-Consider presenting 3 years of utility data.** **-Include annual totals in the utility chart.** **-Figure 3 is a nice addition but consider color coding it similar to the color format of Figure 2.** **-The energy modeling calibration charts are nice but what is CV(RMSE) and NMBE? If you use an acronym, you should define it first and then use it throughout the report. Also, I would put the months along the x-axis in these charts or label the axis. The months are used in the other charts so ultimately this is what I would use to be consistent.** **-The modeled energy usage charts are in the energy use and utility data section. These charts seem like they should be in the energy modeling section and this should just be a utility data section. Just a suggestion.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 3/10	**-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building. It is critical to include a detailed building description.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 8/10	**-The costing generally seems reasonable. It would be good to references some of the costs (e.g., cost of the chiller).** **-The prioritization of the HVAC ECMs seems to be incorrect. ECM #3 has a 41.1 year payback, ECM #4 has a 42.0 year payback, ECM #5 has a 11.1 year payback, and ECM #6 has a 2.9 year payback.** **-The prioritization of the plug loads ECMs seems to be incorrect. ECM #7 has a 10.02 year payback, ECM #8 has a 15.4 year payback, ECM #9 has a 88.2 year payback, and ECM #10 has a 2.9 year payback.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 6/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.** **-The replace desktop computers with laptops ECM should be done on an incremental cost basis since it has an 88.2 year payback. You also might consider doing the low wattage T8s and chiller replacement as an incremental cost.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**Life cycle cost isn't presented.**

Question 8:

Criteria	Observations

Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 7/10	**-The measures are pretty well described but more detail could be given (e.g., number of VAV boxes could be stated).**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 7/10	**-There are a variety of measures listed (e.g., envelope, lighting, HVAC, plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description is my biggest concern with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-Another major concern is that water efficiency and renewable energy are never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-It would be nice if you could add a few photos to the report. You should at least include a photo of the building. Also consider including photos of the various systems (e.g., HVAC, lighting, plug loads, etc.).

-Be consistent with the number of significant digits in the energy conservation measures tables.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

- It might be a good idea to add color or something to make the tables not look so plain.

-The date of the actual assessment was never clearly stated? Was the assessment performed in the winter or summer?

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich – Updated 2014-10-06**

Audit Report Identifier: **Johnson Controls Simuwatt Report for Building 259**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 8/10	**-Spell out Building in the title of the report. Do not use the acronym Bldg.** **-The Executive Summary states that this is an energy efficiency and renewable energy site assessment. No renewable energy measures are addressed in the report and so renewable energy should be removed. Along similar lines, water efficiency was addressed and should be included when describing the type of site assessment.** **-There are a few poorly worded sentences (see track changes in Word document).** **-There are large gaps between some sections for no apparent reason (see track changes).** **-The energy usage overview section states that the building uses 26,493 thousand gallons of water per year. This is most likely a typo.** **-All of the figures in the Appendices need figure numbers and captions.** **-The column headings of the tables are poorly named and the format is inconsistent at times.** **-Sometimes retro-commissioning is spelled as one word and then other times it is spelled as two words.** **-The y-axis isn't labeled in Figure 2.** **-There are extra spaces between words sometimes.** **-The calculations method section says building energy models were created. Was there more than one building or is Building 259 the only model?**

	-The color choices of the energy model image are not intuitive. Why are there so many different colors? **-Several acronyms were used before being defined (e.g., Bldg, ECM, and HVAC). Define all acronyms the first time you introduce them.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 5/10	**-The calculation assumptions for the energy efficiency measures are somewhat described but not nearly enough detail is provided. This is a major deficiency. Without knowing all of the assumptions, it is very difficult to determine if energy savings are overestimated.** **-For measures that reduce the lighting and equipment loads, there should be an increase in heating energy. Why isn't the OpenStudio model showing an increase in heating energy for these types of measures?** **-For the low-wattage T-8s measure, the assumptions should be clearly stated. How many T-8s are being replaced? What is the assumed labor rate of implementing this measure? How many labor hours will it take to implement this measure?** **-For the thermostat setback measure, the assumptions should be clearly stated. What is the current schedule for the heating system? What is the proposed heating system schedule? How many labor hours would it take to install a building automation system and at what labor rate?** **-The energy and water savings for the faucet aerator measure seem to be underestimated. It is stated that the existing 2.5 gpm faucet aerator is being replaced with a 0.5 gpm faucet aerator. It is stated that the savings is estimated at 30% but it seems like this could be as high as 80% savings if you assume the faucet is used for the same amount of time.** **-For the retro-commissioning the steam system measure, the assumptions should be clearly stated. What are the materials and installations costs?**

Question 3:

Criteria	Observations

Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 4/10	**-The utility rates are given and an annual electricity chart is given but there are no usage charts and there are no charts provided for steam. I know you based the steam use on the model but you should at least show that.** **-Table 1 does not add up to the 68,756 kWh/yr or the $7,632 and only 11 months of data are given.** **-Consider presenting 3 years of utility data.** **-State what year of utility data you are presenting. I have no idea if I am looking at 2010 utility data or 2014 utility data.** **-Consider presenting water use and cost for the building.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 5/10	**-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 5/10	**-Some assumptions are given but more detail is needed.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a more detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 3/10	**-Life cycle cost results are not presented in the report. The simuwatt software is capable of performing life cycle costs and these results should be presented in the report.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 5/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. Another example is the setback temperatures are not stated and neither are the hours that the setbacks are implemented. In general, the labor time to implement each measure is never stated along with the assumed labor rate and materials costs are not provided with quantities.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs, and water) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a very detailed building description and not stating all the calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided with more detail. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that renewable energy is mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-Put in figure and table numbers and captions.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

-I would consider reformatting headings, especially for the individual ECMs, so that the report is more readable.

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich – Updated 2014-10-06**

Audit Report Identifier: **Johnson Controls Simuwatt Report for Building 330**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 8/10	**-The Executive Summary states that this is an energy efficiency and renewable energy site assessment. No renewable energy measures are addressed in the report and so renewable energy should be removed.** **-State the agency that this audit is being done for. I assume it is the Naval Support Activity Campus.** **-There are a few poorly worded sentences (see track changes in Word document).** **-There are large gaps between some sections for no apparent reason (see track changes).** **-The energy usage overview section states that the building uses 196,551 thousand gallons of water per year. This is most likely a typo.** **-The figures in the Appendices need figure numbers and captions.** **-The column headings of the tables are poorly named and the format is inconsistent at times.** **-The y-axis isn't labeled in Figure 2.** **-The calculations method section says building energy models were created. Was there more than one building or is Building 330 the only model?** **-The color choices of the energy model image are not intuitive. Why are there so many different colors?** **-Several acronyms were used before being defined (e.g., ECM and HVAC). Define all acronyms the first time you introduce them.**

	-The word "radiator" is misspelled in the constant speed to VSD hot water pumping section.

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 5/10	**-The calculation assumptions for the energy efficiency measures are somewhat described but not nearly enough detail is provided. This is a major deficiency. Without knowing all of the assumptions, it is very difficult to determine if energy savings are overestimated.** **-For measures that reduce the lighting and equipment loads, there should be an increase in heating energy. Why isn't the OpenStudio model showing an increase in heating energy for these types of measures?** **-For the lighting occupancy sensor measure, the assumptions should be clearly stated. How many occupancy sensors are being installed? What is the cost of going to low-wattage T-8s? What is the assumed labor rate of implementing this measure? How many labor hours will it take to implement this measure?** **-For the low-wattage T-8s measure, the assumptions should be clearly stated. How many T-8s are being replaced? What is the assumed labor rate of implementing this measure? How many labor hours will it take to implement this measure?** **-For the variable speed hot water pumping measure, the assumptions should be clearly stated. What are the labor hours associated with implementing this measure and what are the labor rates?** **-For the reduce electric equipment loads by high efficiency UPS measure, the assumptions should be clearly stated. What are the materials costs? How long will the measure take to implement and at what labor rate?**

Question 3:

Criteria	Observations

Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 4/10	**-The utility rates are given and an annual electricity chart is given but there are no usage charts and there are no charts provided for steam.** **-The values in Table 1 do not add up to the stated electricity use and cost of 1,765,107 kWh/yr and $195,943.** **-Consider presenting 3 years of utility data.** **-State what year of utility data you are presenting. I have no idea if I am looking at 2010 utility data or 2014 utility data.** **-Consider presenting water use and cost for the building.** **-There are no charts showing the OpenStudio model calibration. You should include monthly calibration charts for at least electricity given that you did not have steam data.** **-The energy modeling section should contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 5/10	**-There isn't a site overview in the body of the report. The executive summary is typically considered a stand-alone section. Include a site overview section in the body of the report and make it much more detailed.** **-There is no detailed description of the building envelope, lighting systems, plug load equipment, HVAC equipment, schedules, or occupancy. It is very important to state what is in the existing building.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 5/10	**-Some assumptions are given but more detail is needed.**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 5/10	**-Without a detailed description of the existing building conditions, it is very difficult to comment on proper selection of projects.**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 3/10	**-Life cycle cost results are not presented in the report. The simuwatt software is capable of performing life cycle costs and these results should be presented in the report.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 5/10	**-The measures are somewhat described but more detail is needed. For example, the number of T-8 lights that would need to be replaced is not given. In general, the labor time to implement each measure is never stated along with the assumed labor rate and materials costs are not provided with quantities.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 5/10	**-There are a variety of measures listed (e.g., lighting, HVAC, and plugs) but there is no way of knowing if all opportunities have been identified because the existing conditions of the building have not been stated.**

Other Misc. Comments:

-Not having a detailed building description and not stating the calculation assumptions are my two biggest concerns with this report.

-A detailed building description (building envelope, lighting systems, plug load equipment, HVAC, etc.) needs to be provided. Not having a detailed building description is a major deficiency.

-The assumptions for the energy efficiency calculations need to be provided. Without stating the assumptions, you lose a lot of credibility.

-Another major concern is that renewable energy is mentioned in the executive summary but then never addressed.

-A list of what energy efficiency, water efficiency, and renewable energy measures that have already been implemented at the building should be provided.

-The energy modeling section should contain a list or table of energy modeling assumptions.

-Put in figure and table numbers and captions.

-The table of contents lists lighting energy efficiency measures, HVAC efficiency measures, and plug load conservation measures. Consider being consistent in your naming conventions.

-I would consider reformatting headings, especially for the individual ECMs, so that the report is more readable.

Auditing Expert – Scorecard for Energy Audit Report

Participant Name: **Jimmy Salasovich**

Audit Report Identifier: **Third Party Traditional Audit Report for Buildings 259 and 330**

Question 1:

Criteria	Observations
Energy audit is free of mistakes, not including calculation mistakes. Mistakes can include; typos, unit mistakes, duplicate sections, inadequate proof reading, etc. Score: 9/10	**-There are large gaps between some sections for no apparent reason (see track changes).** **-There are a few places where there are 2 spaces between words that are unneeded.** **-Several acronyms were used before being defined (e.g., HVAC). Define all acronyms the first time you introduce them.**

Question 2:

Criteria	Observations
Energy savings are not overestimated. Due to the difficulty of calculation errors, only very apparent calculations should be noted (>50% error). Things such as poor assumptions, neglecting interactive effects, and uncalibrated energy models should be noted. Score: 8/10	**-The calculation assumptions for the energy efficiency measures are described in detail.** **-An energy modeling section should be included.**

Question 3:

Criteria	Observations
Utility bills have been adequately analyzed. Analysis should include benchmarking, monthly summaries, dialogue surrounding anomalies, and some method of "true up" if used to calibrate an energy model. Score: 9/10	**-The utility data section is well written and has a good level of detail.** **-Consider presenting 3 years of utility data.** **-There are no charts showing the eQUEST energy model calibration. You should include monthly calibration charts for at least electricity given that you did not have steam data.** **-An energy modeling section should be included and contain a list or table of energy modeling assumptions.**

Question 4:

Criteria	Observations
Building is described in sufficient detail. Descriptions should include at least 5 systems (construction, equipment, lighting, HVAC, DHW, windows, etc). Score: 10/10	**-Great building description section.**

Other Misc. Comments:

Question 5:

Criteria	Observations
Capital improvement measures have defensible costs attached to them. Also, proper prioritization of measures recommended for implementation. Score: 9/10	**-Cost assumptions are described in good detail and are reasonable.** **-The HVAC measures and lighting measures need to be prioritized (e.g., based on shortest simple payback to longest).**

Question 6:

Criteria	Observations
Proper selection of projects for implementation. This could include projects that payback prior to the end of equipment life, projects that do not have apparent barriers to implementation, and audits that did not miss small opportunities. Score: 9/10	**-The measures that were selected are reasonable and there is a wide range of measures (e.g., HVAC, lighting, equipment, water, and data center measures).**

Question 7:

Criteria	Observations
Projects have life cycle cost economics calculated which will allow projects to be compared side by side. LCC calculations should include operations and maintenance costs, economic parameters listed in the assumptions, and project life. Score: 0/10	**-Life cycle cost isn't presented.**

Question 8:

Criteria	Observations
Improvement scope has been adequately described. The scope should include location/quantity, energy rating of new product, and any special considerations for the improvement. Score: 8/10	**-The measures are described with adequate detail. Consider including more detail on the energy modeling in eQUEST.**

Question 9:

Criteria	Observations
All opportunities have been identified. Projects large and small, high investment as well as low cost/no cost measures have identified. Opportunities should include things across all system types Score: 9/10	**-There are a variety of measures listed (e.g., lighting, HVAC, plugs, water, and data center) and given the detailed building description, a majority of the measures have been identified.**

Other Misc. Comments:

-I added comments to the Word document.

-Overall, this is a nice report. I was a little skeptical when I saw that the two buildings were combined into one report but it was really well done.

-Add a cover page and an executive summary with the measures bundled.

-An energy modeling section should be added to the report. The energy modeling section should contain a list or table of energy modeling assumptions. The energy modeling section should also contain an image of the energy model.