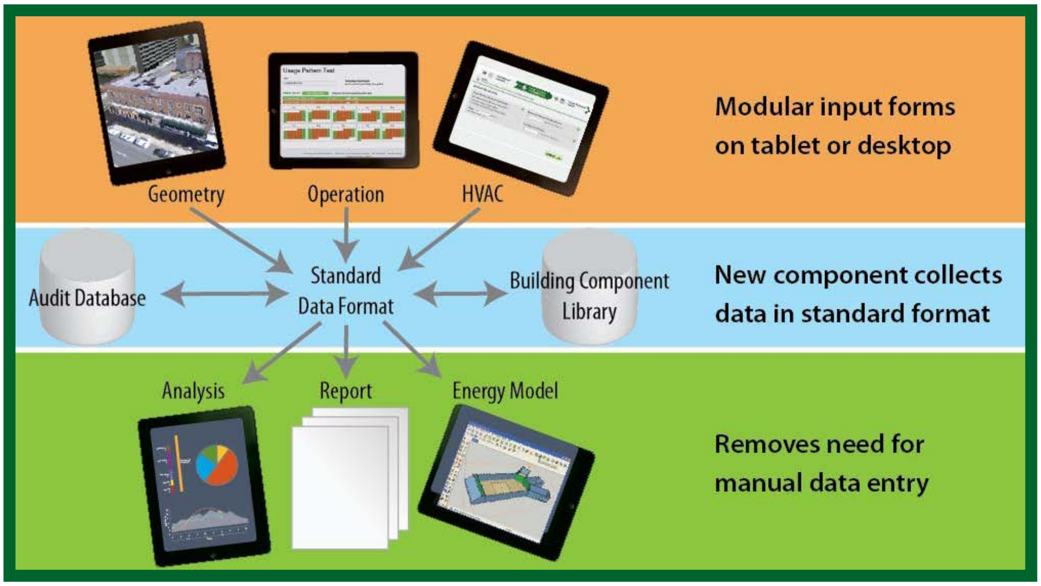
ESTCP
Cost and Performance Report

(EW-201260)



Electronic Auditing Tool with Geometry Capture

January 2015

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ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

COST & PERFORMANCE REPORT
Project: EW-201260

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BCL	building component library
Btu	British thermal unit
CAD	computer-aided design
DHW	domestic hot water
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
ECM	energy conservation measure
EEAP	Energy Efficiency Analysis Program
EISA	Energy Independence and Security Act
ESTCP	Environmental Security Technology Certification Program
ft^2	square feet
HVAC	heating, ventilating, and air conditioning
NAVFAC SE	Naval Facilities Engineering Command Southeast
NREL	National Renewable Energy Laboratory
NSAM	Naval Support Activity, Monterey
USAFA	U.S. Air Force Academy

ACKNOWLEDGEMENTS

The team would like to thank all the installation staff members who assisted with the demonstration audits: Tom Hykes, Jon Caldwell, Andrew Carmean, Scott Sheffield, BJ Tomlinson, Donald Vincent, Dennis Wike, Matt Suess, Doug Taber, and Ken Jenvey. A special thanks goes out to Jim Galvin, Paul Volkman, and the rest of the Environmental Security Technology Certification Program steering committee for guidance and support throughout process.

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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 American Society of Heating, Refrigerating and Air-Conditioning Engineers (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 the 1.9 billion square feet (ft^2) of covered facilities each year. A 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 two 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 semiautomated, 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 as well as used to support model-based control strategies.

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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, as well as 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 (ECM). 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 the 1.9 billion square feet (ft^2) of covered facilities each year (Brown and Dirks, 2001; Lisell, 2011). These are typically level I or II audits. During the course of this project, the U.S. Army Corps of Engineers shared with the NREL team the cost data from the 2012 Energy Efficiency Analysis Program (EEAP) energy auditing initiative (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 on site, uses a standard data format, and can be accessed with a desktop computer. This program is expected to provide high-quality audits at or above level II at a cost lower than the level I and level II audits that DoD is currently performing.

The initial development of simuwatt™ Energy Auditor targeted an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) level III audit. However, feedback from the 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, therefore, the project team focused the simuwatt™ development on level I or II audits. The project team only added features in excess of a level II audit when these features would not increase the audit cost.

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 establishing an energy analysis software in a single tool. Application of the software-guided workflow at the first four 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 four sites are referred to as Phase 1; 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 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. Furthermore, 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.

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 preserves 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.

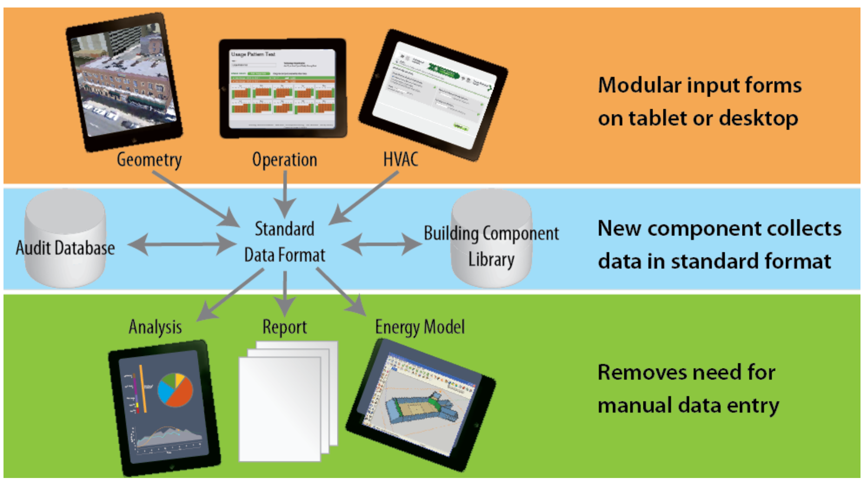

Figure 1. simuwatt™ Energy Auditor concept.

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.

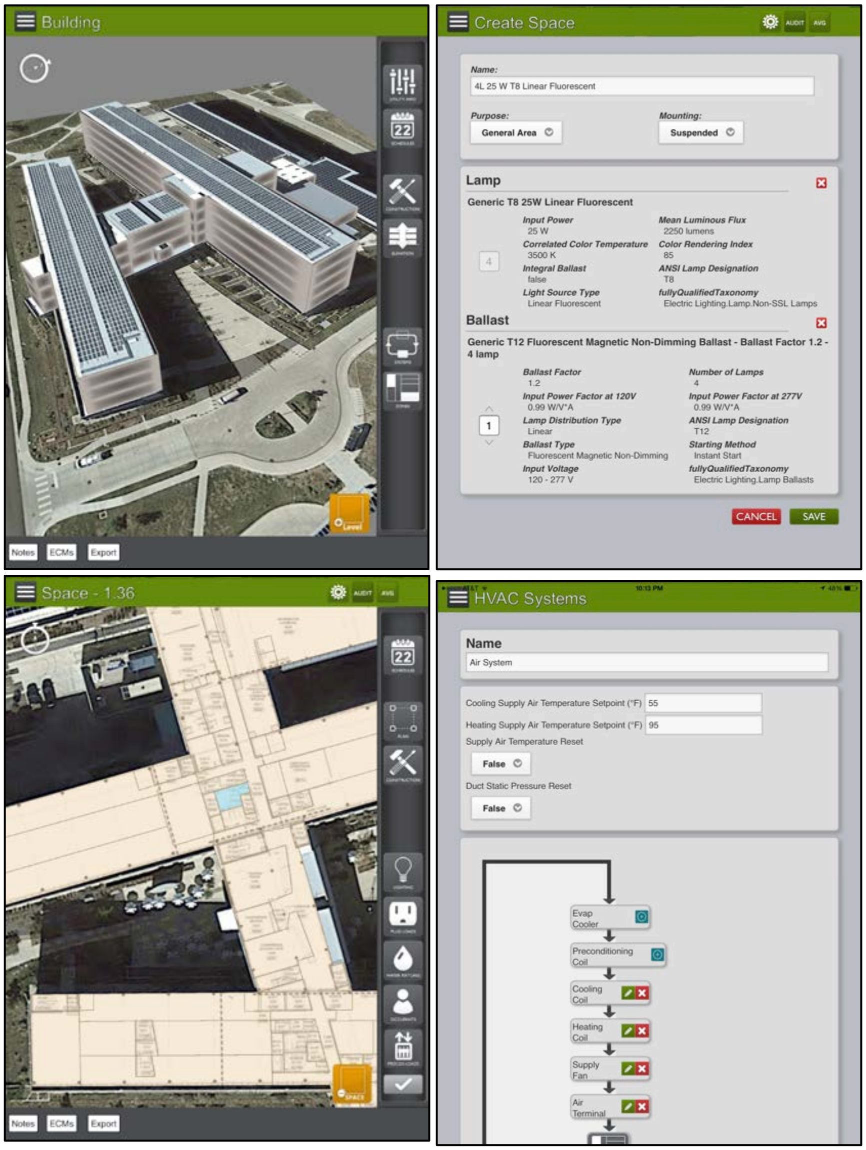

Figure 2. Sample simuwatt™ Energy Auditor screenshots illustrating geometry, lighting, and HVAC system data collection.

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.

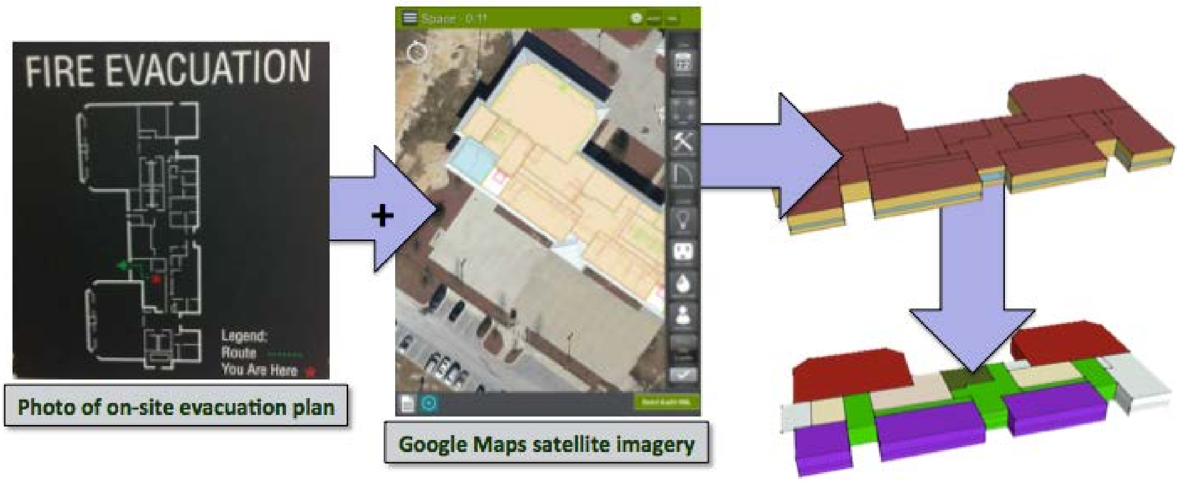

Figure 3. simuwatt™ Energy Auditor geometry capture for Building 10400 at Fort Jackson.

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.

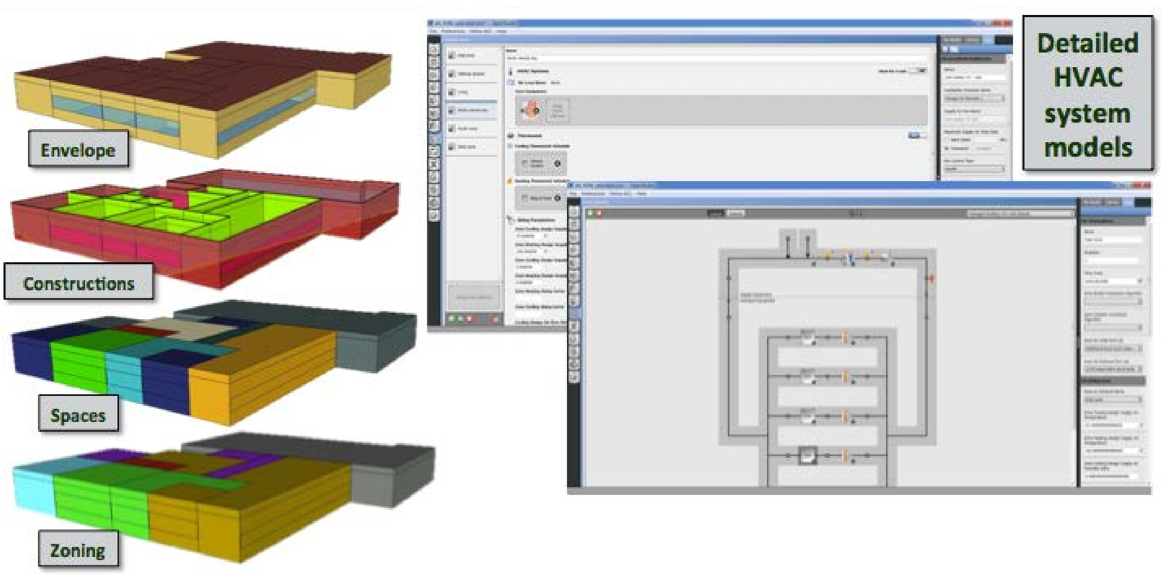

Figure 4. Detailed model contents based on simuwatt™ Energy Auditor input for Building 4198 at Air Force Academy.

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.

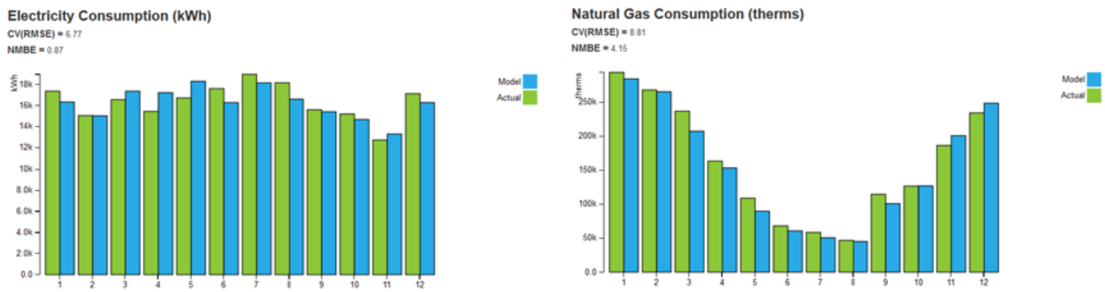

Figure 5. Comparison of measured and modeled electricity and natural gas consumption following calibration for Building 4198 at Air Force Academy.

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.

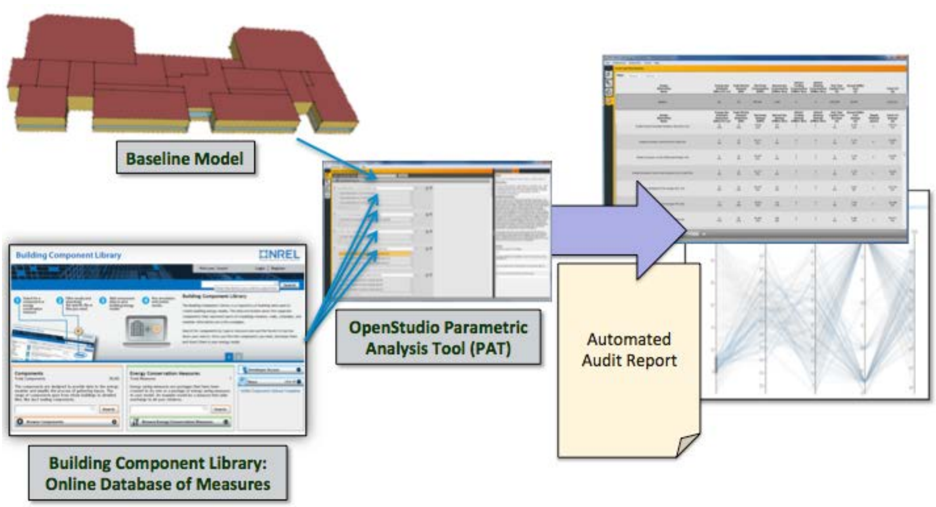

Figure 6. ECMs are applied to the calibrated model for life cycle analysis and reporting.

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. Furthermore, 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.

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 received by DoD 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 4.4 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 was completed for both audit reports. The score sheet (see Appendix D in final report) 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 in full report) 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 1.

Table 1. 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
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

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4.0 TEST DESIGN

This energy audit demonstration project included a total of 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.

4.1 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 3 in Section 5.1), 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/hour 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.

The Phase 1 design called for NREL auditors to perform audits on 11 buildings spanning multiple climate zones at the following locations:

- Air Force – three buildings at the U.S. Air Force Academy (USAFA) 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; and
- Air Force – two buildings at Tyndall Air Force Base (AFB) in Panama City, FL.

The initial demonstration plan also called for three buildings at Naval Facilities Engineering Command Southeast (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 computer-aided design (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. This precluded the Fort Jackson buildings from being included in the analysis of the results later in the report.

4.2 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 in order to represent the outcome as if simuwatt™ Energy Auditor were used by those 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 7 (in Section 5.2).

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).

4.3 BASELINE CHARACTERIZATION

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 2.

Table 2. 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/ ft^2 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.

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5.0 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.

5.1 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 is 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.

U.S. 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 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 5 and 6 (in Section 5.1).

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 incidents. 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 that 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 would 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 3, 5, and 6.

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 reviewed the hands-on field trial of simuwatt™. 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 3. 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. Because analysis and report results could not be completed for the Fort Jackson site, buildings at that site are not included in Table 3.

Table 3. Phase 1 audit time and costs.

	Site 1			**Site 2**			**Site 3**	
Task	**USAFA 8116 /8120**	**USAFA 6202**	**USAFA 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

Table 3. Phase 1 audit time and costs (continued).

Task	Site 1			Site 2			Site 3	
	USAFA 8116 /8120	USAFA 6202	USAFA 4198	Fort Bliss 20105	Fort Bliss 20107	Fort Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662
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. Currently, 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 3. Based on experiences during the Phase 1 audits, times to complete each of the tasks in future years were also estimated (Table 4) assuming a previous simuwatt™ audit was conducted. The time to complete the site visit was reduced considerably, assuming that the building's geometry and basic inventory have not changed substantially, with only minor updates required. Multiple buildings are assumed to stand on each site to audit; therefore, 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. Consequently, 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 4. 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. This feedback is summarized in Table 5. For each item, the possible score was 10/10. The actual review forms are attached in Appendix D 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 5.

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 not involved 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. The reviews are summarized in Table 6. For each item, the possible score was 10/10. The actual review forms are attached in Appendix D of the final report.

5.2 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), which served as the primary demonstration 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, therefore, was 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; and

- Provide web browser, Microsoft Windows, and Android tablet support for the application.

Table 5. Phase 1 audit report clarity review by DoD site personnel.

Criteria (out of 10)	Site 1			Site 2			Site 3		Average
	USAFA 8116 /8120	USAFA 6202	USAFA 4198	Fort Bliss 20105	Fort Bliss 20107	Fort Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662	
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 that 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 6. Phase 1 technical audit comprehensiveness review by auditing expert.

Criteria (out of 10)	Site 1			Site 2			Site 3		Average
	USAFA 8116 /8120	USAFA 6202	USAFA 4198	Fort Bliss 20105	Fort Bliss 20107	Fort Bliss 20355	Tyndall AFB 1060	Tyndall AFB 662	
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 are 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 five 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. Life cycle cost 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
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
DHW = domestic hot water

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; 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. The review is summarized in Tables 7 through 9. For each item, the possible score was 10/10. The actual review forms are attached in Appendix D of the full report.

Table 7. Phase 2 audit time and costs.

Task	Traditional Team NSAM 259 and 330	simuwatt™ Team 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 8. 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 that 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 9. 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 five 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. Life cycle cost 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, and 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

6.0 COST ASSESSMENT

6.1 COST MODEL

Cost to perform an energy audit was one of the key performance metrics of this demonstration. As described in detail in Section 5, the average cost of an audit using simuwatt™ was $0.11/ft^2$. Historical DoD audit costs for a comparable level audit were $0.20/ft2. As described in Table 4, 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, as well as 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.

6.2 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 10 below shows the potential direct energy audit cost savings over 25 years.

Table 10. 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
Year 4 Recurring Audit	$0.20	$380	$0.05	$95	$285
Year 8 Recurring Audit	$0.20	$380	$0.05	$95	$285
Year 12 Recurring Audit	$0.20	$380	$0.05	$95	$285
Year 16 Recurring Audit	$0.20	$380	$0.05	$95	$285
Year 20 Recurring Audit	$0.20	$380	$0.05	$95	$285
Year 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 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 11 shows the potential annual energy and energy cost savings that could result from energy audits DoD-wide.

Table 11. 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

Btu = British thermal unit

Using the $399/auditor-month license fee estimate given by concept3D, Table 12 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. This also does not factor in the implementation issues identified in Section 7, which may increase costs. This estimate should only be interpreted as the starting point for a discussion.

Table 12. Estimate of annual software cost to cover DoD portfolio.

EISA 2007 Covered Facilities	1,900,000,000	ft^2
Audit 25%/year	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, 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.

7.0 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.

7.1 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. Furthermore, 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.

7.2 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.

7.3 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; 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 DoD 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.

8.0 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. It was also created to 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 four DoD sites, and a third-party energy auditor with minimal training used it successfully in two 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 (four sites, 11 buildings) 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 (one site, two buildings) 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

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APPENDIX B

AUDIT REPORT SUMMARY

A total of eight 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 the full project report.

The table below shows the bundled savings from all ECMs identified for each of the demonstration sites. Fort 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); plug loads were 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

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