FINAL REPORT

Rapid Building Assessment Project

ESTCP Project EW-201261

MAY 2014

Swapnil Shah
FirstFuel Software

Distribution Statement A

This document has been cleared for public release

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*
09-05-2014

2. REPORT TYPE
Final Report

3. DATES COVERED *(From - To)*
October 2012-May 2014

4. TITLE AND SUBTITLE
Rapid Building Assessment Project

5a. CONTRACT NUMBER
W912HA-12-C-0039

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Shah, Swapnil

5d. PROJECT NUMBER
EW-201261

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
FirstFuel Software
420 Bedford Street
Suite 200
Lexington, MA 02420

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Rapid Building Assessment demonstration project focused on determining whether FirstFuel's end-to-end solution can enable the DoD to scale energy efficiency initiatives across its large and varied building portfolio. FirstFuel analytics were applied to 100 Department of Defense (DoD) buildings in total across five different DoD specific categories ofbuilding types and 11 locations. The successful achievement of the performance objectives suggest that the FirstFuel RBA can present significant advantages for the DoD over traditional approaches to onsite energy audits and continuous performance monitoring. Traditional audits are too costly and time-consuming to deliver savings at scale, and yield reports that are often difficult to use for efficiency prioritization and planning. In contrast, FirstFuel's remote audits can be accomplished at a fraction of the cost and time, without a site visit, and at minimal complication to the site managers, while simultaneously yielding performance analysis results similar to ASHRAE Level II onsite audits (the comparison onsite used in this demonstration project). In addition, the FirstFuel remote analytics solution was found to be compatible with approximately 90% of the DoD's building portfolio.

15. SUBJECT TERMS
Rapid Building Assessment, Remote Energy Assessment, FirstFuel, Energy Audits

16. SECURITY CLASSIFICATION OF:	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
			Swapnil Shah

Table of Contents

Executive Summary 1
1.0 Introduction 5
1.1 Background 5
1.2 Objective of the Demonstration 6
1.3 Regulatory Drivers 7
2.0 Technology Description 9
2.1 Technology Overview 9
2.2 Technology Development 19
2.3 Advantages and Limitations of the Technology 21
3.0 Performance Objectives 24
3.1 Performance Objectives 24
3.2 Performance Objectives Descriptions 26
4.0 Facility/Site Description 29
4.1 Facility/Site Location and Operations 29
4.2 Facility Site Conditions 31
5.0 Test Design 32
5.1 Conceptual Test Design 32
5.2 Baseline Characterization 35
5.3 Design and Layout of System Components 36
5.4 Operational Testing 39
5.5 Sampling Protocol 39
5.6 Sampling Results 41
6.0 Performance Assessment 52
7.0 Cost Assessment 58
7.1 Cost Model 59
7.2 Cost Drivers 59
7.3 Cost Analysis and Comparison 60
8.0 Implementation Issues 61

List of Tables

Table 1: RBA Demonstration Building Types 5
Table 2: Performance Objectives 24
Table 3: Host Installations and Building Count 30
Table 4: Average Hours to Complete One Building Audit 41
Table 5: ECMs identified in FirstFuel RBAs and ASHRAE Level II audits 43
Table 6: ECM Count in FirstFuel RBA and ASHRAE Level II audits by Building Type 44
Table 7: ECM Count - Table 54
Table 8: Summary of model performance metrics 56
Table 9: Cost Model 59

List of Figures

Figure 1: FirstFuel's Inverse Modeling Remote Audit Process 10
Figure 2: Sample Building Summary Page, Part 1 12
Figure 3: Sample Building Summary Page, Part 2 13
Figure 4: Sample Whole Building Analysis, Part 1 13
Figure 5: Sample Whole Building Analysis, Part 2 14
Figure 6: Sample End Use Analysis 15
Figure 7: Sample Recommendations 17
Figure 8: Portfolio View 18
Figure 9: Continuous Performance Monitoring Screenshot 19
Figure 10: Chronological Summary of FirstFuel's technology deployment 20
Figure 11: Map of Host DoD Installations 29
Figure 12: DoD FirstFuel RBA Portal Login Screen 36
Figure 13: Sample FirstFuel Portal "Home" Tab 37
Figure 14: Sample FirstFuel RBA "Portfolio Dashboard" tab 38
Figure 15: Sample FirstFuel RBA "Building Dashboard" tab 38
Figure 16: Energy Site manager time for FirstFuel RBA Time vs ASHRAE Level II Audit Time (in hours) for one building 42
Figure 17: Type 1 Average Annual End Use (kWh/sf) 44
Figure 18: Type 2 Average Annual End Use (kWh/sf) 45
Figure 19: Type 3 Average Annual End Use (kWh/sf) 45
Figure 20: Type 4 Average Annual End Use (kWh/sf) 46
Figure 21: Type 5 Average Annual End Use (kWh/sf) 46
Figure 22: Average kWh Savings Per Building 47
Figure 23: Average kWh Savings per Gross Square Footage (GSF) 48
Figure 24: Top 3 ECMs--Type 1 buildings 49
Figure 25: Top 4 ECMs--Type 2 Buildings 49
Figure 26: Top 3 ECMs--Type 3 Buildings 50

Figure 27: Top 3 ECMs--Type 4 Buildings 50
Figure 28: Top 3 ECMs--Type 5 Buildings 51

Appendices

Appendix A: Points of Contact

Appendix B: Timeline of Activities

Appendix C: Building Information Questionnaire

Appendix D: Overview of Monitoring and Verification Methodologies: Options A, B, C and D

Appendix E: RBA Results

Appendix F: Meter Data Communication and Storage Best Practices

List of Acronyms

AMI: Advanced Metering Infrastructure

ASHRAE: American Society of Heating Refrigeration and Air Conditioning Engineers

DoD: Department of Defense

ECM: Energy Conservation Measures

ESCO: Energy Service Company

ESTCP: Environmental Security Technology Certification Program

FTP: File Transfer Protocol

GIS: Geographical Information Systems

GSA: General Services Administration

IPMVP: International Performance Measurement and Verification Protocol

JBLM: Joint Base Lewis-McChord

JCI: Johnson Controls Energy Services Group

kBtu: Thousand British Thermal Units

kWh: Kilowatt Hour

M&V: Monitoring and Verification

NAVFAC EXWC: Naval Facilities Engineering Command and Expeditionary Warfare Center

NOAA: National Oceanic and Atmospheric Administration

PGE: Pacific Gas & Electric

RBA: Remote Building Analytics

REST: Representational state transfer

ROI: Return on Investment

SasS: Software-as-a-Service

Acknowledgements

The work in this report was performed under the project EW-201261, administered by ESTCP (Environmental Security Technology Certification Program) technology program of the Department of Defense. The FirstFuel team and would like to thank and gratefully acknowledge the financial support and technical guidance provided by the ESTCP Office, led by Dr. Jim Galvin.

The team is also thankful for the support provided by the following site partners:

Name: Energy Program Coordinator, Sakhawat Amin
Site Affiliated: JBLM

Name: Chief/Environmental Division, Nathan Edwards
Site Affiliated: Tobyhanna Army Depot

Name: Resource Efficiency Manager, Craig Volz
Site Affiliated: Oregon National Guard

Name: Mark Fincher
Site Affiliated: Fort Benning

Name: Nicholas Stecky, Gricel Robles
Site Affiliated: Picatinny Arsenal

Name: NAVFAC EXWC, Vern Novstrup
Site Affiliated: Port Hueneme

Name: Installation Energy Manager, Ray Smalling
Site Affiliated: Naval Station Everett

Name: Garrison Energy Manager, Mohammed Ikram
Site Affiliated: Detroit Arsenal

Name: DPW OMD Resource Efficiency Manager, Dennis Wike
Site Affiliated: Fort Bliss

Name: NDW N6 (CIO), Jeffrey Johnson, Dana Sevier
Site Affiliated: Naval District Washington

Executive Summary

Background

In recent years, the Department of Defense (DoD) has launched several initiatives to reduce its fossil fuel use by improving energy efficiency (i.e. reducing wasted energy). Reducing the amount of energy used and wasted across the DoD's portfolio of buildings is a significant opportunity and key to reducing emissions and energy consumption across the U.S. However, identifying and profiling the energy savings potential of individual buildings presents significant challenges for the DoD's large and diverse building portfolio.

FirstFuel Software is a Boston-based commercial energy analytics company that provides a breakthrough solution with the potential to address this large-scale challenge. The company's Remote Building Analytics ("RBA") platform is an analytics-driven energy information service designed to help large government agencies and utilities rapidly and cost-effectively target, prioritize, quantify, enable and track energy savings in heterogeneous building portfolios, at scale. The platform utilizes advanced, proprietary statistical methods and data mining techniques to deliver an end-to-end efficiency solution that is being deployed at over 15 government agencies and utilities across North America and Europe.

Requiring only hourly utility electric meter data, the building type, and address, FirstFuel produces a remote set of building-specific performance insights and customized recommendations at an end-use consumption level that can be utilized by agencies such as the DoD at the management, site, and/or building level to identify opportunities, plan and execute efficiency projects. In addition, FirstFuel's analytics can track the efficiency measures enacted by building managers/operators and quantify their effectiveness over time. All of these services are performed remotely, and require no onsite visits or additional metering device installations. FirstFuel analytics have been independently and repeatedly validated by third-parties across many dimensions of performance (e.g. accuracy, speed, cost, scale, impact potential). The FirstFuel methodology produces completely unique analysis on each building and each ECM is verified based on actual building performance. These results are much more comparable to onsite audits than to automated energy analysis solutions that use 'like-building' analysis, benchmarking and/or simulation models to try to infer how a building might be performing.

Furthermore, the results from each building can be shown in an aggregated view that provides detailed energy consumption, savings recommendations, and efficiency performance tracking views across a building portfolio. This aggregated 'roll-up' view of the results from remote audits and continuous performance monitoring enables the ongoing management of commercial energy efficiency. No other company offers all of these proven services on a seamless, integrated Software-as-a-Service (SaaS) platform.

Demonstration Project:

The Rapid Building Assessment demonstration project focused on determining whether FirstFuel's end-to-end solution can enable the DoD to scale energy efficiency initiatives across its large and varied building portfolio. FirstFuel analytics were applied to 100 Department of Defense (DoD) buildings in total across five different DoD specific building types. Specifically, FirstFuel worked with 11 installations across the country to conduct the performance analysis.

Performance Objectives and Results:

The FirstFuel demonstration project was designed around three specific Performance Objectives: (1) Cost, (2) Scalability, and (3) Accuracy. To support the DoD's evaluation of these primary Performance Objectives, a third-party engineering firm, The Cadmus Group, conducted ASHRAE Level II on-site audits across 16 of the DoD buildings.

The table below provides details of the performance objectives and the results of FirstFuel's Remote Building Analytics platform (Hereafter 'RBA').

Performance Objective	Success Criteria	Results
FirstFuel RBA Cost	• The average cost for the FirstFuel RBAs performed on the 16 ASHRAE Level II audited buildings (Types 1-5) will be less than or equal to $3,000/building, or $0.12/sq. ft.(whichever is higher)	• FirstFuel met this cost performance objective through its analysis
FirstFuel RBA Scalability	• RBAs for Type 1 buildings completed in 25% of the time of Cadmus ASHRAE Level II Audits. • RBAs for Type 2-5 completed in 50% of the time of Cadmus ASHRAE Level II Audits.	• FirstFuel exceeded these criteria

Performance Objective	Success Criteria	Results
FirstFuel RBA Accuracy	• RBA finds 80% of the ECMs found in Building Type 1 ASHRAE Level II audits. • RBA finds 60% of the ECMs found in Building Types 2-5 • RBA finds recommendations NOT found in Type 1 Building ASHRAE Level II onsite audits. • FirstFuel's continuous performance monitoring satisfies ASHRAE Guideline 14	• RBA found 61% of the ECMs found in Building Type 1 ASHRAE Level II audits (1), which accounted for 16% more savings than the savings found in the same onsite audits.[1] • RBA found 65% of the ECMs found in Building Type 2-5 ASHRAE Level II audits, which accounted for 37% more savings than the savings found in the same onsite audits.[2] • RBA found 18 recommendations NOT found in Type 1 building ASHRAE Level II onsite audits • FirstFuel's continuous performance monitoring satisfied ASHRAE Guideline 14.
Customer Satisfaction	• 75% overall customer satisfaction compared to the Cadmus ASHRAE Level II audits	• Greater than 75% customer satisfaction compared to the ASHRAE Level II audits for 1 of the 2 sites visited[3]

The results of this project and achievement of the performance objectives suggest that the FirstFuel RBA can present significant advantages over the DoD's traditional approach to onsite energy audits and continuous performance monitoring. For example, traditional walk-through audits run between $5,000-$10,000, and take several weeks or more to complete, including multiple days on-site. These traditional audits are too costly and time-consuming to deliver savings at scale, and yield large reports that are often difficult to use as an efficiency prioritization and planning tool. In contrast, FirstFuel's remote audits can be accomplished in hours, regardless of size or type of building and at a fraction of the cost, without a site visit, while simultaneously yielding performance analysis results similar to ASHRAE Level II onsite audits (the comparison onsite used in this demonstration project). In addition, the FirstFuel remote analytics solution was found to be compatible with approximately 90% of the DoD's building portfolio.

More specifically, the FirstFuel ESTCP demonstration suggests that DoD will find significant value in using FirstFuel's tool to launch, manage and track major energy efficiency initiatives across its vast portfolio of buildings, primarily through:

[1] The ASHRAE LII onsite audits identified 421,909 kWh of savings in the 6 Type 1 buildings. FirstFuel RBA identified 491,196 kWh of savings in the same buildings.
[2] The ASHRAE LII onsite audits identified 289,561 kWh of savings in the 6 Type 2-5 buildings. FirstFuel RBA identified 396,220 kWh of savings in the same buildings.
[3] Survey was not completed by the second of the two sites visited

- Immediately implementing low/no cost operational savings uniquely identified through the FirstFuel platform
- Significantly reducing the time and cost relative to traditional on-site audits across a range of building types specific to the Department of Defense.
- Providing DOD on-site energy managers with an insightful, intuitive tool to focus and refine their energy savings efforts, compare their buildings to others within the portfolio, and share insights with others that drive more effective energy management
- Tracking energy performance and savings over time to track progress of long-term efforts, aid reporting, validate the effectiveness of energy conservation projects, and maintain the persistence of savings.

In addition to the advantages listed above, the FirstFuel customer delivery model suggests an advantage in overall effectiveness. By providing the use of an intuitive online web portal, interactive Efficiency Planning Webinars with FirstFuel energy engineering experts, and dynamic performance monitoring/tracking features, FirstFuel's integrated approach enables a deeper level of continuous insight and engagement than a static audit report and monitoring tools which lack features, ongoing engagement and a human element to keep users interested and active. Early results suggest that this new approach to efficiency engagement will increase site managers' ability and propensity to act on recommended energy conservation measures.

Because FirstFuel does not require any onsite devices or visits, the platform can be deployed rapidly and with no further installation cost, to all DoD buildings with interval meters. Given the widespread deployment of such meters throughout both the Army and Navy branches, with extensive work underway for almost complete coverage of Advanced Metering Infrastructure (AMI) in all service branches, the FirstFuel RBA platform provides the optimal combination of effectiveness and leverage of existing or planned infrastructure investments.

1.0 Introduction

Energy efficiency is the "first fuel" the Department of Defense (DoD) is addressing, and FirstFuel's demonstration was designed to test the validity of its approach to remote building assessments while also helping the DoD to meet its energy efficiency goals.

1.1 Background

In recent years, the DoD has launched several initiatives to reduce its fossil fuel use by improving energy efficiency (i.e. reducing wasted energy).[4] Reducing the amount of energy used and wasted across the DoD's portfolio of buildings is a significant opportunity and key to reducing emissions and energy consumption across the U.S. However, identifying and profiling the energy efficiency savings potential of individual buildings presents significant challenges for a building portfolio as large and diverse as that of the DoD.

Over the course of the 16 month project, FirstFuel worked with 11 DoD installations to perform remote audits on 100 buildings utilizing FirstFuel's Remote Building Analytics (RBA) platform. In order to evaluate the technology on a range of DoD specific buildings, FirstFuel divided the 100 buildings assessed into five building type categories. The first type consisted of 30 "Type "1 buildings, which were building types that FirstFuel's RBA was already optimized to analyze—company headquarters and administrative buildings. Seventy (70) buildings made up the four other buildings types that are specific to the DoD.

The table below explains the breakdown of building category by "Type" for the purposes of this demonstration:

	Building Type	**Number of RBAs**
1	Offices, municipal, schools, training facilities	30
2	Barracks, dining facilities, mess halls	31
3	Warehouses, Shipping Centers, Commissaries	18
4	Rec centers, auditoriums, chapels	12
5	Motor pools, hangars, garages--facilities with lighter process and specific equipment loads	9
	Total Sites	**100**

Table 1: RBA Demonstration Building Types

[4] "Fact Sheet: DoD's Energy Efficiency and Renewable Energy Initiatives. Environmental and Energy Study Institute. http://www.eesi.org/dod_eere_factsheet_072711

FirstFuel performed R&D to customize the RBA software in order to provided end-use analysis for buildings of this type.

The experience and outcome of this ESTCP demonstration suggests that DoD will find significant value in using FirstFuel's tool to track the energy performance of its vast portfolio of buildings, primarily through:

- Immediately implementing low to no cost operational savings uniquely identified through the platform.
- Reducing the time and cost relative to traditional onsite audits across a range of building types specific to the Department of Defense.
- Using the platform for onsite energy managers to focus and refine their energy savings efforts, compare their buildings to others within the portfolio, and share insights with others to more effectively manage energy consumption.
- Use of the platform to track performance and savings over time which both helps with reporting efforts and validates the effectiveness of energy conservation measures.

1.2 Objective of the Demonstration

FirstFuel's demonstration examined how the DoD could measure the impact of energy audits across hundreds of buildings. In order to test this question, FirstFuel performed remote building assessments across 100 DoD buildings. To conduct each remote audit, FirstFuel utilized four pieces of information: 1 year of historical electric interval consumption data, weather data from the building's closest weather station, GIS information from the building's location, and a building information survey completed by DoD site energy managers. The weather and GIS data were sourced by FirstFuel, and not provided by the DoD.

The project's objectives were designed around measuring the time, cost, and accuracy of FirstFuel's remote audits, as compared to ASHRAE Level II onsite audits. FirstFuel demonstrated the that remote audits could be done at one third the cost when compared to the onsite approach, and three to five times faster versus ASHRAE Level II onsite audits. While the ECMs between the two approaches did not match up to the expected success criteria of 80% in the Type 1 buildings, the FirstFuel approach did find 16% more savings compared to the onsite audits in these buildings, suggesting that number of ECMs as a metric may be a less important than the savings found. For example, ECMs recommended via onsite audits may not be uncovered by the FirstFuel RBA (or vice versa) because omissions may reflect a different set of energy management objectives or scope. By their very nature, onsite audits are more likely to capture smaller value capital improvements, because they result from visual confirmation,

whereas analytics based approaches, like FirstFuel's, are likely to capture larger value operational ECMs.

1.3 Regulatory Drivers

FirstFuel's ESTCP Rapid Building Assessment Proposal addresses the following drivers:

Driver		Explanation
Energy Policy Act, 2005, Section 103	Mandate for using advanced meters to reduce electricity in federal buildings by October, 2012	FirstFuel's software platform provides a straightforward way for the DoD to use the data generated from the advanced meters to identify and encourage reductions in electricity consumption.
Executive Order (EO) 13123	"Greening the Government through Efficient Energy Management"	This executive order set energy management goals for the Federal Government. The inefficient use of energy wastes defense funds. The success of FirstFuel's project offers the DoD a way to identify areas to reduce energy waste in a manner that is cost effective and timely.
Strategic Sustainability Performance Plan, 2011; Pg I-14	"decisions made at the facility level are not always in the best long term interests of the Department as a whole, including its sustainability objectives. DoD needs to ensure that personnel working on site-level projects bring a broad perspective to the decision-making process that considers objectives of the Department beyond those of the site alone."	The project may contribute to the driver by giving energy site managers insight into the energy consumption of different DoD buildings, thereby allowing DoD to make strategic decisions in their entire building portfolio and comparing the performance of buildings within the DoD.

Driver		Explanation
Memorandum of Understanding between U.S. Department and Energy and U.S. Department of Defense Concerning Cooperation in Strategic Partnership to Enhance Energy Security; 2010; Section IV. Activities	"Expand cooperation related to energy management practice and knowledge exchange, working to ensure that Federal Leadership is in compliance with all statutory and Executive Order goals and objectives…Encourage the sharing of data, including, but not limited to, data on internal energy management projects and technical assistance projects."	The project may contribute to the support of the MOU between the DOE and the DoD as the RBAs can be made available for viewing through the online portal. Leaders from both the DoD and DOE may use the insights gained from the building assessments and subsequent energy consumption monitoring to learn about how the certain DoD buildings consume energy and use the portfolio view to identify the biggest opportunities for energy savings.

2.0 Technology Description

2.1 Technology Overview

Core Technology

FirstFuel's Remote Building Analytics (RBA) platform combines interval meter data with hourly weather and climate data and geographical information systems (GIS) mapped building characteristics to provide a consistent, reliable view of how energy is used inside a building. The platform utilizes advanced, proprietary statistical methods and data mining techniques based on FirstFuel's patent pending technology. The core technology utilizes a unique approach based on "inverse modeling," which examines each building and data set independently. The technology infers the building's energy use utilizing only its own unique consumption patterns and signatures. The platform infers the building's energy use breakdown without the use of outside databases/benchmarks of "like" buildings, traditional energy simulation models (e.g. eQuest, DOE-2, EnergyPlus), or models that compare a building's interval usage data to a simulated model of the building operating at 'optimal performance'. This enables FirstFuel platform users to view energy analysis and recommendations that each have been individually verified based on actual building performance, as opposed to automated content based on how their building should be performing. The output from FirstFuel's inverse model is a highly accurate breakdown of the actual hour-by-hour consumption across end-uses for the building. This inverse-modeling approach enables a level of simultaneous individual building analysis customization, scale across portfolios, and accuracy of results that is unparalleled in the industry.

The only inputs that the FirstFuel RBA platform requires is 1 year of historical electrical interval data (5/15/30/60 minute building electric consumption data) and the building address. The data can be delivered to FirstFuel seamlessly through a variety of data transfer methods, including encrypted .csv files uploaded to our secure File Transfer Protocol (ftp) server, using Representational state transfer (REST) services, and through Green Button Connect. The electric interval data must represent only the building being analyzed. For example, buildings that are served by a central heating/cooling plant cannot be analyzed unless the building's electric consumption is measured on an interval basis. From there, FirstFuel pulls in additional information about the building including (a) Hourly local weather data, (b) GIS building data, and (c) Additional building data through semantic searches that are publicly available including square feet, occupancy type, etc.

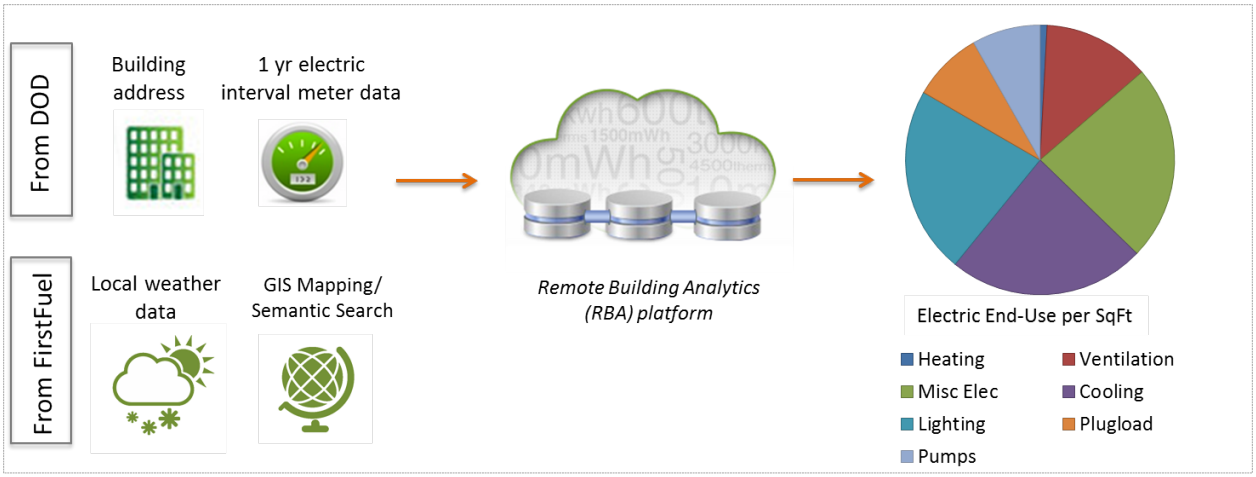


Figure 1: FirstFuel's Inverse Modeling Remote Audit Process

The analytics output includes building-specific performance benchmarks, base lining, load disaggregation, and customized recommendations for actions at the end-user level, as well as predictive projections of each building's potential for energy efficiency. FirstFuel's technology is particularly adept at detecting and detailing operational savings opportunities, and instructing energy administrators or building-level managers regarding how best to implement changes and track performance. When monthly thermal data (natural gas, fuel oil, etc.) is available for the building, FirstFuel is able to perform an analysis of the building's thermal use. The analysis includes a breakdown of the weather related and non-weather related thermal fuel consumption, and energy conservation measures related to thermal energy reductions.

To provide results more consistent with those of ASHRAE Level II equivalent audits, FirstFuel asked the energy site managers to complete a short building information survey for each building analyzed. These surveys provide asset-related information needed for FirstFuel building engineers to make implementation more refined cost & ROI estimates associated with the Energy Conservation Measures (ECMs). While a large majority of the remote energy audit process is automated through analytics, FirstFuel's team of in-house energy engineers verify each ECM to ensure the energy savings recommendations are relevant, customized, and actionable.

Through this approach, FirstFuel creates a level of detail about each building that was previously unavailable without going onsite, including end-use consumption profiles by hour, detailed building operational schedules, setpoints, equipment sequences, ventilation configurations and more. FirstFuel is the only fully remote commercial energy analytics solution that has been independently and repeatedly validated by 3rd parties across many dimensions of performance. FirstFuel's successful technical validations include a Scaled Field Placement completed by PG&E in 2013 as an Emerging Technologies Coordinating Council initiative, the Fraunhofer

Institute (a U.S. DOE-funded study), the Cadmus Group, The Electric Power and Research Institute (EPRI), Johnson Controls Energy Services Group (JCI), and the US DOE's Energy Efficiency Buildings Hub (EEB Hub).

For this project, FirstFuel worked with 11 Department of Defense (DoD) installations across the country to identify buildings for remote audit participation. Participating sites provided just three pieces of information for the remote audits and remote performance monitoring: (1) 1 year of historical electrical interval data (2) the building address and (3) a completed building information survey.

Technology Application

FirstFuel's deploys its Remote Building Analytics platform to customers in an industry leading integrated approach – through an intuitive web-based portal, demonstrated to the end user in a webinar by our skilled team of in-house energy engineers.

The engagement of building operators remains a critical step to accelerating energy efficiency across the federal sector. In this project, FirstFuel's team of in-house energy engineers directly engaged building operators through an Efficiency Planning Session. Conducted via webinar by, FirstFuel discussed the full energy analysis and results, gained acceptance and buy-in around leading energy savings recommendations, and secured initial commitment to act through collaborative dialogue.

Following the webinar, FirstFuel energy engineers can continue to provide on-going coaching to motivate and support action through regular engagement touch-points and by working with 3rd party implementers to ensure that uncovered opportunities translate into projects and energy savings opportunities. The resulting remote audit and customer delivery process incorporates the best of analytics, building engineering experience and local knowledge that cannot be accomplished with the "push of a button" alone.

Following completion of the Efficiency Planning Session, participants were given access to FirstFuel's web-based energy portal for ongoing usage by DoD energy managers. This portal includes all underlying building performance analysis (including leading energy conservation recommendations) and ongoing tracking of energy savings through FirstFuel's remote performance monitoring. The following screenshots provide a snapshot of FirstFuel's web-based energy portal:

Building Information and Current Energy Use:

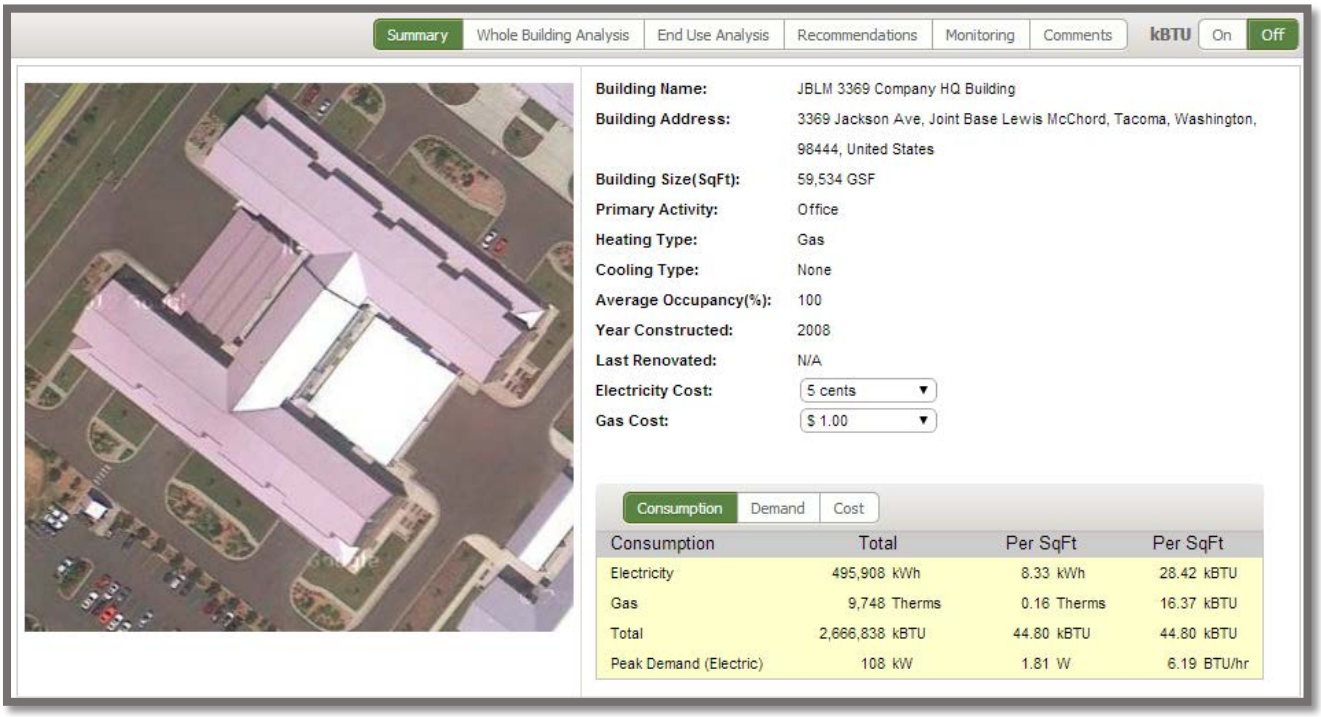


Figure 2: Sample Building Summary Page, Part 1

Savings Potential

Savings Potential	Energy		Savings	Carbon
Electricity	3,427,324 kWh	(16%)	$342,732	2,179 tonnes
Total	11,694,029 kBTU		$342,732	2,179 tonnes

Figure 3: Sample Building Summary Page, Part 2

Operational and Occupancy Analysis:

Derived Building Insight

Energy Consumption	Total	Per SqFt	Per SqFt
Electricity			
Peak Demand	4,779 kW	5.87 W	20.05 BTU/hr
Mean Demand-Occupied	3,391 kW	4.17 W	14.23 BTU/hr
Mean Demand-Unoccupied	2,068 kW	2.54 W	8.68 BTU/hr
Weather related	1,813,027 kWh	2.23 kWh	7.60 kBTU
Non-weather related	20,170,222 kWh	24.79 kWh	84.58 kBTU

Analysis

Occupied / Unoccupied Ratio

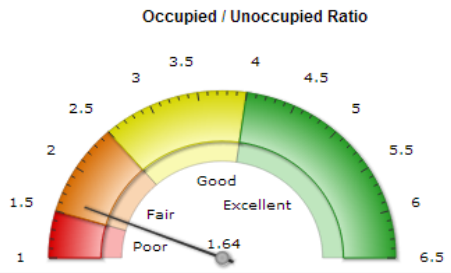


Figure 4: Sample Whole Building Analysis, Part 1

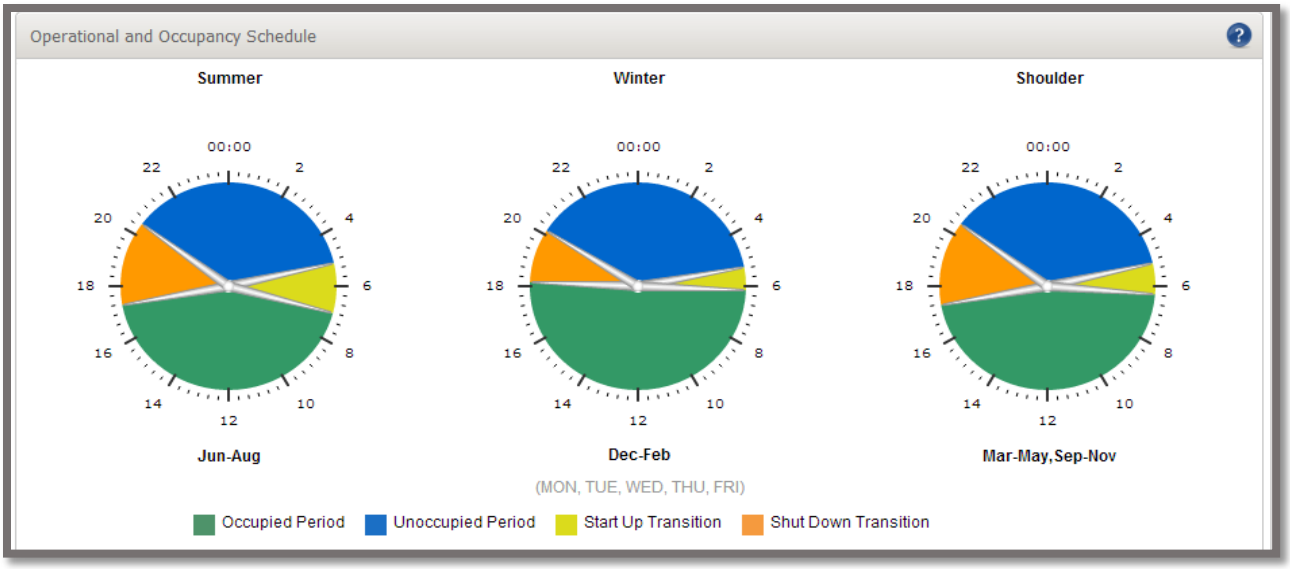


Figure 5: Sample Whole Building Analysis, Part 2

End Use Analysis:

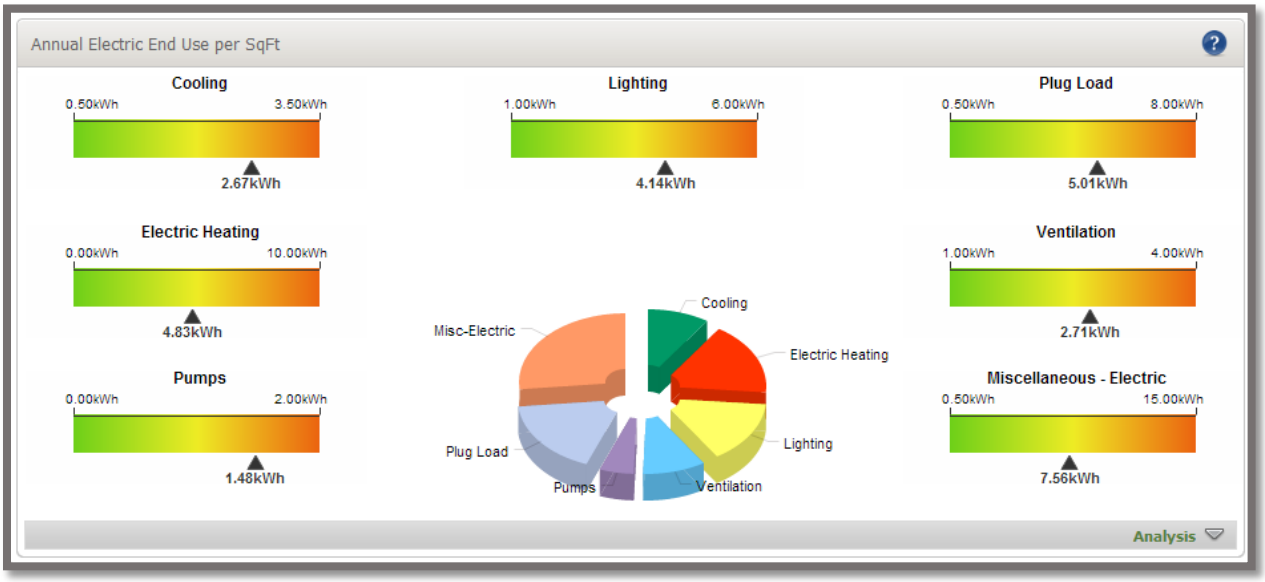
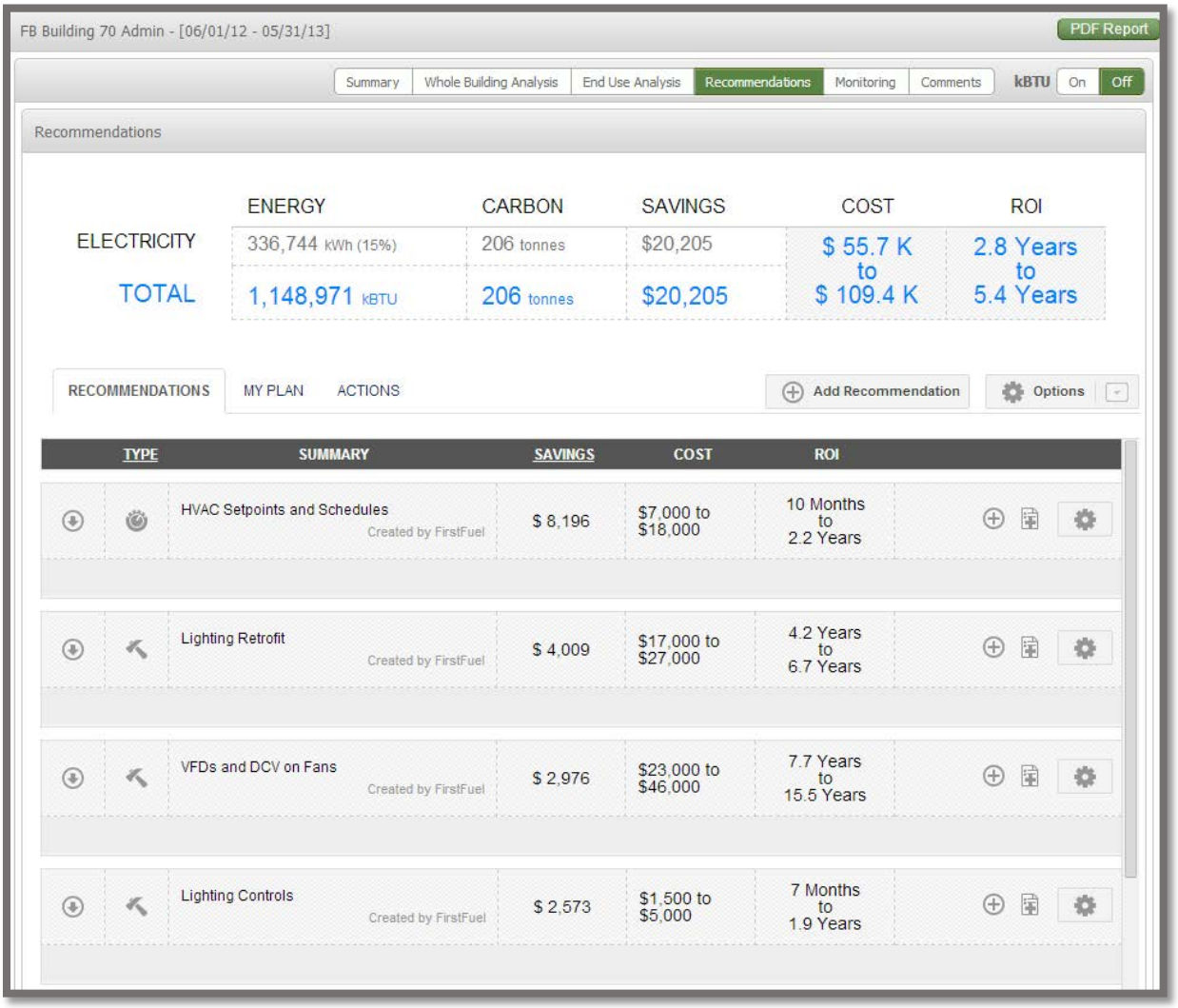


Figure 6: Sample End Use Analysis

Energy Conservation Measures (ECMs):



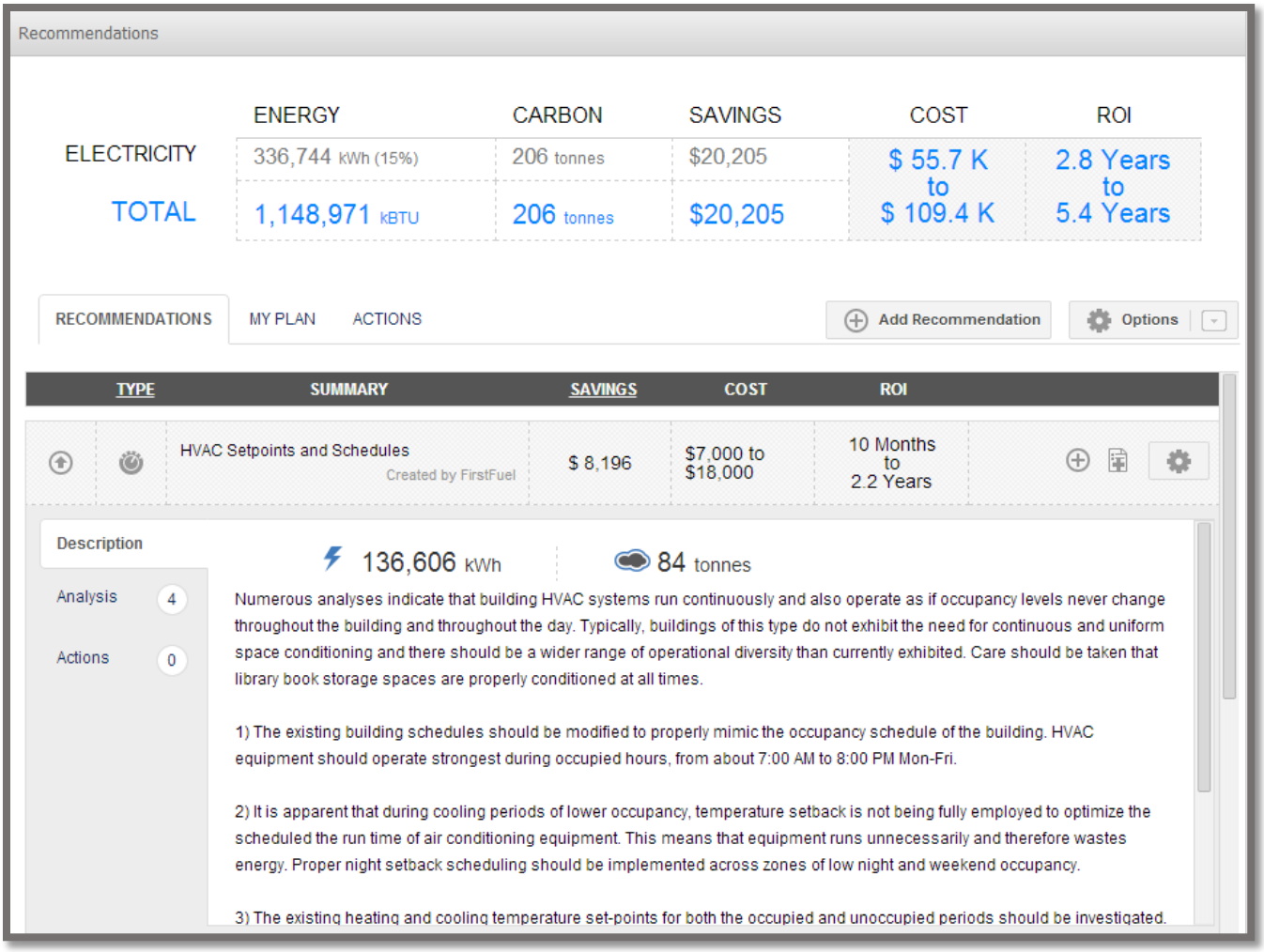


Figure 7: Sample Recommendations

FirstFuel portal users that oversee more than one building have portfolio viewing privileges. Portfolio users are able review the results of the assessments across multiple buildings to identify areas of highest opportunity, by building type, by location or by opportunity type (e.g. lighting, schedule changes, etc.). Below is an example of the DoD portfolio view for potential energy savings sorted by building type:

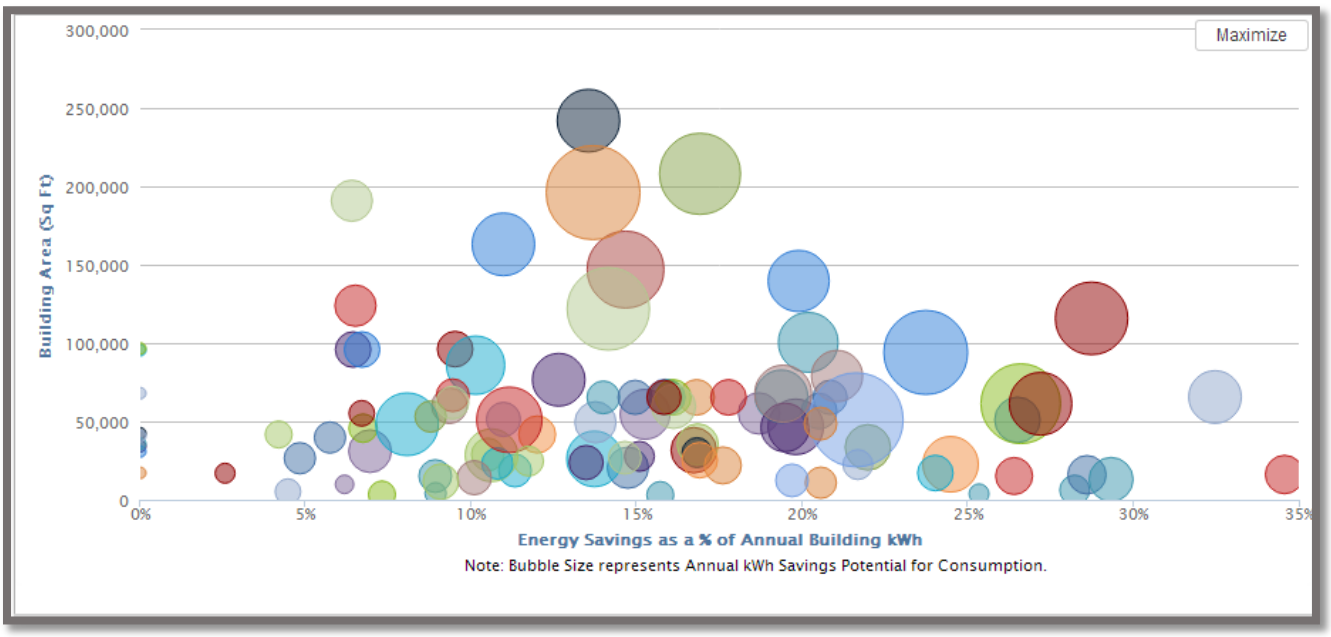


Figure 8: Portfolio View

Sites that provided FirstFuel with post-audit electric consumption data were given access to FirstFuel's continuous performance monitoring service. Similar to the remote audit service, FirstFuel continuous monitoring is conducted without the use of onsite devices or site visits, and requires only regular updates of interval data. With this data, FirstFuel is able to: (1) establish a weather and occupancy-normalized baseline of consumption based on the initial year of data; (2) measure the deviation, at a whole building level, between the baseline and actual consumption, i.e., measure energy savings at a whole building level; (3) correct for major non-efficiency changes in the building during either the initial year of data or in the following years; (4) alert customers on a monthly or quarterly basis to significant changes in the building's energy consumption profile; and (5) demonstrate persistence of operational measures for enhanced savings. Figure 9 below is an example of FirstFuel's continuous performance monitoring:

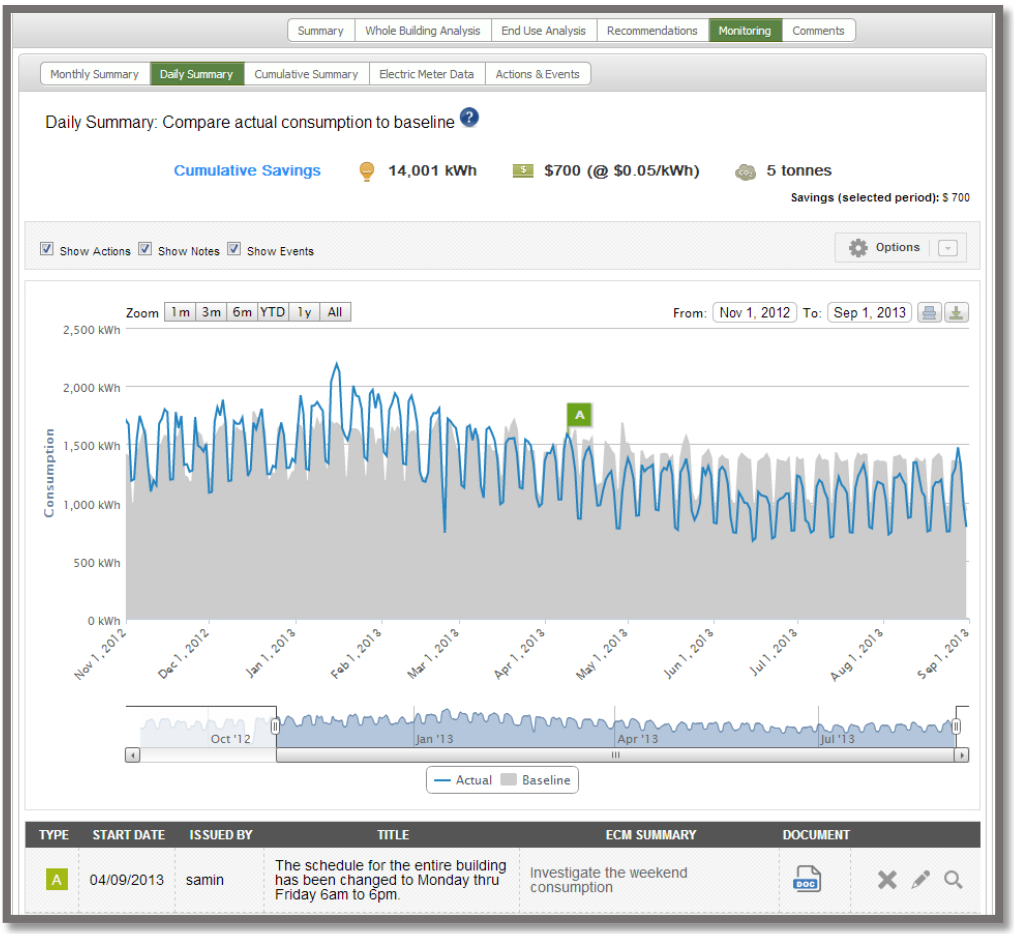


Figure 9: Continuous Performance Monitoring Screenshot

2.2 Technology Development

FirstFuel developed the remote audit technology, now called FirstAudit, through two years of intensive research and development. After launching FirstAudit in mid-2011, FirstFuel has added a suite of additional Software-as-a-Service analytics capabilities to support the entire energy efficiency lifecycle, including portfolio efficiency screening and energy audits to customer engagement and performance monitoring and verification. The timeline below illustrates the chronological summary of the FirstFuel's deployment of the RBA technology to date.

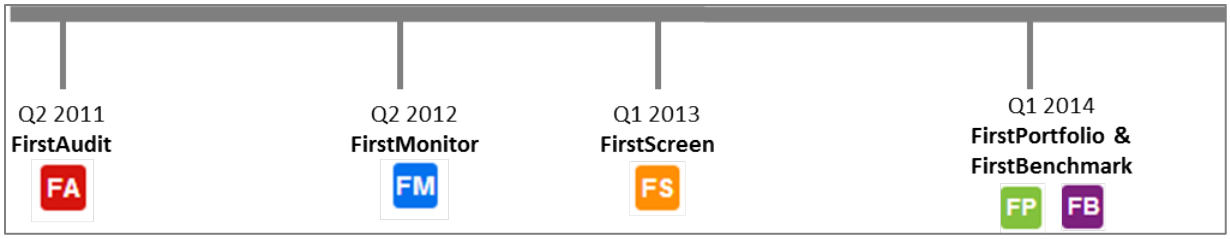


Figure 10: Chronological Summary of FirstFuel's technology deployment

Expected Application of the Technology

Following technical and field evaluation of FirstFuel's RBA platform, the software has been fully commercialized. FirstFuel is engaged in several deployments with customers, including several of the largest North American utilities, the U.S. General Services Administration, and the Washington D.C. Department of General Services. As of January 2014, FirstFuel customers were tracking over $250 million in potential savings on the FirstFuel RBA platform, which includes an identified 14% electricity savings potential across 5.5 million square feet of DoD buildings.

FirstFuel's demonstration involved conducting remote audits on DoD buildings, using FirstFuel's existing RBA technology. Research that occurred as part of the demonstration focused on optimizing the RBA platform for DoD's unique building types in addition to the common commercial building types that were previously available through the platform. Specifically, FirstFuel building engineers spent time researching how each new building type operates in order to incorporate that learning into the key algorithms and processes of the RBA platform, including the end-use disaggregation and other component analytics of the remote audit. To understand the unique features associated with DoD buildings, a team of FirstFuel building engineers conducted building walkthroughs at two sites – Fort Benning and Naval Station Everett – which each hosted several example buildings in the new types. The onsite walkthroughs consisted of visual inspection and discussions with onsite building operators to review the buildings' operational schedules, types of equipment and overall design specifications.

The onsite review and study of DoD specific building types provided FirstFuel's team the necessary information to optimize the RBA platform, analytics and disaggregation engine for these new buildings. The research also yielded the realization that not all DoD buildings can be analyzed using only FirstFuel's traditional RBA tool. A particularly unique feature of DoD buildings' energy consumption is that many buildings are not always occupied throughout the year (e.g. barracks). Because FirstFuel's original audit tool worked by analyzing a building's own unique consumption patterns and signatures over a 12 month period, those buildings with significantly different patterns within the year period required a slightly modified analytics approach. In order to provide end-use level consumption detail for these buildings, FirstFuel's

traditional "inverse modeling" approach was supplemented by another proprietary approach, using a high-speed variant of traditional building models, such as DOE-2. The method was also remote and meets similar cost, speed and accuracy specifications to FirstFuel's core methodology, as it still incorporates most aspects of the inverse modeling approach.

2.3 Advantages and Limitations of the Technology

There are three primary alternatives to FirstFuel's remote audit technology in the market today.

1. Traditional onsite energy assessments and audits
2. Remote energy analysis and benchmarking tools
3. Analytics tools requiring onsite devices

The FirstFuel RBA has been designed to present significant advantages over each, and these advantages have been demonstrated successfully in this project.

1. The traditional approach to building energy assessments begins with a walk-through audit. Typical onsite assessments run between $5,000-$10,000, and take several weeks or more to complete, including multiple days onsite. These audits are too costly and time-consuming to deliver savings at scale across the DoD's portfolio of buildings. FirstFuel's remote audits can be accomplished in hours regardless of the size or type of building and at a fraction of the cost, without a site visit, yielding results similar to ASHRAE Level II onsite audits (the comparison onsite used in this demonstration project) that can take weeks to complete.

   In addition to cost and speed advantages, the FirstFuel methodology suggested an advantage in overall effectiveness. Between the use of the online portal, interactive Efficiency Planning Sessions via webinar and the remote monitoring tracking features, the FirstFuel approach creates a more interactive and ongoing engagement than a static audit. Early results suggest that this engagement will increase building managers' ability and propensity to act on the recommended ECMs provided. Key interactive features not available from onsite audits include:

   - Easy access via web portal by multiple stakeholders
   - Updateable and easy to understand dynamic charts, graphs and analysis describing energy performance and ECMs
   - Tracking of overall building performance over time
   - Impact measurement of enacted ECMs

- ECM recommendation, personalized plan creation and documentation features

2. Other remote technologies currently available in the market are inexpensive but do not offer the same level of scalability, accuracy or actionable results as FirstFuel's RBA platform. Although many bill themselves as "remote audits", FirstFuel's inverse modeling approach is the only one to examine each building utilizing only its own unique consumption patterns and signatures. This is analogous to an onsite audit that bases its conclusions on observation and analysis of the actual building in question, rather than on a series of comparisons to other buildings. Using its proprietary approach, FirstFuel analysis is able to include: end-use consumption profiles by hour, detailed building operational schedules, setpoints, equipment sequences, ventilation configurations and more. The net result is a series of ECMs, cost and savings estimates that are uniquely verified for each building. In contrast, other remote technologies offer results that rely only partially on building data, and instead make recommendations based on comparisons to "like" buildings or models that simulate the performance of a particular building operating at maximum efficiency. This approach especially falls short when analyzing DoD type buildings, as the unique building types make "like building" comparisons less accurate or insightful due to the lack of "like buildings" to compare to.

   Taking into consideration the above, it is notable that FirstFuel offers the only remote technology that has been extensively validated by 3rd parties, now including this demonstration project, for its accuracy and comparability to onsite audits. As the DoD investigates the use of tools now and in the future, this demonstration underscores the importance of such validation of both accuracy and actionability of results.

3. Analytics tools that utilize onsite devices are typically more expensive than the FirstFuel solution – ranging from $5,000 installed cost for the lightest devices to over $100,000 for high-end BMS systems or building sub-meters. The "light-device" solutions tend to lack the diagnostic detail found in the FirstFuel RBA, for example end-use level benchmarking and detailed recommendations. These light-device solutions are often classified as a "dashboard" or "energy monitoring" and provide few actionable insights. At the higher end, more detail is provided, but at much higher price, and often foregoing the "whole building" view in favor of much higher detail and control of a few key systems. However, the key advantage of the FirstFuel platform relative to systems that require onsite devices is the speed, cost and ease of implementation – all of which enable scale across of a multitude of building types and sizes. The FirstFuel platform can be deployed rapidly, with no further installation cost, to all DoD buildings with interval meters. Given the already widespread deployment of such meters in both the Army and Navy, with extensive work underway for almost complete coverage of AMI in all service

branches, the FirstFuel RBA platform provides the optimal combination of effectiveness and leverage of existing or planned infrastructure investments.

Through this demonstration we have observed two potential limitations to the demonstrated approach. The first relates to building energy data. Buildings that do not have interval electric consumption data are not applicable for the remote audits. Additionally, for those buildings with significantly less than one years' worth of interval electric consumption, the remote analysis can be difficult or impossible to complete. Such meter data issues are often not discovered until those twelve months are requested, and the undetected problem means the building's analysis cannot be completed until either more data is gathered by the meter or more complete data is gathered from an earlier time period. The second limitation concerns buildings that are not occupied for months at a time, typically while troops are deployed, or buildings that have very low energy consumption. These buildings may present challenges to perform the end use analyses. However, the impact of this limitation is partially mitigated by the finding that these types of buildings often have lower consumption and/or limited energy efficiency opportunities.

One final issue to consider regarding FirstFuel platform advantages and limitations is the total cost of ownership and return to the DoD. When conducting an audit- either onsite or remotely, one of the major cost considerations is the resources that the DoD must offer to complete the assessment. Onsite audits typically require a site manager to accompany the building engineers to each of the buildings. This can mean that a DoD employee is occupied for an entire day for one building walkthrough. In addition, the DoD resource often is asked to pull building drawings and building automation system data. Alternative remote energy analysis and benchmarking solutions bill themselves as "push button", but return results that require extensive additional work to detail actual savings opportunities.

FirstFuel's remote audits require only the time of the site manager to collect the building's data (including completing a building information survey) and participate in a webinar-based Planning Session. As such, a significant advantage of FirstFuel's approach is that it helps to reduce the time and burden that the DoD energy site manager, or their staff, must devote to energy audits.

3.0 Performance Objectives

3.1 Performance Objectives

Table 2: Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Cost of the RBA	RBA price per building and per square foot	• 12 months of historical electric data in interval format for each building • Building Information Survey for each building	• The average cost for the RBAs performed on the 16 ASHRAE Level II audited buildings (Types 1-5) will be less than or equal to $3,000/building, or $0.12/sq. ft.(whichever is higher)	• The RBA met or exceeded this criteria
Scalability of the RBA	Hours per engineer per RBA	• 12 months of historical electric data in interval format for each building • Building Information Survey for each building • Results from 12 Cadmus ASHRAE Level II audits	• RBAs for Type 1 buildings completed in 25% of the time of Cadmus ASHRAE Level II Audits. • RBAs for Type 2-5 completed in 50% of the time of Cadmus ASHRAE Level II Audits.	• The RBA met or exceeded this criteria
Accuracy of the RBA	• # of RBA ECMs identified • # of ASHRAE Level II ECMs	• Outputs from the FirstFuel RBAs • Results from 12 Cadmus ASHRAE Level II audits	• RBA finds 80% of the ECMs found in Building Type 1 ASHRAE Level II audits. • RBA finds 60% of the ECMs found in Building Types 2-5 • RBA finds recommendations NOT found in Type 1 Building ASHRAE Level II onsite audits.	• RBA found 61% of the ECMs found in Building Type 1 ASHRAE Level II audits (1), which accounted for 16% more savings than the savings found in the same onsite audits.[5] • RBA found 65% of the ECMs found in Building

[5] The ASHRAE LII onsite audits identified 421,909 kWh of savings in the 6 Type 1 buildings. FirstFuel RBA identified 491,196 kWh of savings in the same buildings.

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
				Type 2-5 ASHRAE Level II audits, which accounted for 37% more savings than the savings found in the same onsite audits.[6] • RBA found 18 recommendations NOT found in Type 1 building ASHRAIE Level II onsite audits
Accuracy of the Continuous Performance Monitoring	FirstFuel's predictions compared to actual consumption during the monitoring period	• Three months' worth of interval data from the 12 ASHRAE Level II buildings	• FirstFuel's continuous performance monitoring satisfies ASHRAE Guideline 14	• FirstFuel's continuous performance monitoring satisfies ASHRAE Guideline 14
Qualitative Performance Objectives				
Customer Satisfaction	Degree of Satisfaction	• Standard, web-based Likert Scale Survey to include criteria such as: RBA invasiveness, speed, opinion on applicability of results and recommendations, portal ease of use, among others	• 75% overall customer satisfaction compared to the Cadmus ASHRAE Level II audits	• Greater than 75% customer satisfaction compared to the ASHRAE Level II audits for 1 of the 2 sites visited[7]. Responding sites had 39 buildings with remote audits.

[6] The ASHRAE LII onsite audits identified 289,561 kWh of savings in the 6 Type 2-5 buildings. FirstFuel RBA identified 396,220 kWh of savings in the same buildings.
[7] Survey was not completed by the second of the two sites visited

3.2 Performance Objectives Descriptions

Cost of RBA: FirstFuel demonstrated its applicability to the large and disparate DoD building portfolio by showing that its process can be executed much more cost effectively than onsite ASHARE Level II building audits.

Purpose: To prove the low-cost nature of FirstFuel's RBA methodology compared to onsite ASHRAE Level II audits.

Metric: The units used to measure this performance objective were cost per building to perform RBAs and the costs of the equivalent ASHRAE Level II onsite audit.

Data: In order to perform the RBAs, FirstFuel used the 12 months' worth of hourly interval electric meter data. Additionally, FirstFuel's engineers used a completed building information questionnaire, when it was available. This data was then used to complete the remote audit.

Analytical Methodology: FirstFuel used its standard building price schedule to determine the per-building remote audit cost.

Success Criteria: FirstFuel's cost per RBA per building would be less than or equal to $3,000/building.

Results: FirstFuel's cost per RBA met or exceeded this criterion.

Scalability of RBA: FirstFuel demonstrated its applicability to the large and disparate DoD building portfolio by demonstrating that building energy assessments can be performed rapidly, providing a scalable solution for a large portfolio of buildings.

Purpose: To prove the scalability of FirstFuel's RBA as compared to the traditional approach of onsite ASHRAE Level II audits.

Metric: Time to complete each RBA and time spent to conduct each ASHRAE Level II audit and produce the final report.

Data: FirstFuel's building engineers recorded their time spent to perform each RBA, and present the audit using the company's project management software. The data for this Performance Objective also included the average time spent on behalf of the DoD energy site manager to complete the building information survey, and participate in a webinar to review the results of the building. To gather the data for the time spent on the onsite audits and reports, FirstFuel used the cost and time provided in the invoice documents from the Cadmus Group. To account for the DoD energy site manager time for the onsite audits, we used their time spent supervising the walk through of the building.

Analytical Methodology: FirstFuel's building engineers recorded their time for each remote assessment in the company's project management software. That data, plus the DoD time was then used to analyze the amount of time it took for the completion of the

RBA compared to the time it took for the completion of the onsite audit and the resulting report. The onsite audit time also included the energy site manager's time.

Success Criteria: The success criteria for Type 1 buildings was based on completing a Type 1 RBA in 25% of the time that it took Cadmus to complete the ASHRAE Level II audit for the same Type 1 buildings. For building types 2-5, FirstFuel's success metric was to complete the RBAs in 50% of the time it took Cadmus to complete the ASHRAE Level II audits for the same buildings.

Results: FirstFuel's project exceeded these criteria.

Accuracy of RBAs: FirstFuel demonstrated the validity of its approach to remote building assessments.

Purpose*:* For technical due diligence and credibility.

Metric: ECMs from the Building Type 1 and audits from each of the ASHRAE Level II audit reports and the RBAs of the same 12 buildings.

Data: The ECMs identified in the FirstFuel RBAs for the 12 buildings and the ECMs identified in the 12 Cadmus ASHRAE Level II onsite audits.

Analytical Methodology: FirstFuel created a table comparing 12 onsite audit ECMs to the ECMs of the 12 RBAs of the same buildings.

Success Criteria:

1. The RBA identifies 80% of the measures/recommendations found in the Cadmus onsite audits for type 1 building, and 60% of the measures/recommendations found in the Cadmus onsite audits for building Types 2-5.
2. The RBA identifies ECMs NOT found in the Type 1 ASHRAE Level II audited buildings.

Results: FirstFuel's RBAs identified 61% of the ECMs that the ASHRAE Level II audits found in the Type 1 buildings, which accounted for 16% more energy savings compared to the ASHRAE Level II audits in the same buildings. For the Type 2-5 buildings, FirstFuel's RBAs identified 65% of the ECMs that the ASHRAE Level II audits found, which accounted for 37% more savings compared to the savings found in the same onsite audits. It is important to recognize that the omissions of ECMs in the RBAs compared to the ASHARE Level II audits may reflect a different, broad approach to energy management, rather than an indication that the RBA "missed" ECMs. The RBA identified 18 measures/recommendations NOT found in the Type 1 building onsite audits.

Accuracy of Continuous Performance Monitoring: FirstFuel will demonstrate the value of our continuous monitoring by proving the accuracy of our predictions for 12 buildings (Types 1-5) compared to the buildings' actual consumption data.

Purpose*:* For technical due diligence and credibility.

Metric: FirstFuel's baseline predictions in line with actual consumption data.

Data: FirstFuel offered the continuous monitoring to all 100 buildings, however, quarterly data collection proved difficult for many of the sites. Therefore, FirstFuel selected 11 Type 1-5 buildings that represent the range of buildings in the sample set and also had sufficient data from which to compare the predictions and actual performance data after the initial baseline period.

Analytical Methodology: FirstFuel's continuous performance monitoring utilized the whole building approach based on sophisticated weather normalized statistical models of the baseline energy consumption for each of these 11 buildings.

Success Criteria: FirstFuel's continuous performance monitoring satisfies ASHRAE Guideline 14.

Results: FirstFuel's continuous performance monitoring satisfied ASHRAE Guideline 14.

Customer Satisfaction

Purpose: To prove the customer value and satisfaction of FirstFuel's RBA platform compared to onsite audits.

Metric: Degree of satisfaction

Data Requirements: FirstFuel sent a Likert style survey (using an online survey provider, Survey Monkey) to the two site energy managers that Cadmus also visited for the onsite audits. FirstFuel considered satisfied customers those that respond "Neutral", "Agree" and "Strongly Agree" on the web-based online Likert scale survey distributed to the site energy managers.

Analytical Methodology: FirstFuel analyzed the results of the survey using tables and graphs.

Success Criteria: 75% customer satisfaction compared to the Cadmus ASHRAE Level II site audits.

Results: As of this time, only one of the two energy site managers has completed the survey. Therefore, the results are inconclusive.

4.0 Facility/Site Description

4.1 Facility/Site Location and Operations

FirstFuel performed the remote audit (through the RBA platform) on 100 DoD buildings. 30 buildings consisted of offices, municipal/community buildings and schools. The remaining 70 buildings were prevalent types across the broader DoD portfolio, such as barracks, training facilities, and warehouses.

In addition to identifying building types relevant to the DoD, FirstFuel focused on incorporating buildings from sites that represented a range of climate zones. The following map illustrates the 11 DoD sites that participated in the demonstration project:

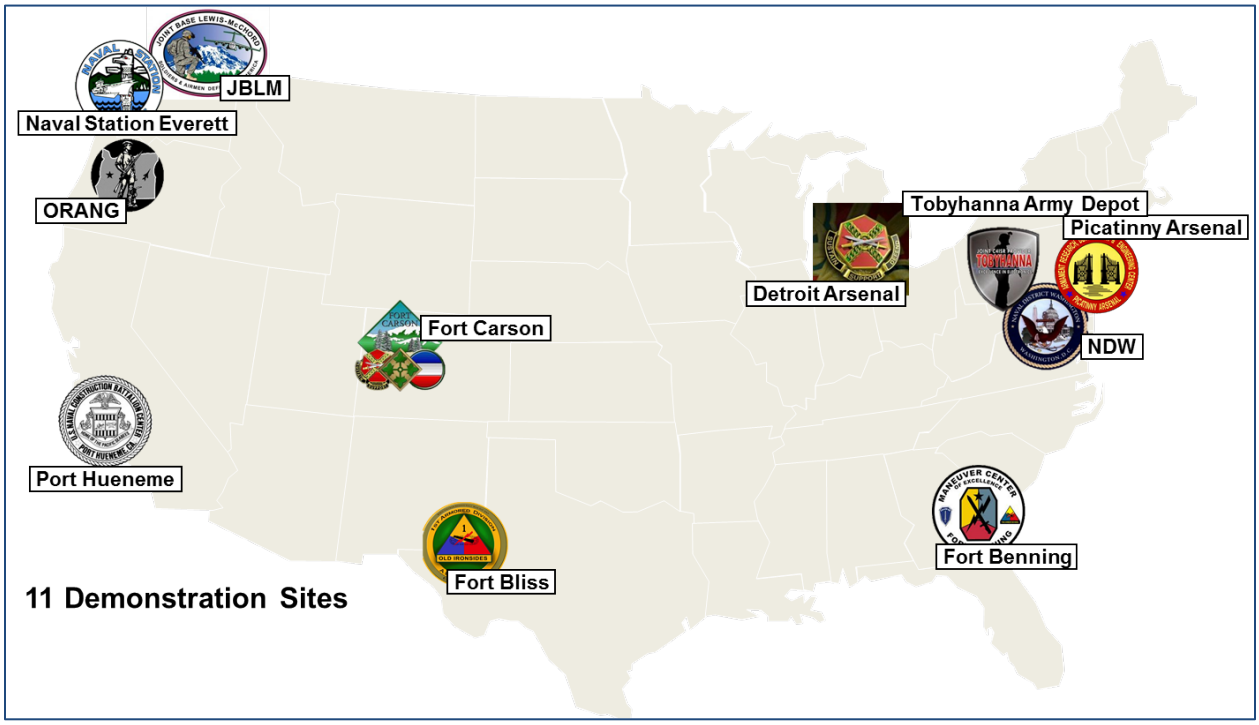


Figure 11: Map of Host DoD Installations

To meet the participation criteria, each site needed to provide FirstFuel with 12 months' worth of historical electric interval data for its building. The interval data had to represent the entire electrical consumption of the building. The table below outlines the number of buildings, by type, from each installation.

FirstFuel RBA Site Partners	Type 1 – Admin	Type 2 – Barracks, Dining	Type 3 – Warehouses	Type 4 – Rec Centers/Auditoriums	Type 5 – Bldgs w/special process loads	Total
Naval Station Everett	7	4	6	3	3	23
Fort Benning	5	22	3	6	3	39
JBLM	1	1	1	-	-	3
Oregon Army National Guard	2	-	-	-	-	2
Picatinny Arsenal	5	-	-	-	-	5
Port Hueneme	4	-	-	-	-	4
Naval District Washington	1	-	-	-	-	1
Tobyhanna Army Depot	2	-	-	-	-	2
Fort Carson	2	4	2	-	1	9
Fort Bliss	1	1	5	2	2	11
Detroit Arsenal			1			1
	30	**31**	**19**	**10**	**9**	**100**

Table 3: Host Installations and Building Count

Cadmus's onsite audits were performed on 16 of the RBA buildings at two sites: Naval Station Everett and Fort Benning. FirstFuel briefly visited both Naval Station Everett and Fort Benning to learn more about DoD specific building types. The following table lists the buildings that were visited at each site:

Installation	Building Number	Building Name/Use	Site Visit Activity
Naval Station Everett	2200	LOGISTICS COMPLEX (FISC)	ASHRAE Level II AUDIT
Naval Station Everett	2202	TRANSIT SHED	ASHRAE Level II AUDIT
Naval Station Everett	1950	FITNESS CENTER	ASHRAE Level II AUDIT
Naval Station Everett	2000	FLEET HQ/ADMIN	ASHRAE Level II AUDIT
Naval Station Everett	2130	GSE SHOP	ASHRAE Level II AUDIT
Naval Station Everett	1980	CHILD DEVELOPMENT CTR	ASHRAE Level II AUDIT
Naval Station Everett	2025	GALLEY	ASHRAE Level II AUDIT
Naval Station Everett	2125	PORT OPERATIONS	ASHRAE Level II AUDIT
Naval Station Everett	1800	LOCATION EXCHANGE	ASHRAE Level II AUDIT
Naval Station Everett	2114	SECURITY/FIRE STATION	ASHRAE Level II AUDIT
Fort Benning	4105	GEN INST BLDG	ASHRAE Level II AUDIT
Fort Benning	6	ENGINEERING ADMIN	ASHRAE Level II AUDIT
Fort Benning	3575	TRAINEE BKS	ASHRAE Level II AUDIT
Fort Benning	4320	DFAC (Dining Facility)	ASHRAE Level II AUDIT
Fort Benning	2653	CHILD DEVELOPMENT CTR	ASHRAE Level II AUDIT
Fort Benning	2827	ENGINEERING ADMIN	ASHRAE Level II AUDIT

4.2 Facility Site Conditions

As long as the buildings satisfy the data criteria [12 months' of historical interval (5/15/ 30/60 minute) electricity data], and they fall under one of five buildings types indicated in Table 1: RBA Demonstration Building Types, then the FirstFuel RBA tool will be able to provide useful outputs, regardless of the climate or other infrastructure on the installation.

5.0 Test Design

Fundamental Problem: The Department of Defense has not yet developed a long-term, highly scalable approach to energy efficiency across its portfolio of buildings. Identifying and profiling energy savings potential presents three fundamental problems for the DoD's building portfolio: achieving scale, uncovering and delivering operational savings opportunities, and measuring and verifying consumption and savings.

FirstFuel Software Demonstration Question: How can the DoD use remote audits to accurately identify and verify Energy Conservation Measures across the DoD's diverse portfolio of buildings?

5.1 Conceptual Test Design

FirstFuel conducted remote audits on 100 buildings that were representative of the DoD's diverse building portfolio. To conduct each remote audit, FirstFuel utilized four pieces of information: 1 year of historical electric interval consumption data, weather data from the building's closest weather station, GIS information from the building's location, and a building information survey completed by DoD energy managers.

The demonstration hypothesis was that FirstFuel's RBA platform would enable the DoD to conduct remote building energy audits across hundreds of buildings using interval meter data in 3x+ lower costs and 3-5x faster speeds compared to traditional ASHRAE Level II onsite audits.

The conceptual test was designed around measuring the time, cost, and accuracy of FirstFuel's 100 remote audits. FirstFuel tracked the time to complete the remote audit (also referred to as the RBA) for each building. The results of 12 of the 16 ASHRAE Level II onsite audits conducted by The Cadmus Group were used to compare energy savings recommendations and help prove the remote audit' accuracy. The remaining four audits (one for each building Type 2-5), were be used to aid the R&D effort associated with optimizing the FirstFuel RBA for those building types.

The buildings included in the demonstration were divided into five types:

Building Types		Percent of DoD's Building Stock[8]
1	Offices, municipal, schools, training facilities	11%
2	Barracks, dining facilities, mess halls	12%
3	Warehouses, Shipping Centers, Commissaries	24%
4	Rec centers & auditoriums	Unknown
5	Facilities with lighter process and specific equipment loads (e.g. large data centers and light manufacturing processes)	13%

While all the building types selected represent the DoD's diverse building portfolio, it is the Type 2-5 building that FirstFuel's platform was not yet optimized for at the start of the demonstration. FirstFuel's team spent time optimizing the process so that the remote audits could be performed effectively.

Design Steps

Step 1: Data Quality Assurance (QA)

Each site's energy manager was responsible for transferring 12 months' of historical interval (5/15/ 30/60 minute) electricity data for 100 buildings to FirstFuel. In addition, they were asked to complete a building information questionnaire that took less than 40 minutes to complete. Please see Appendix C for an example of the building information questionnaire.

Step 2: FirstFuel Remote Audits

The first 30 RBAs were Type 1 buildings. FirstFuel analytics were already optimized for these building types, and therefore required no additional research and development resources to complete. For building Types 2-5, FirstFuel used site visits and building walkthroughs to refine its analytics platform and complete the remote audits for these types of buildings. FirstFuel tracked the time involved to complete the RBA for each building in the deployment.

Step 3: Efficiency Planning Session

Following the completion of each RBA, FirstFuel published the results of the analysis on the online, DoD-specific portal and led an Efficiency Planning Session via webinar for the site's energy manager. The webinar covered the results of the remote audit, focused the energy

[8] http://www.arpa-e.energy.gov/sites/default/files/documents/files/AdvancedBuildings_DOD.pdf

managers on an initial set of recommendation to consider, and included training on how to use the web portal.

The efficiency planning session was also used to get feedback from the building team regarding assumptions made to complete the analysis. Any necessary changes discovered during the webinar, were then made to the audit by FirstFuel's building engineers after the call, and the updated audit was made available directly to the site's building team via the online portal.

Step 4: ASHRAE Level II Onsite Audits

Simultaneously, Cadmus performed the ASHRAE Level II onsite assessments on 16 of the buildings at Fort Benning and Naval Station Everett.

Prior to visiting Fort Benning and Naval Station Everett, Cadmus gathered information and documentation about the buildings from the site managers. This information included:

- Building characteristics, which include details about the shell, mechanical systems, lighting systems, tenant types, operational schedules, and other parameters needed to verify the accuracy of whole building simulation models.
- Building construction and operation information
- Component measure data, such as model numbers

While onsite, Cadmus' field staff gathered data, such as operating schedules, trend data, and other building characteristics and parameters. Where possible, the field staff took one-time spot measurements or performed short-term trend logging for two to four weeks. Cadmus also interviewed the building staff to better understand equipment performance, technical issues, and occupant behavior.

After the site visits, Cadmus wrote an assessment report for each building. The final reports were made available to the sites' energy managers, and the final ECMs were used to compare against the results of the FirstFuel RBA.

Step 5: Data Analysis and Comparison

FirstFuel compiled the time it took to complete each RBA, along with the associated cost and compared it to the time and cost it took to complete the onsite Level II assessments. During this analysis phase, FirstFuel also compared the number of similar recommendations for saving energy between the RBA and the onsite ASHRAE Level II audit.

5.2 Baseline Characterization

The Cadmus Group followed ASHRAE Level II guidelines to conduct the 16 onsite audits Cadmus's data collection included: operating schedules, trend data, and other building characteristics and parameters. Site visits were used to confirm equipment was working as expected, and to interview building operators to better understand how equipment performance and pre-identified technical issues.

For each building, Cadmus obtained square footage data, using site visit data, reported program values, or secondary sources. Then, using available data, Cadmus determined each building's energy-use intensity. The final analysis included trends in building performance and offered potential explanations for outliers.

In contrast, FirstFuel's remote audit process used each building's historical high frequency (5/15/30/60 minutes) consumption data, the corresponding local historical weather data (gathered by FirstFuel via NOAA and other weather agencies) and physical building characteristics (extracted by FirstFuel via online mapping sources) and the building's information survey (as completed by the site manager). Most often, each building's energy data was downloaded from the meter data management system by the person at the site most familiar with the site's advanced metering system. From site to site, the role of who was most familiar with the advanced metering system was not consistent, but it commonly was the person who oversaw building operations and the site's energy service provider contractors. No onsite presence or device installation/tracking was needed to establish the consumption baseline.

To complete the remote audit, FirstFuel used core statistical modeling methodology to disaggregate a building's end uses by employing a combination of Neural Networks, Linear Programming (LP), Ordinary Least Squares (OLS) and other proprietary optimization techniques. The cost estimations associated with the Energy Conservation Measures were derived using the building's completed information survey and recognized facilities' cost data (e.g. RS Means).[9]

[9] RS Means is an industry standard for facility construction cost data, updated annually.

5.3 Design and Layout of System Components

FirstFuel's RBA platform is an "in the cloud" service, meaning that is accessed remotely on via the Internet and is hosted by FirstFuel. The screen shot below is an example of the login screen for the DoD-specific FirstFuel portal:

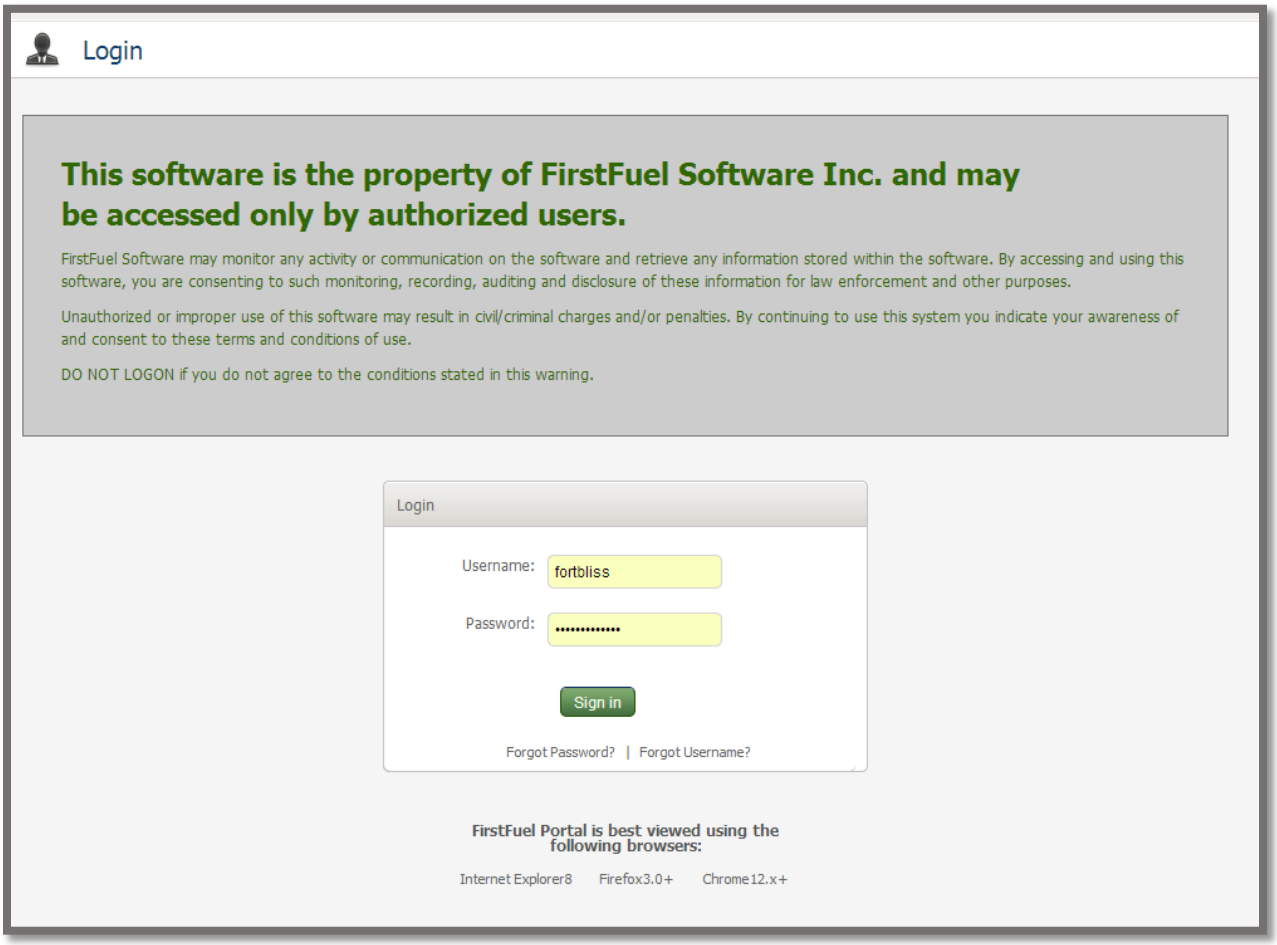


Figure 12: DoD FirstFuel RBA Portal Login Screen

The site's energy managers are given a username and they set their password for their own personal login. Once they've logged in, they are brought to the "Home" tab:

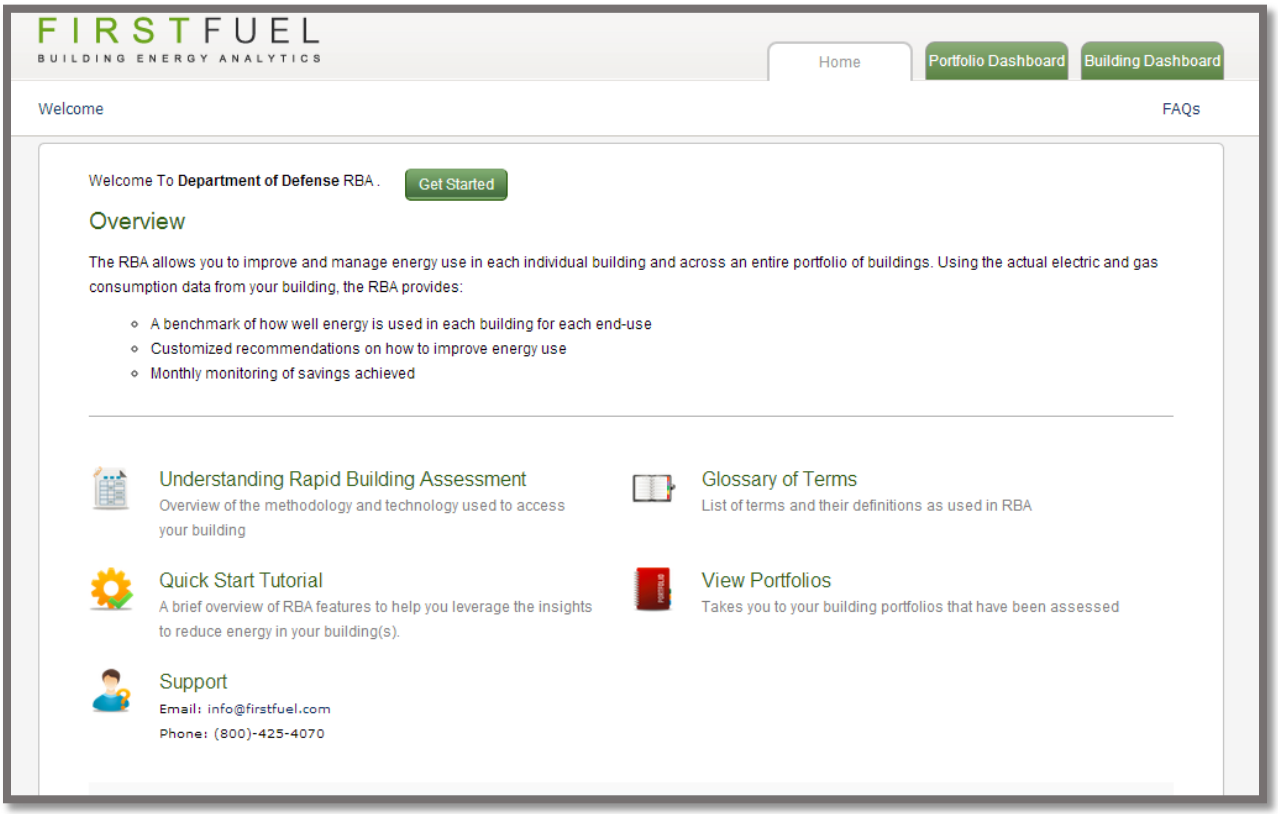


Figure 13: Sample FirstFuel Portal "Home" Tab

The home tab provides resources for understanding the RBA and a Glossary of Terms.

The next tab provides a look at the site's portfolio of analyzed buildings:

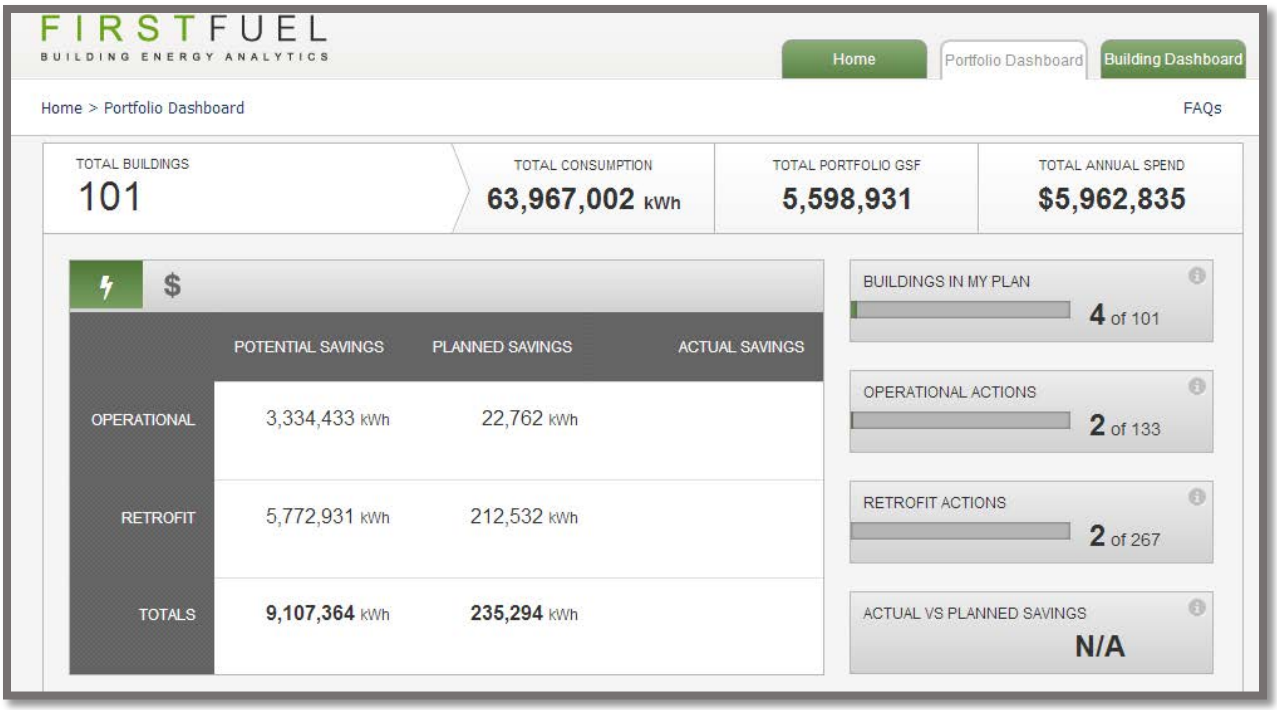


Figure 14: Sample FirstFuel RBA "Portfolio Dashboard" tab

The third, and final tab, is the list of buildings that were analyzed along with key statistics. Clicking on the building's name takes the user to the building's RBA summary page.

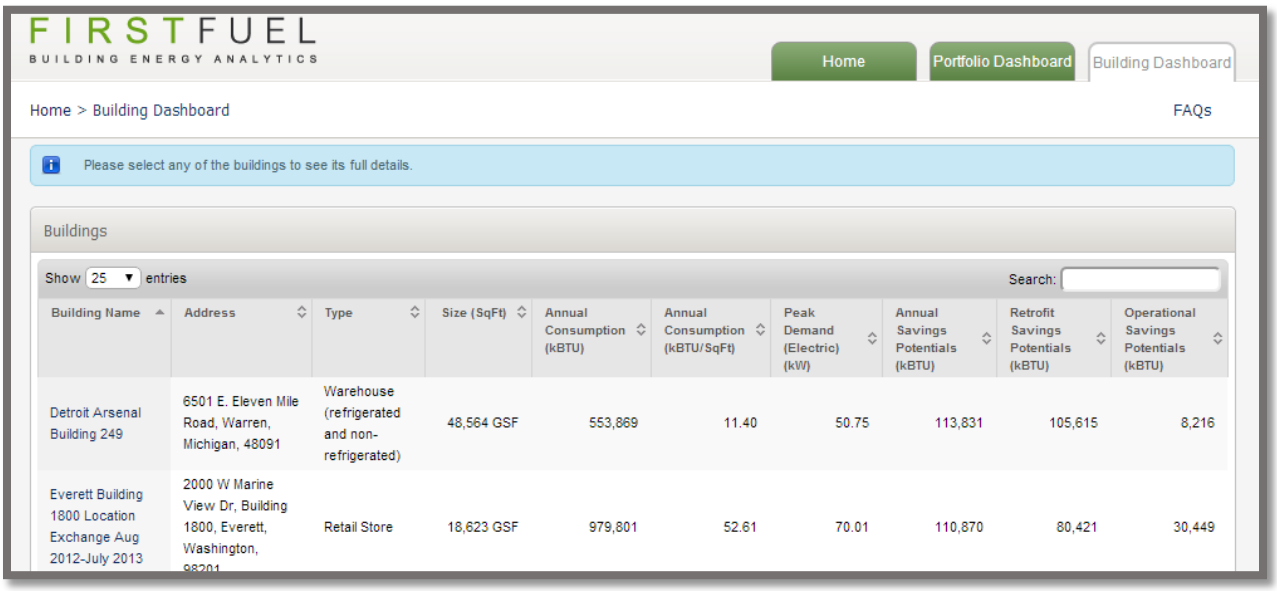


Figure 15: Sample FirstFuel RBA "Building Dashboard" tab

Each building's RBA is analyzed in a similar fashion within their building type and all buildings have the same outputs. In addition, the web-based portal visualizes each building and all analyses the same way.

5.4 Operational Testing

To test cost, speed and performance of the RBAs, FirstFuel first collected data files containing 12 months of electric interval data for each DoD building. FirstFuel received the data as a *.csv or flat file via email, FTP, and via CD-ROM.

FirstFuel used the building's high frequency electrical data, GIS information, and building questionnaire responses to perform the RBA. The time to complete the RBA was officially tracked to properly account for the resources associated with the demonstration activities.

FirstFuel used basic business intelligence techniques and elementary statistics – mean, variance, range, and trend lines to measure the completion time, cost and accuracy (defined by # of measures) comparisons to the ASHRAE Level II audits.

Please see Appendix B for a Gantt chart showing the timeline of project activities.

5.5 Sampling Protocol

Data collected to perform the assessments included: each building's historical high frequency (5/15/30/60 minutes) consumption data (available from the utility or onsite smart meters), corresponding local historical weather data (gathered by FirstFuel via NOAA and other weather agencies) and physical building characteristics (extracted by FirstFuel via online mapping sources) and the building's information survey (as completed by the site manager).

FirstFuel's sample included 100 buildings across 11 distinct DoD sites. See Table 3 in "Section 4.0 Facility Description" for building type distribution and their site locations.

Cadmus collected the following data for 16 buildings where ASHRAE Level II audits were conducted:

- Analyzed building details to accurately characterize the shell, mechanical systems, lighting power density, and other parameters
- Conducted Interviews with facility personnel
- Utilized BAS data (when available) to check operation of sensors, valves, actuators and dampers
- Examined set-back and reset schedules, including whether optimized start and stop were employed

- Examined air and hydronic delivery systems to look for how those systems were adjusted for loads including VSDs on fans and pumps
- Determined the presence of demand control ventilation with CO_2 sensing
- Reviewed lighting controls
- Checked for economizer operation through use of run time logs and interviews
- Reviewed any pertinent files located at the site

The test approach measured five dependent pieces of data:

1) *Time to complete* – All buildings that had onsite audits
2) *Cost* – All buildings
3) *Accuracy* (# of recommendations relative to ASHRAE Level II audits) – 12 buildings that had onsite audits
4) *Remote Monitoring*—11 buildings with sufficient monitoring data
5) *Customer satisfaction* – one online survey[10]

Time to complete – The time to complete each RBA was tracked in FirstFuel's project management system. FirstFuel also tracked the time it took for the site manager to complete the building information, attend the RBA webinar, and to supervise the ASHARE Level II audits. The time to complete the ASHRAE Level II audits, including writing the reports, was tracked by Cadmus and sent to FirstFuel.

Cost – FirstFuel used its standard pricing schedule.

Accuracy – FirstFuel collected the results of the ECMs from Cadmus' reports and recorded them in a spreadsheet that also contained the FirstFuel RBA recommendations.

Continuous Performance Monitoring – FirstFuel's continuous performance monitoring solution relies on electric interval data (5/15/30/60 minute) for each of the three months following the remote audit and the predicted monthly consumption data that FirstFuel generates using a variety of statistical methodologies including but not limited to Mean Bias Error (MBE), R-squared, tests of significance including p-value and confidence interval measures, CVRMSE, etc. to demonstrate the accuracy of both in-sample and out-of-sample fits. The results of the monitoring, both the predicted and the actual consumption, are displayed on the web portal for each DoD building that submitted data.

[10] While customer satisfaction surveys were distributed to the two sites with the ASHRAE Level II onsite audits, only one completed the survey.

FirstFuel demonstrated the value of our baseline model used for continuous performance monitoring by proving the accuracy of our predictions for 11 buildings (Types 1-5) compared to the buildings' actual consumption data. These buildings were selected because they represent the range of buildings in the sample set and they provided sufficient data from which to compare the predictions and actual performance data after the initial baseline period. FirstFuel's model used for continuous performance monitoring meets or exceeds the criteria established in ASHRAE Guideline 14. Guideline 14 was developed by ASHRAE to fill a need for a standardized set of energy (and demand) savings calculation procedures.

For additional information on the continuous performance monitoring results, see Section 6, "Accuracy of FirstFuel Models for Continuous Performance Monitoring".

Customer Satisfaction – A customer satisfaction survey was designed via web-based survey service, using a Likert scale style. The responses were scored along a range of "agree" to "disagree". FirstFuel captured the results/data from the online survey via Excel spreadsheet.

5.6 Sampling Results

The following section provides the results for each of the samples collected and additional information about the remote audit results.

Time to Complete

The table below demonstrates the average amount of time involved on the part of the installation's energy site manager to contribute to the completion of the audit.

	Energy Site Manager
RBA	2
ASHRAE Level II Audit	8

Table 4: Average Hours to Complete One Building Audit

Figure 16: Energy Site manager time for FirstFuel RBA Time vs ASHRAE Level II Audit Time (in hours) for one building

Accuracy

The table below gives the number of ECMs found in the 12 ASHARE Level II onsite audits, the number found by both methodologies and the number found only use the FirstFuel RBA.

Building Site and Type	ASHRAE Level II ECMs	ECMs found in Both	RBA ECMs	ECMs found in RBAs only
Fort Benning (Type 1)	4	3	3	2
Fort Benning (Type 1)	3	1	3	2
Fort Benning (Type 2)	4	3	3	1
Fort Benning (Type 2)	3	3	5	2
Fort Benning (Type 1)	2	1	4	3
NS Everett (Type 1)	7	2	7	5
NS Everett (Type 1)	5	5	6	3
NS Everett (Type 2)	2	1	6	5
NS Everett (Type 4)	2	2	4	2
NS Everett (Type 1)	2	2	5	3
NS Everett (Type 3)	4	2	3	1
NS Everett (Type 5)	5	2	3	1
Totals	**43**	**27**	**52**	**30**

Table 5: ECMs identified in FirstFuel RBAs and ASHRAE Level II audits

As part of the demonstration, FirstFuel also looked at comparing the ECMs between the ASHRAE Level II audits and the RBAs by Type 1 buildings and Type 2-5 buildings. The table below summarizes ECM count by Type 1 buildings and Type 2-5 buildings.

	ASHRAE Level II		FirstFuel RBA		*Both* ASHRAE Level II and FirstFuel RBAs		FirstFuel RBA only	
	Type 1	Type 2-5	Type 1	Type 2-5	Type 1	Type 2-5	Type 1	Type 2-5
ECM Count	23	20	28	24	14	13	18	12

Table 6: ECM Count in FirstFuel RBA and ASHRAE Level II audits by Building Type

Remote Audit Results

Of the 100 buildings analyzed, FirstFuel successfully disaggregated the buildings' energy consumption into its building level end uses of 91 of them. FirstFuel provided targeted energy conservation recommendations for nine buildings that could not be disaggregated; however, savings calculations are not provided, as they are partially dependent on the facility's energy end-use breakdown. The primary challenges of the nine buildings without end-use disaggregation were either a) very low annual energy consumption or b) intermittent occupancy leading to highly irregular data. It should be noted that buildings with very low energy consumption present limited energy efficiency opportunity, by definition, and that buildings with intermittent occupancy also present challenges for accurate onsite audit calculations.

The following charts illustrate the breakdown of average energy use (kWh per square foot) by building type.

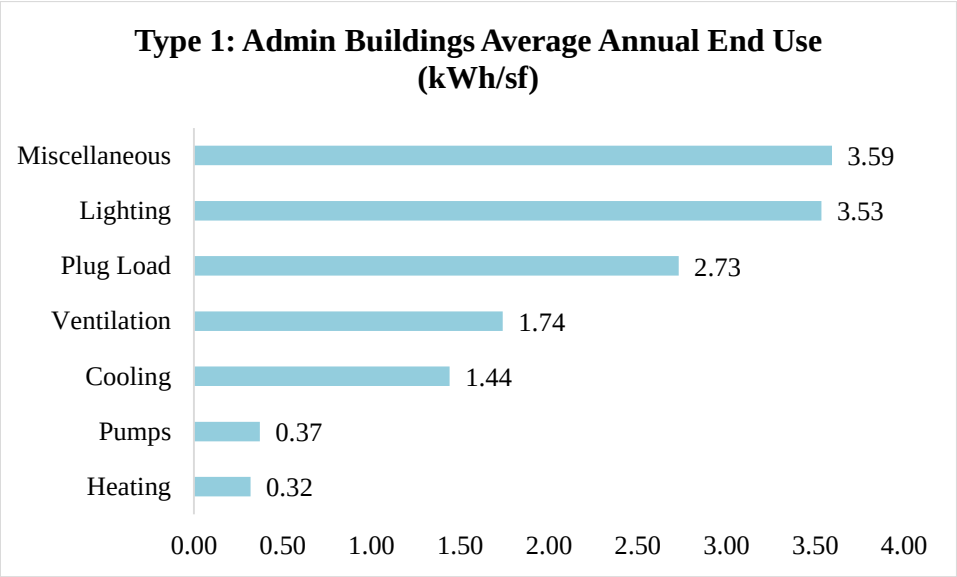


Figure 17: Type 1 Average Annual End Use (kWh/sf)

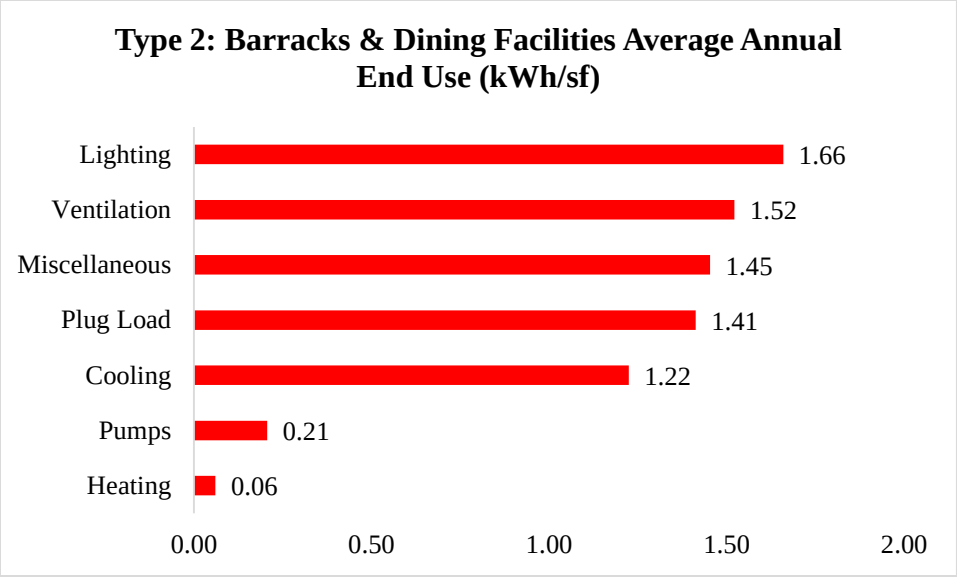


Figure 18: Type 2 Average Annual End Use (kWh/sf)

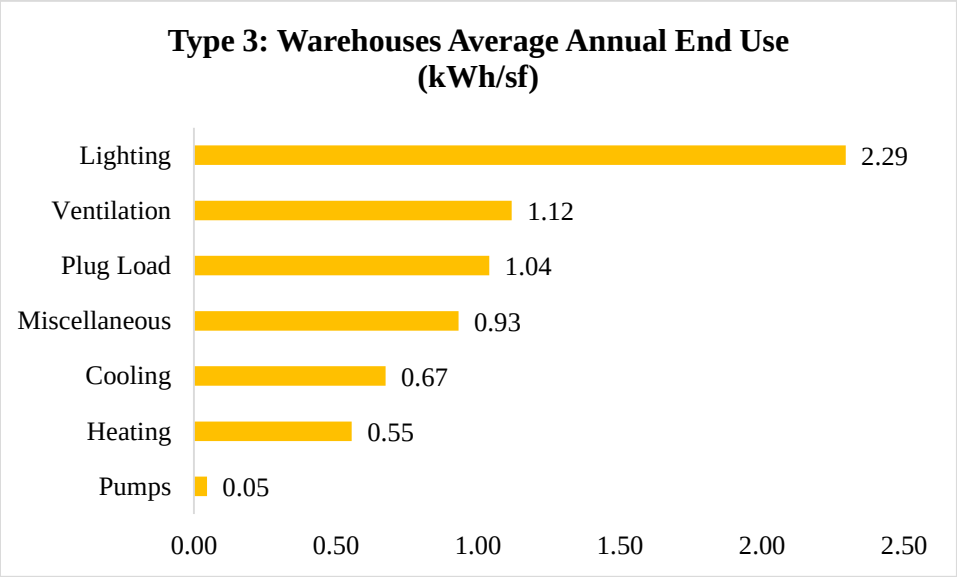


Figure 19: Type 3 Average Annual End Use (kWh/sf)

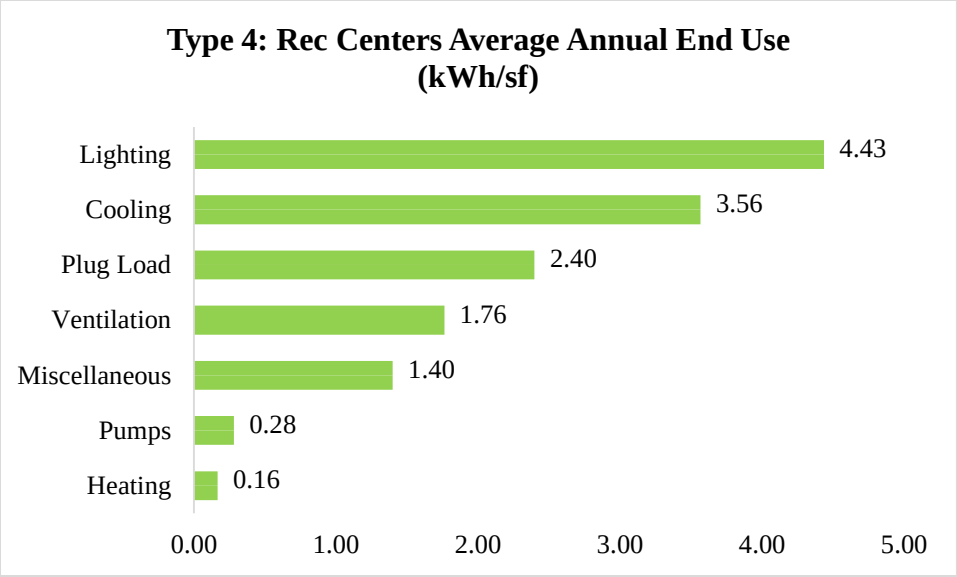


Figure 20: Type 4 Average Annual End Use (kWh/sf)

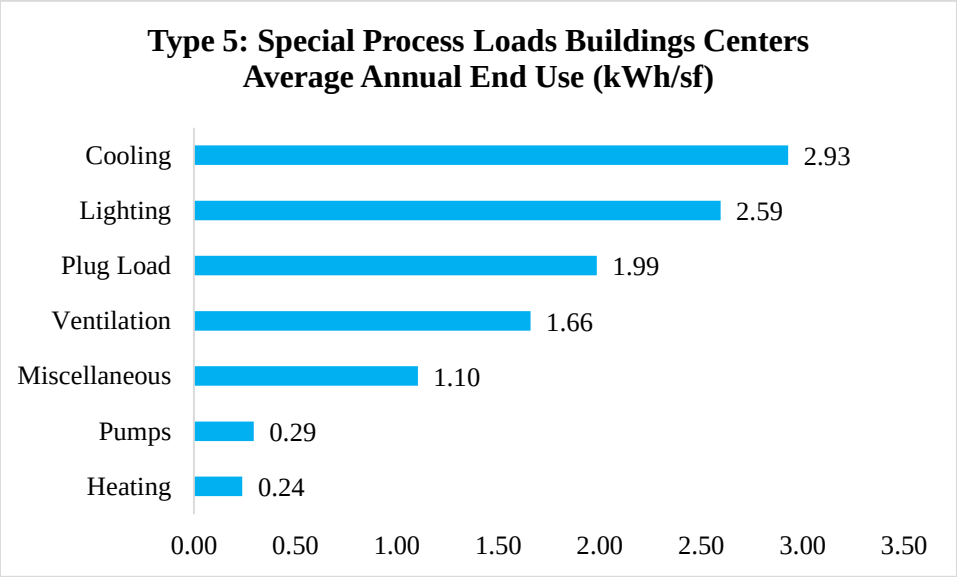


Figure 21: Type 5 Average Annual End Use (kWh/sf)

Across these 100 buildings, FirstFuel's RBA tool identified approximately 8.6 million kWh in energy savings, which represents a potential 14% reduction in energy spending.

The charts below shows how the outcome of the kWh savings per building and per square foot.

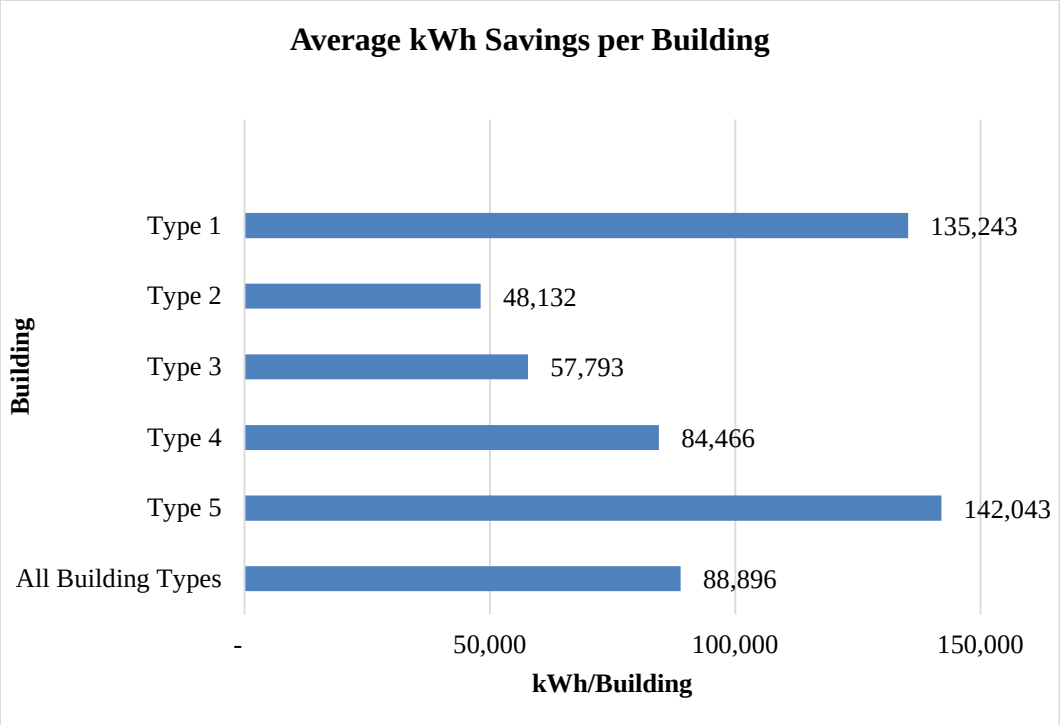


Figure 22: Average kWh Savings Per Building

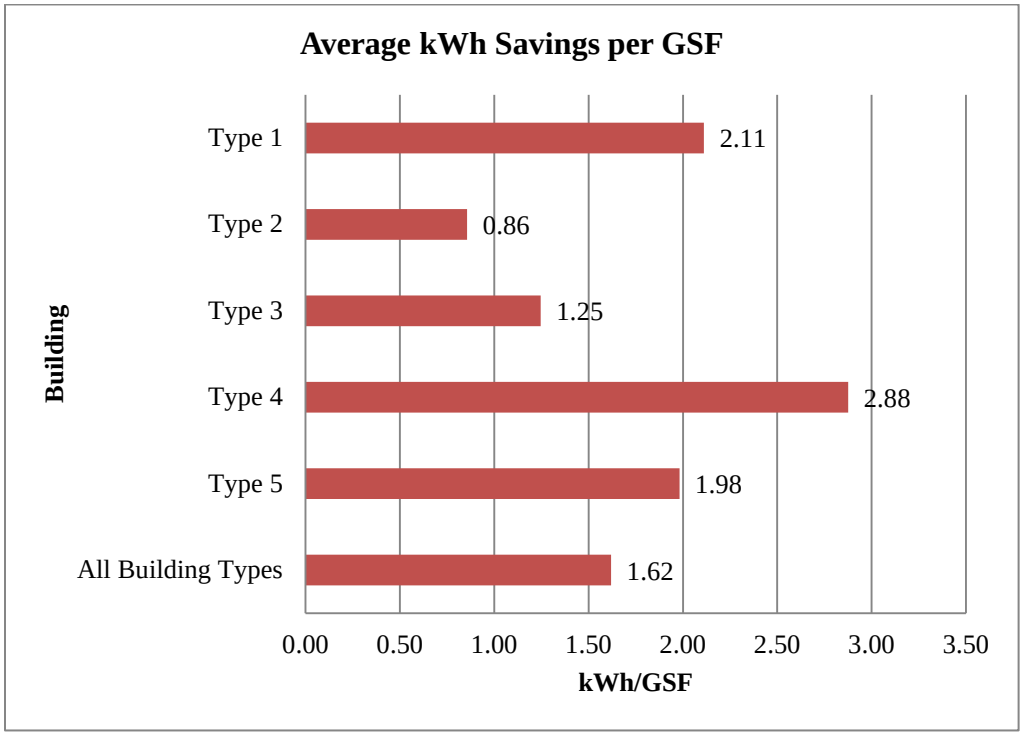


Figure 23: Average kWh Savings per Gross Square Footage (GSF)

Figure 23 demonstrates that the buildings that tended to have the highest savings per square foot were not necessarily the largest.

Figures 24-28, below, illustrate the categories of top energy conservation measures identified within each building type.

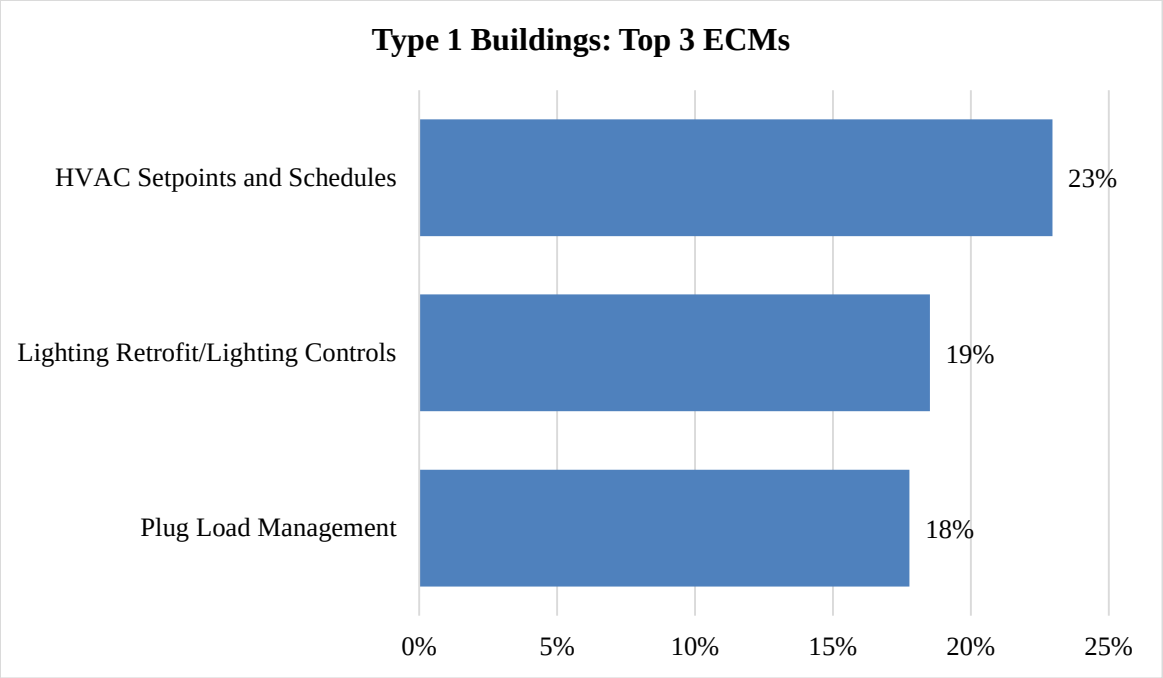


Figure 24: Top 3 ECMs--Type 1 buildings

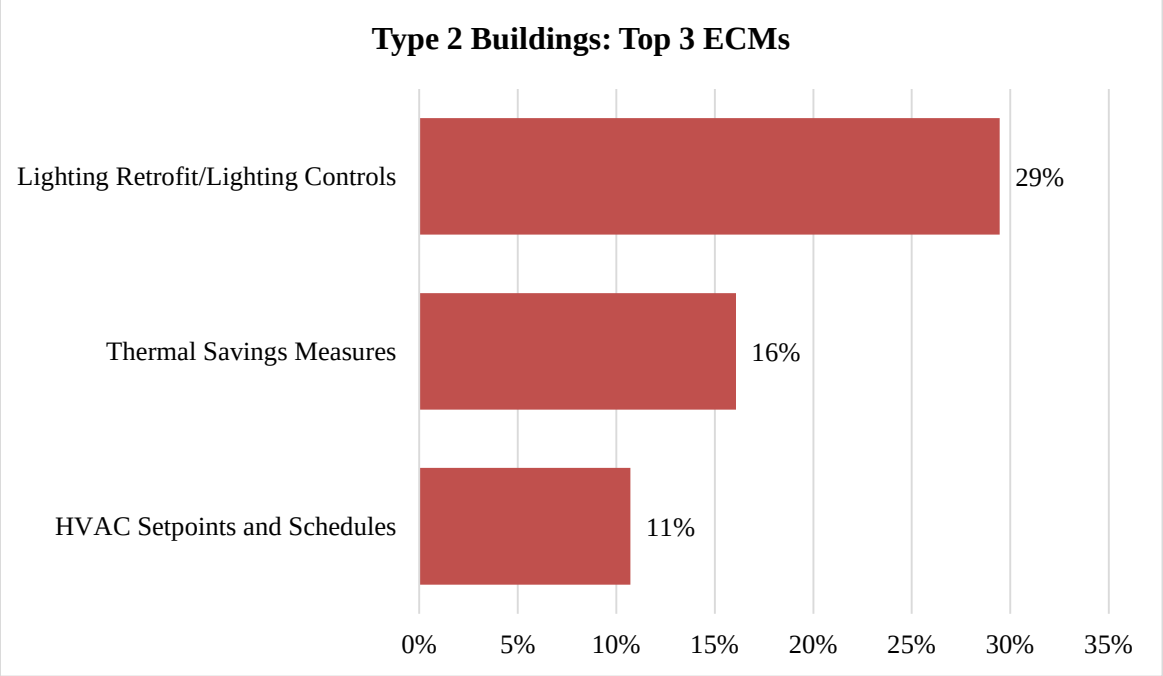


Figure 25: Top 4 ECMs--Type 2 Buildings

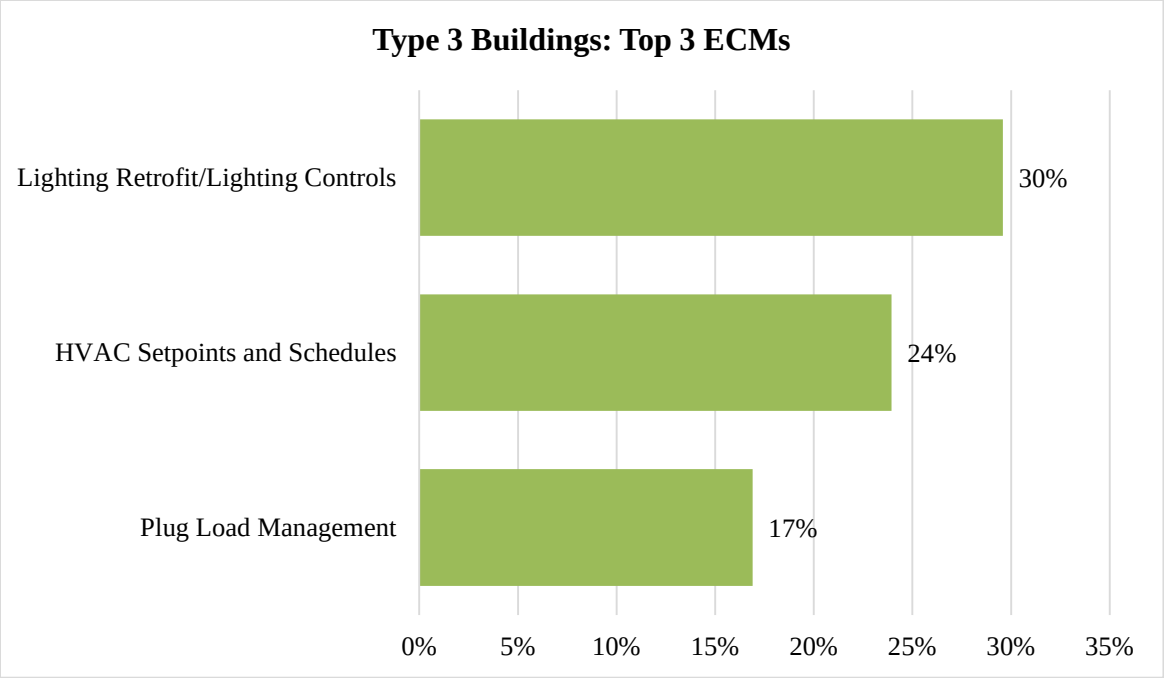


Figure 26: Top 3 ECMs--Type 3 Buildings

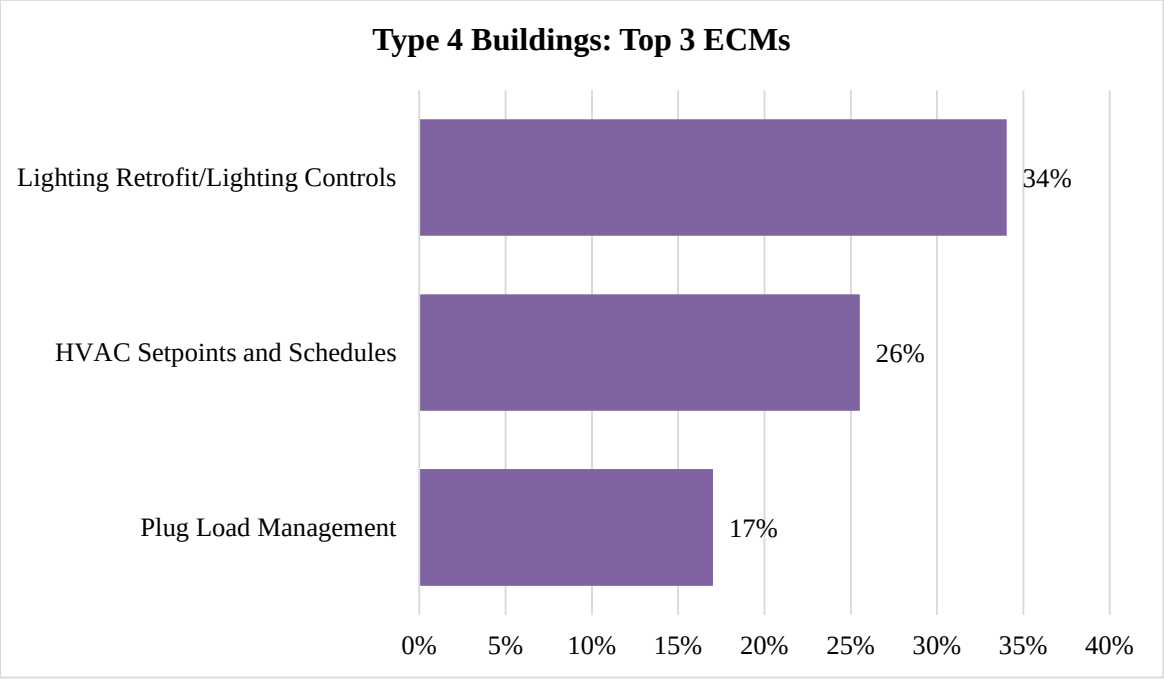


Figure 27: Top 3 ECMs--Type 4 Buildings

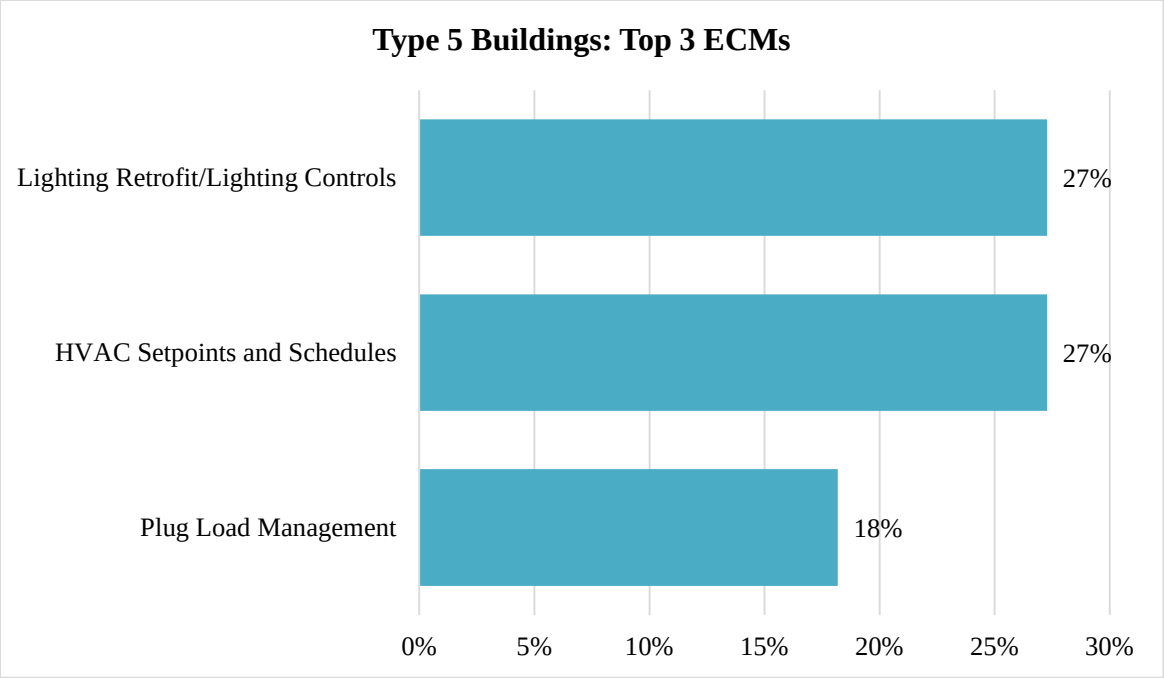


Figure 28: Top 3 ECMs--Type 5 Buildings

Figures 24-28 demonstrate that all five building types had similar recommended measures. Buildings with regular occupancy, but irregular, or sub-optimal building operations are candidates for scheduling adjustments. Type 1 buildings tend to have such regular occupancy patterns, and we found that many of them would benefit from scheduling adjustments. Other types (2-5) included more buildings with irregular occupancy or round-the-clock occupancy, and therefore were not candidates for scheduling improvements. We did find that many of the Type 2-5 buildings would benefit from lighting and plug load related measures.

Additional results collected include the results of the remote building assessments on the 100 DoD buildings. To view the end use analysis breakdowns and recommendations identified by building, please refer to Appendix E.

6.0 Performance Assessment

FirstFuel chose each Performance Objective (PO) with the major project goals in mind: cost, scalability and accuracy. Tools like FirstFuel's RBA platform can help the DoD more rapidly and cost-effectively achieve energy efficiency at scale across its unique portfolio of buildings.

The individual Performance Objective subsections below include the data and graphs obtained during the demonstration to illustrate how the objective was met.

Cost of FirstFuel RBA:

Performance Objective: FirstFuel will demonstrate its applicability to the large and disparate DoD building portfolio by showing that its process can be executed much more cost effectively than traditional ASHRAE Level II onsite building energy assessments.

Success Criteria: FirstFuel's cost per RBA per building would be less than or equal to $3,000/building.

FirstFuel's standard pricing sheet was utilized to the cost of an RBA to the cost of an onsite ASHRAE Level II audit the Cadmus performed on the same DoD building.

Results: FirstFuel's cost per RBA met or exceeded this success criterion.

Scalability of FirstFuel RBA:

Performance Objective: FirstFuel will demonstrate its applicability to the large and disparate DoD building portfolio by demonstrating that building energy assessments can be performed much more rapidly than traditional methods, providing a scalable solution for a large portfolio of buildings.

Success Criteria: 1) RBAs for Type 1 buildings completed in 25% of the time of Cadmus ASHRAE Level II Audits. 2) RBAs for Type 2-5 completed in 50% of the time of Cadmus ASHRAE Level II Audits.

In order to measure the scalability of FirstFuel's RBA platform, we compared the time to complete the remote audits to the time for onsite audits. The time to complete each RBA was tracked in FirstFuel's project management system. FirstFuel also tracked the time it took for the site manager to complete the building information, attend the RBA webinar, and to accompany the ASHRAE Level II auditors on site. The time to complete the ASHRAE Level II audits was tracked by Cadmus and sent to FirstFuel.

Results: The FirstFuel RBA exceeded these criteria.

Accuracy of FirstFuel RBA:

Performance Objective: FirstFuel will demonstrate the validity of its remote audits by comparing the recommendations and energy conservation measures identified in 12 Cadmus ASHRAE Level II audited buildings to the recommendations (both operational and retrofit) uncovered by FirstFuel RBAs.

Success Criteria: 1) The RBA identifies 80% of the measures/recommendations found in the Cadmus onsite audits for type 1 building, and 60% of the measures/recommendations found in the Cadmus onsite audits for building Types 2-5. 2) The RBA identifies measures/recommendations NOT found in the Type 1 Cadmus onsite audits.

Through FirstFuel's technology advancements and customer deployments across the 18 months since the DoD demonstration project, the company has learned that this performance metric is less important and relevant than other metrics. For example, ECMs recommended in onsite audits may not be uncovered by the FirstFuel RBA (or vice versa) because omissions may reflect a different set of energy management objectives or scope. Nevertheless, for the purposes of this demonstration, the table below shows the number of ECMs found in the ASHRAE Level II onsite audit, the FirstFuel RBA, and by both approaches.

The buildings below were selected for the ASHRAE Level II onsite audits and the FirstFuel RBAs based on building data availability and DoD energy site manager preference.

Building Site and Type	ASHRAE Level II ECMs	ECMs found in Both	FirstFuel RBA ECMs	ECMs found in Type I RBAs only
Fort Benning (Type 1)	4	3	3	2
Fort Benning (Type 1)	3	1	3	2
Fort Benning (Type 2)	4	3	3	
Fort Benning (Type 2)	3	3	5	
Fort Benning (Type 1)	2	1	4	3
NS Everett (Type 1)	7	2	7	5
NS Everett (Type 1)	5	5	6	3
NS Everett (Type 2)	2	1	6	
NS Everett (Type 4)	2	2	4	
NS Everett (Type 1)	2	2	5	3
NS Everett (Type 3)	4	2	3	
NS Everett (Type 5)	5	2	3	
Totals	**43**	**27**	**52**	**18**

Table 7: ECM Count - Table

Results: FirstFuel's RBAs identified 61% of the ECMs that the ASHRAE Level II audits found in the Type 1 buildings, which accounted for 16% more energy savings compared to the ASHRAE Level II audits in the same buildings. For the Type 2-5 buildings, FirstFuel's RBAs identified 65% of the ECMs that the ASHRAE Level II audits found, which accounted for 37% more savings compared to the savings found in the same onsite audits. The RBA also identified 18 ECMs that were not found in the Type I ASHRAE Level II audits, and a higher percentage of savings potential overall.

Reasons for ECMs not matching often was a result of different approaches to the audits. For example, in one audit, the ASHRAE Level II audit recommended implementing a supply air temperature reset strategy for each air handling unit. FirstFuel's RBA did not make this recommendation because of the humidity levels in the climate zone. In another case, the ASHRAE Level II audit recommendation de-lamping fixtures to reduce lighting density and installing motion sensors. The FirstFuel RBA for the same building did not include a lighting recommendation because based on the disaggregration, the lighting levels were found to be relatively low.

Accuracy of FirstFuel Models for Continuous Performance Monitoring:

FirstFuel demonstrated the value of our baseline model used for continuous performance monitoring by proving the accuracy of our predictions for 11 buildings (Types 1-5) compared to the buildings' actual consumption data. These buildings were selected because they represent the range of buildings in the sample set and they provided sufficient data from which to compare the predictions and actual performance data after the initial baseline period. FirstFuel's model used for continuous performance monitoring meets or exceeds the criteria established in ASHRAE Guideline 14. Guideline 14 was developed by ASHRAE to fill a need for a standardized set of energy (and demand) savings calculation procedures.

ASHRAE Guideline 14 is titled, "*Measurement of Energy and Demand Savings*" and it describes the procedures that are acceptable for measuring energy when evaluating buildings. This Guideline is based on the "*International Performance Measurement and Verification Protocol*" (IPMVP) which is the globally accepted standard for measuring energy savings. Per the ASHRAE Guideline, "*The purpose of this document is to provide guidelines for reliably measuring the energy and demand savings due to building energy management projects.*"

Guideline 14 comprises four different approaches and the approach the FirstFuel monitoring method falls under is the "Whole Building Performance" method. This approach utilizes meter data for the building as a whole, rather than a subset of building systems. Any change in energy use after one or more energy conservation measures (ECM) therefore is captured by evaluating the post measure consumption relative to how the building would have performed had the change(s) not been made.

To determine how the building would have performed had the ECM not been implemented requires the construction of a model using the pre-ECM energy use data. The Guideline does not prescribe how that model is to be constructed, but it does suggest independent variable selection and prescribes the metrics required to quantify how good the model output correlates to the actual consumption. To comply with the guideline the model uncertainty and bias error must be determined and must be within a prescribed tolerance band. It is up to the modeler to determine how the best model is to be constructed—the better the model, the smaller the uncertainty variable and smaller the bias.

Energy use in a building is generally impacted by two variables, occupancy and weather. Occupancy based load variances include lighting, plug or receptacle load, and depending on how the building is operated HVAC loads. When evaluating energy use on an hour by hour basis, the occupancy variable generally correlates well to day of the week and hour of the day. This is because people generally come and go at the same times for each type of day.

The independent variables in the FirstFuel model therefore are the type of day (weekday, Saturday, Sunday, or Holiday), the hour of the day, the dry bulb temperature, wet bulb temperature, wind velocity, and solar radiation (GHR). This data is used to create a multi-variable model which in turn accurately predicts the hourly electric consumption regardless of how the independent variables vary.

The quality of any model can be evaluated by using the same independent variables from the base period to predict the hourly energy use, and then comparing it to the actual measured use which is known. The Coefficient of Variation of the Root Mean Square Error (CV-RMSE) and Net Mean Bias Error (NMBE) are statistical performance values which the Guideline prescribes for determining the uncertainty and bias in any model.

The ASHRAE Guideline 14 prescribes Coefficient of Variation, CV (or CVRMSE-a measure of the uncertainty in the model) < 30% as a compliance criterion for hourly data for post-retrofit calibration. Additionally, ASHRAE Guideline 14 prescribes that the normalized mean bias error (or NMBE), is < 10% to be compliant for hourly data. For additional details on Monitoring and Verification methodologies, see Appendix D.

The table below presents a summary of the results of the 11 buildings analyzed. Note that in every case, the FirstFuel models are ASHRAE Guideline 14 compliant for the CVRMSE and NVBE measures. In fact, the results demonstrate far less uncertainty and a much lower bias than the ASHRAE thresholds, indicating the FirstFuel model is an excellent predictor of how a building uses energy hour by hour, regardless of weather conditions. Further, the important R^2 metric is in the range of 0.85 for all but two buildings, one of which is below a threshold R-Square of 0.75.

Building Name	CV-RMSE	NMBE	R^2
Everett Building 2000 Fleet HQ-Admin	18.89%	0.20%	0.86
Everett Building 2025 Galley	19.04%	0.10%	0.75
Everett Building 2026 BACHELOR ENLISTED QRTS I	13.52%	0.18%	0.49
Everett Building 2102 Redcom Northwest	21.30%	0.24%	0.84
Everett Building 2120 Fleet Region Readiness Ctr	17.62%	0.29%	0.81
Everett Building 2125 Port Operations	16.98%	0.17%	0.85
FB 2653 Child Development Center	11.74%	0.08%	0.86
Picatinny Building 65 Admin	14.93%	0.25%	0.91
Picatinny Building 92 Admin	26.13%	0.17%	0.86
Port Hueneme Building 1444 Admin Space	10.62%	0.01%	0.88
Everett Building 1980 Child Development Center	18.01%	0.19%	0.87

Table 8: Summary of model performance metrics

The two buildings with low R^2 metrics result because of the unpredictable nature of their occupancy, which can be attributed to the mission of the Naval Station Everett facility that

services ships of all sizes and accommodates their crews while ashore. The occupancy of the barracks fluctuates based on the number of sailors ashore and at times are empty. Likewise, the galley operation and loads fluctuates. Regardless of the poor R^2, the CV-RMSE and NMBE are within ASHRAE 14 Guidelines. The poor R^2 could be improved, if the daily number of sailors ashore could be obtained and incorporated in FirstFuel's models.

Performance Objective: FirstFuel will demonstrate the value of our baseline model used for continuous performance monitoring by proving the accuracy of our predictions for 11 buildings (Types 1-5) compared to the buildings' actual consumption data. These buildings were selected because they represent the range of buildings in the sample set and they had sufficient data.

Success Criteria: FirstFuel's model used for continuous performance monitoring meets or exceeds the criteria established in ASHRAE Guideline 14.

Results: FirstFuel's continuous performance monitoring met or exceeded this criterion.

Customer Satisfaction:

Performance Objective: FirstFuel will prove the customer value and satisfaction of FirstFuel's RBA platform compared to ASHRAE Level II onsite audits.

Success Criteria: 75% customer satisfaction compared to the Cadmus ASHRAE Level II site audits.

Results: Only one site responded to the survey provided. That site expressed satisfaction with the FirstFuel RBA approach compared to the ASHRAE Level II onsite audits, however, the results for this performance objective are considered inconclusive. Anecdotally, the FirstFuel approach also received positive feedback or expressions of interest and enthusiasm during the web-based Efficiency Planning Sessions, with few, if any, exceptions.

7.0 Cost Assessment

Since beginning the ESTCP demonstration, FirstFuel has advanced its analytics platform. The advancements include better capabilities and more commercial proof points working across 15 large utilities and government agencies. With the new platform, FirstFuel has updated names for each specific analytics product, or module. These names are as follows:

- **FirstAudit:** Building specific remote audits that deliver customized, actionable energy savings recommendations.
- **FirstMonitor:** Advanced predictive Analytics for efficiency savings monitoring, measuring, and alerting.
- **FirstPortfolio**: Advanced tools for managing building efficiency performance across portfolios.

FirstFuel's RBA platform costs typically range by the number of buildings that will be included in the project and by the buildings' size. The low end costs assume the installation has less than about 50 buildings participating in the FirstFuel RBA deployment and their sizes range from 20,000 to 100,000 gross square feet. The high range assumes that there are 100 buildings in the deployment, and they are between 50,000 and 300,000 gross square feet. On a per building basis, typical remote audits range between $1,000 and $7,000, depending on building size.

7.1 Cost Model

Item	Cost Element	Description	Estimated Costs 50-100 buildings
A	**FirstAudit Costs**	Costs to develop the FirstAudit report.	$50,000-$350,000
B	**Hardware capital costs**	None	$0
C	**Installation costs**	Labor to complete building data survey (about one hour), and Set-Up costs.	$14,000-$29,500
D	**Consumables**	None	$0
E	**Facility operational costs**	None	$0
F	**Annual FirstMonitor**	$1,000 per building per year	$0-100,000/yr.
G	**Maintenance & Support**	Annual Integrated Support $1,000 per building per year.	$50,000-$100,000/yr.
H	**Hardware lifetime**	None	$0
I	**Operator training**	None, Included in above	$0
J	**Salvage Value**	None	$0
K	**Estimated Total Cost of Deployment**	For Year 1	$114,00-$579,500

Table 9: Cost Model

7.2 Cost Drivers

In addition to the RBA platform costs, there are two additional cost drivers that should be considered when selecting FirstFuel's technology for future implementation: data collection and data security. The time and resources required to collect the buildings' data can be minimal, if the site's meter data management system is functional and well-understood. However, if the meter data collection is challenging or not well-understood, additional DoD resources may need to be devoted to data gathering. The second driver to be considered is data security & privacy. Should the DoD require the hosting of FirstFuel's servers behind a DoD firewall (or some other alternative), this will increase the costs and resources necessary to maintain the system.

7.3 Cost Analysis and Comparison

This technical paper illustrates the significant cost advantages that FirstFuel's RBA platform holds over traditional onsite audit methods. While ASHRAE Level II audits vary in terms of approach and rigor, FirstFuel's remote audit technology has been designed to replace these onsite evaluations under certain circumstances. The General Services Administration, for example, utilizes the FirstFuel RBA as an ASHRAE Level II replacement to meet their EISA 432 audit requirement. Rather than sending energy auditors onsite to walk through hundreds of buildings as a means to identify potential energy efficiency projects, which cannot scale, FirstFuel's RBA platform offers DoD installations a highly scalable approach to targeting and driving energy savings projects.

A DoD installation can expect to pay around $0.10-$0.15 a square foot for an ASHRAE Level II audit. FirstFuel's remote audits have been shown to cost significantly less, and have the potential to offer additional benefits, including a more interactive approach and ongoing engagement. Key interactive features not available from onsite audits include:

- Easy access via web portal by multiple stakeholders
- Updateable and easy to understand dynamic charts, graphs and analysis describing energy performance and ECMs
- Tracking of overall building performance over time
- Impact measurement of enacted ECMs
- ECM recommendation, personalized plan creation and documentation features

8.0 Implementation Issues

The biggest issue that FirstFuel encountered during the demonstration was selecting buildings that had sufficient quality meter data. In order to perform the remote analysis, FirstFuel relies on the building's actual consumption data for the entire assessment period (12 months). Often times, meter data would be requested, and the issues with the data would not be discovered until FirstFuel performed the standard Data QA checks. The most common data issues were as follows:

- Meters scaled incorrectly
- Data not properly labeled, and units unclear
- Zero readings
- Random recording resets
- Random Spikes (unrelated to real kW consumption)
- Negative readings
- Repeated readings
- Blank readings

Because the meter data issues were often not discovered until FirstFuel review the data, there was no way to go back and recover sufficient data for the particular buildings. As a result, time was added to the project to identify alternative buildings. Another issue was that sometimes facility personnel were unaware of how to interpret the data or how it was scaled. At many sites, the lack of a centralized resource for building meter data management made it challenging to address questions or issues with the meter data.

To gain better value out of the meters deployed across the DoD, FirstFuel recommends training personnel onsite to manage the meter data system. Furthermore, FirstFuel recommends the DoD adopt a standard across the branches for meter data collection and storage. The standardization may help to reduce the bottleneck of meter data collection efforts as well as the amount of concerns and questions regarding the integrity of the readings. In our professional opinion, these recommendations are important not just for the future success of the FirstFuel project, but for any endeavors seeking to obtain value from the advanced metering investments.

As site managers were made aware of the data discrepancies, they often asked what other installations were doing to address this prevalent issue. While researching solutions for the DoD, FirstFuel came across a United States Department of Energy document called *Metering Data Best Practices*: *A Guide to Achieving Utility Resource Efficiency*[11]. The most helpful and relevant section is "Chapter 6: Meter Communications and Storage" (see Appendix F). This

[11] Full report is available via the Federal Energy Management Program's website: http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf

section outlines meter data storage standards that are in line with FirstFuel's experience of "good" practices. FirstFuel specifically recommends that the DoD adopt the following key guidelines related to meter data recording and storage:

- Interval meter data (5, 15, 30, 60 minutes) be collected and stored for a period of at least 24 months
- Date/time/unit fields should be standard across all meters, buildings, and sites
- Data should be contained in a single, flat file
- Meter communications issues should signal an alert to facility or energy manager so blank values do not go undetected
- Meter database shall allow other applications to reach and access the data
- Applications that access the data should be straight-forward to allow non-technical users to monitor the building's consumption, and download and send files

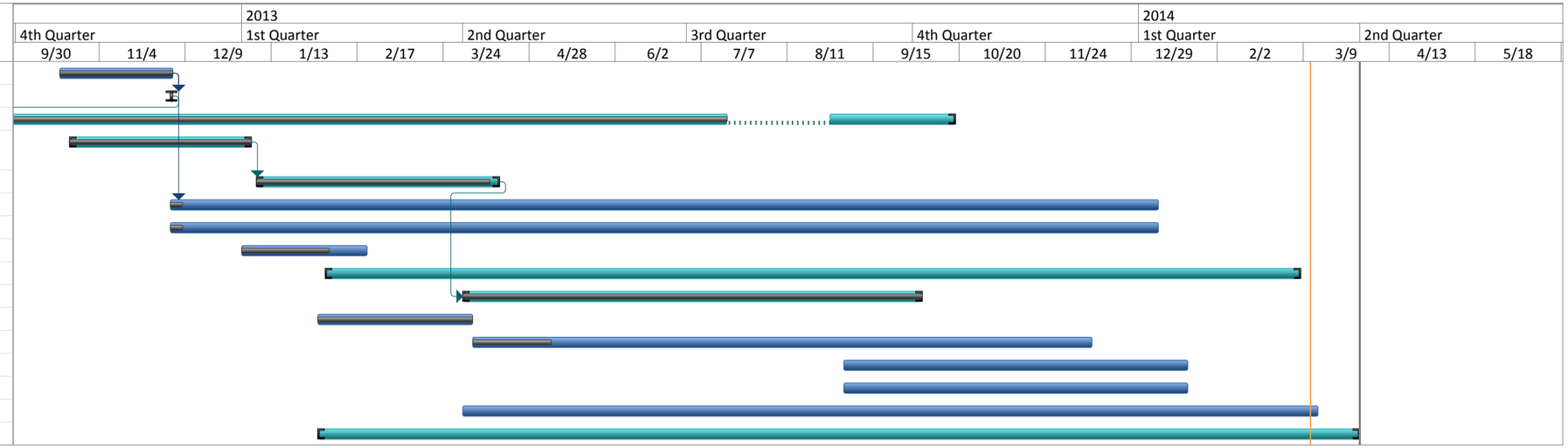
While the US General Services Administration (GSA) is not immune to data issues, our experience working with their buildings' data has been less prone to delays or roadblocks, thanks, in part, to their centralized management of the meter data collection. Resources throughout the GSA's energy division are trained on how to manage and interpret the building's advanced meter data, and as result issues with recordings are identified in a timely manner and FirstFuel is able to provide the GSA with high quality remote audits and monitoring with minimal time spent on Data QA. While the DoD may be constrained in adopting a policy that all branches can adhere to, standardizing the approach to meter data collection and meter data storage at least within the branches, will go a long way toward helping to achieve the full value of the advanced meter deployment.

Appendix A: Points of Contact

POINT OF CONTACT	ORGANIZATION	Phone	Role in Project
Swapnil Shah	FirstFuel Software	781-538-4560	Principal Investigator
Domenic Armano	FirstFuel Software	781-538-4541	Co-Investigator
Cara Giudice	FirstFuel Sofware	781-538-4544	Project Manager
Dave Korn	The Cadmus Group	617-673-7116	Principal
Allison Bard	The Cadmus Group	617-673-7264	Project Manager

Appendix B: Timeline of Activities

ID	Task Name	Duration	Start	Finish
1	Demonstration Plan Approval	32 days	Fri 10/19/12	Mon 12/3/12
2	Project Kick Off	1 day	Mon 12/3/12	Mon 12/3/12
3	Building Selection	288 days	Wed 8/1/12	Fri 10/18/13
4	Identify 16 Buildings for Cadmus ASHRAE LII Audits	54 days	Tue 10/23/12	Fri 1/4/13
5	Cadmus ASHRAE LII Audits- 6 buildings	71 days	Mon 1/7/13	Mon 4/15/13
6	Receive Data	288 days	Mon 12/3/12	Wed 1/8/14
7	Distribute Building Info Surveys	288 days	Mon 12/3/12	Wed 1/8/14
8	RBA- Type 1 Buildings	37 days	Tue 1/1/13	Wed 2/20/13
9	RBA Webinars	285 days	Mon 2/4/13	Fri 3/7/14
10	Cadmus ASHRAE LII Audits- 10 buildings	135 days	Mon 4/1/13	Fri 10/4/13
11	R&D for RBA on DoD Specific buildings	45 days	Fri 2/1/13	Thu 4/4/13
12	RBA- Type 2 buildings	180 days	Fri 4/5/13	Thu 12/12/13
13	RBA-Type 3 buildings	100 days	Tue 9/3/13	Mon 1/20/14
14	RBA-Type 4 buildings	100 days	Tue 9/3/13	Mon 1/20/14
15	RBA-Type 5 buildings	250 days	Mon 4/1/13	Fri 3/14/14
16	Ongoing remote montoring	302 days	Fri 2/1/13	Mon 3/31/14



Appendix C: Building Information Questionnaire

EW-201261 FirstFuel RBA Project- Building Survey

Building Information

Thank you for participating in the FirstFuel Rapid Building Assessment ESTCP Project (EW-201261). This survey is designed to aid our building engineers as they complete the remote assessment of your building.

Before you begin, a few notes:

1.The person completing the survey should be familiar with the building systems, including HVAC, lighting, ventilation, and other specific building loads.

2. The questionnaire is designed to fit a wide range of building types. If there are notes or specific features concerning the building that you believe are important to the building's energy assessment, please make sure to note them in the comments at the end of the survey.

3. Because we are including the time it takes to complete the survey in the total time of the FirstFuel Rapid Building Assessment, it is important that you **record the time it took to complete the survey.** Please enter the time it took to complete at the end of the survey.

4. A survey needs to be completed for each building that we are including in the project. If you have buildings that are exactly the same, then you may complete one survey for all of them, but please make sure to note it below.

For questions or comments please email us: support@firstfuel.com.

*What building(s) are you completing this survey for?

Site Name	
Building Number	
Building Name	

Note: If you have multiple buildings with the exact same characteristics (ex. 5 barracks constructed at the same time with the same equipment), then you may fill out one survey for all of them. Simply write in the box above all the building numbers applicable to your survey responses. At the end of the survey you will be able to provide additional building information if there notes about specific buildings that may be relevant for the remote building energy assessments.

Please enter the building latitude and longitude coordinates. If these are not readily available, please provide the street address.

*In case we have additional questions, please provide us with your contact information.

Name:	
Email Address:	
Phone Number:	

*What is this building used for?

EW-201261 FirstFuel RBA Project- Building Survey

*Building Construction

Year Originally Constructed

Year of Last Renovation

What % of the building's usable space was occupied in the past year?

On average, how many people are in the building when it is in use?

What is the gross square footage of the building?

Is this building occupied on the weekends?

- Yes
- No
- Sometimes

Additional weekend occupancy notes:

Heating

Please mark all applicable fuel sources.

*What is the primary fuel source for heating?

- Natural Gas
- Electric
- Propane
- #2 Fuel Oil
- #4 Fuel Oil
- #6 Fuel Oil
- District Steam
- District Hot Water
- Biomass
- None
- Unknown
- Other (please specify)

What percent of the building area is heated with this fuel source?

- ◯ 0
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

What is the <u>secondary</u> fuel source for <u>heating</u> (if any)?

- ☐ Natural Gas
- ☐ Electric
- ☐ Propane
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #6 Fuel Oil
- ☐ District Steam
- ☐ District Hot Water
- ☐ Biomass
- ☐ None
- ☐ Unknown
- ☐ Other (please specify)

What percent of the building area is heated with this fuel source?

- ◯ 0
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

Heating Equipment

Primary Heating Equipment:

- ◯ No Central Plant for Heating
- ◯ Condensing Boiler(s)-HW
- ◯ Cast Iron Sectional Boiler(s)- HW
- ◯ Cast Iron Sectional Boiler(s)- Steam
- ◯ Distrct Steam to Hot Water HX(s)
- ◯ District Hot Water
- ◯ Biomass Boiler(s)
- ◯ Electric Boiler(s)
- ◯ Ground Water
- ◯ Unknown
- ◯ Other (please specify)

What percentage of the parts of the building that are heated does this system serve?

- ◯ 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

Please indicate the age of the boiler (if applicable):

- ◯ N/A
- ◯ Less than 5 years
- ◯ 5-10 years
- ◯ 10-15 years
- ◯ Greater than 15 years

Pumping & Motor Speed

	None	Constant Speed	Variable Speed
Hot Water Pumps; Primary	◯	◯	◯
Hot Water Pumps; Secondary	◯	◯	◯
Ground Water Pumps	◯	◯	◯

Cooling Source

Percent of Area Cooled:

- ◯ 0
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

***What is the primary source for cooling?**

- ◯ None
- ◯ District Steam
- ◯ District Chilled Water
- ◯ Electric
- ◯ Natural Gas
- ◯ Unknown
- ◯ Other (please specify)

What percent of the building area is cooled with this source?

- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

What is the secondary source for cooling (if any)?

- ◯ None
- ◯ District Steam
- ◯ District Chilled Water
- ◯ Electric
- ◯ Natural Gas
- ◯ Unknown
- ◯ Other (please specify)

What percent of the building area is cooled with this source?

- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

Cooling Equipment

What is the type of primary cooling equipment?

- ◯ No Central Plant for Cooling
- ◯ Wet Cooling Tower for DX or Heat Pumps
- ◯ Chiller, Air Cooled Condenser
- ◯ Chiller, Wet Cooling Tower
- ◯ Chiller, Dry Coolers
- ◯ District Chilled Water
- ◯ Ground Water
- ◯ Unknown
- ◯ Other (please specify)

What percentage of the parts of the building that are cooled does this system serve?

- ◯ 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

If the building uses a chiller, how old is it?

- ◯ Less than 5 years
- ◯ 5-10 years
- ◯ 10-15 years
- ◯ Greater than 15 years

Pumping & Motor Speed

	None	Constant Speed	Variable Speed
Chilled Water Pumps; Primary	◯	◯	◯
Chiller	◯	◯	◯
Cooling Towers	◯	◯	◯
Chilled Water Pumps; Secondary	◯	◯	◯
Condenser Water Pumps	◯	◯	◯
Tower Water Pumps	◯	◯	◯
Ground Water Pumps	◯	◯	◯

Does the cooling plant utilize free cooling in the Winter (for example through a well-maintained economizer cycle)?

- ◯ No
- ◯ Heat Exchanger(s)
- ◯ Dry Cooler(s)

Building Automation System?

***Does your facility have a Building Automation System?**

- ◯ Yes
- ◯ No

If there is no Building Automation System...

If there is no Building Automation System how is the equipment started and stopped?

- ◯ Manually
- ◯ Time Clocks

Building Automation System Details

Approximately how old is the system?

- ◯ 1 year
- ◯ 2 years
- ◯ 3 years
- ◯ 4 years
- ◯ 5 years
- ◯ 6 years
- ◯ 7 years
- ◯ 8 years
- ◯ 9 years
- ◯ 10 years
- ◯ 11 years
- ◯ 12 years
- ◯ 13 years
- ◯ 14 years
- ◯ 15 years
- ◯ 15+ years

Has the workstation software been updated within the past 5 years?

- ◯ Never
- ◯ Two Years
- ◯ Five Years
- ◯ Don't know

Is the system connected to the internet?

- ◯ Yes
- ◯ No
- ◯ Don't Know

EW-201261 FirstFuel RBA Project- Building Survey

How are building systems controlled?

	N/A	Pneumatic	Electric or Electronic	*DDC not networked	*DDC networked
Boilers	◯	◯	◯	◯	◯
Hot Water Pumps	◯	◯	◯	◯	◯
Chillers	◯	◯	◯	◯	◯
Chilled Water Pumps	◯	◯	◯	◯	◯
Cooling Towers	◯	◯	◯	◯	◯
Air Handlers or Rooftop Units	◯	◯	◯	◯	◯
Exhaust Fans	◯	◯	◯	◯	◯
Terminal Units	◯	◯	◯	◯	◯
VAV Boxes	◯	◯	◯	◯	◯
Unit Ventilators	◯	◯	◯	◯	◯
Fan Coil Units	◯	◯	◯	◯	◯
Heat Pumps	◯	◯	◯	◯	◯
Baseboard Radiation	◯	◯	◯	◯	◯
Computer Room Air Conditioners	◯	◯	◯	◯	◯
Lighting	◯	◯	◯	◯	◯

***DDC = Direct Digital Controls**

Select the features your Building Automation System uses:

	Yes	No	N/A	Don't know
Equipment Scheduling	◯	◯	◯	◯
Optimal Start	◯	◯	◯	◯
Night Setback	◯	◯	◯	◯
Enthalpy Control	◯	◯	◯	◯
Static Pressure Reset	◯	◯	◯	◯
Chilled Water Reset	◯	◯	◯	◯
Chiller Plant Optimization	◯	◯	◯	◯
Condenser Water Reset	◯	◯	◯	◯

Air Handling Equipment

Please all mark applicable equipment

Type of Air Handler?

- ☐ None
- ☐ Roof-Top Unit(s), No Return Fan
- ☐ Roof-Top Unit(s), Return Fan
- ☐ Air Handling Unit(s), No Return Fan
- ☐ Air Handling Unit(s), Return Fan
- ☐ Dedicated Outdoor Air System
- ☐ Unknown

Percent of Building Served

- ○ 0%
- ○ 10%
- ○ 20%
- ○ 30%
- ○ 40%
- ○ 50%
- ○ 60%
- ○ 70%
- ○ 80%
- ○ 90%
- ○ 100%

Approximate Number of Units

☐

Fan Motor Control

	Unknown	Constant Volume	Multi-Speed	Variable Volume
Supply	○	○	○	○
Return	○	○	○	○

Heating

- ◯ None
- ◯ Hot Water Coils
- ◯ Steam Coils
- ◯ Direct Fired Heater(s)
- ◯ Electric Duct Heating Coil(s)
- ◯ Unknown

Cooling:

- ◯ None
- ◯ DX, Air Cooled Condenser
- ◯ DX w/Evap Condensing
- ◯ DX w/Condenser Water
- ◯ Chilled Water
- ◯ Unknown

Do any units have Economizer Cycles?

- ◯ No
- ◯ Air Side
- ◯ Water Side

Do any units have Heat Recovery?

- ◯ Yes
- ◯ No

Interior and Perimeter Space Conditioning

Please mark applicable equipment

Terminal Units

	Interior Spaces	Perimeter Spaces	None
Baseboard Radiation (Electric)	◯	◯	◯
Baseboard Radiation (Hot Water/Steam)	◯	◯	◯
Unit Ventilator (Hot Water/Steam)	◯	◯	◯
Unit Ventilator (Chilled Water)	◯	◯	◯
Unit Ventilator (DX)	◯	◯	◯
Fan Coil Units (2-Pipe)	◯	◯	◯
Fan Coil Units (4-Pipe)	◯	◯	◯
VAV Boxes with Reheat	◯	◯	◯
VAV Boxes without Reheat	◯	◯	◯
Fan Powered Boxes with Reheat	◯	◯	◯
Fan Powered Boxes without Reheat	◯	◯	◯
Window AC Units	◯	◯	◯
DX Split System	◯	◯	◯
Heat Pump(s)	◯	◯	◯
Direct Fired Unit-Heater(s)	◯	◯	◯
Personal Space Heater(s)	◯	◯	◯
Electric Unit-Heater(s)	◯	◯	◯
Steam Unit Heater(s)	◯	◯	◯
Induction Units	◯	◯	◯
Unknown	◯	◯	◯

Other (please specify)

Centralized IT Areas

How large is the building's data center or computer server room? (please enter number of square feet)

Number of Servers

What cooling equipment is used ONLY for the data center?

- [ ] Building Air Conditioning System
- [ ] Dedicated Computer Air Conditioner with DX
- [ ] Dedicated Computer Air Conditioner with Chilled Water
- [ ] Split System

Capacity (Tons)

Plug/Receptical Load

Please indicate the predominant type of computers in the building

- ( ) Desktop with LCD monitor
- ( ) Desktop with CRT Monitor
- ( ) Laptops
- ( ) Laptops with LCD monitor
- ( ) Other (please specify)

What percentage of people in the building have computers? (Number can be higher than 100% if some people have more than one)

- ◯ 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%
- ◯ 110%
- ◯ 120%
- ◯ 140%
- ◯ 150%
- ◯ 160%
- ◯ 170%
- ◯ 180%
- ◯ 190%
- ◯ 200%

Do people use electric space heaters?

- ◯ Yes
- ◯ No

Do the majority of occupants use task/desk lighting?

- ◯ Yes
- ◯ No

Please describe any additional electrical appliances used in the building.

Dining Facility?

***Does your building include a dining facility?**

- ◯ Yes
- ◯ No

Dining Facility Information

***How many meals are served per day?**

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4+

Are there different meal schedules on the weekends? If so, please explain.

What types of fuel do you use for cooking equipment? (You can chose more than one if necessary)

- ☐ Gas
- ☐ Propane
- ☐ Electric

Exhaust Hoods?

***Does the kitchen have exhaust hoods?**

- ◯ Yes
- ◯ No
- ◯ Don't Know

Exhaust Hoods

How are the exhaust hoods controlled?

- ◯ Manual On/Off
- ◯ Timer
- ◯ Sensors

Do you have a dishwasher?

☐

Dishwasher

Does the dishwasher have booster heaters?

- ◯ Yes
- ◯ No

Booster Heaters?

Are the booster heaters gas or electric?

- ◯ Gas
- ◯ Electric

Indoor Lighting

Please select all that are applicable

Date of last Retrofit/Upgrade--INDOOR LIGHT FIXTURES

- ◯ None
- ◯ 2012
- ◯ 2011
- ◯ 2010
- ◯ 2009
- ◯ 2008
- ◯ 2007
- ◯ 2006
- ◯ 2005
- ◯ 2004
- ◯ 2003
- ◯ 2002
- ◯ 2001
- ◯ 2000
- ◯ 1999
- ◯ 1998
- ◯ 1997
- ◯ 1996
- ◯ 1995
- ◯ 1994
- ◯ 1993
- ◯ 1992
- ◯ 1991
- ◯ 1990

Notes or comments regarding the upgrade/retrofit?

Fixture Type-INDOOR LIGHT FIXTURES

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Super T-8 "Fluorescent, 1 inch diameter tube" (25W)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
T-8 "Fluorescent, 1 inch diameter tube" (28W)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
T-8 "Fluorescent, 1 inch diameter tube" (32W)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
T-12 "Fluorescent, 1 1/2 inch diameter tube"	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
High Output T-5 "Fluorescent, 5/8 inch diameter tube"	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Incandescent	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CFL	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LED	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Indoor Fixture Control (please check all that apply):

- ☐ None
- ☐ Manual Switch
- ☐ Time Clocks
- ☐ Day Lighting
- ☐ Motion Sensing
- ☐ Building Automation System
- ☐ Daylighting

Parking?

*Do you have a parking lot or garage associated with the building's electricity meter(s)?

- ◯ Yes
- ◯ No

Exterior Parking Lot

***Do you have an exterior parking lot?**

- ◯ Yes
- ◯ No

Exterior Parking Lot Details

Total square footage of exterior parking lot?

What amount (if any) of the total parking area is included in the Building Area (gsf, nsf or rsf) that you entered earlier?

Please indicate the type of the light fixtures:

	% of Parking Lot Served
None	
High-pressure sodium	
Metal Halide	
Induction	
LED	
Florescent	

How are the outdoor parking lights controlled? (Select any that may apply)

- ☐ None
- ☐ Day Lighting
- ☐ Occupancy Control
- ☐ Building Management System
- ☐ Manual Switch
- ☐ Timeclocks

When were these outdoor parking lot light fixtures last upgraded/retrofit?

Notes/Comments

Additional Parking?

***Is there a parking garage associated with the building's electricity meter(s)?**

- Yes
- No

Exterior Parking Garage

***Do the building have an exterior parking garage associated with the building's meter(s)?**

- Yes
- No

Exterior Parking Garage Details

Total square footage of exterior garage?

What amount (if any) of the total parking area is included in the Building Area (gsf, nsf or rsf) that you entered earlier?

Please indicate the type of the light fixtures:

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
None											
High-pressure sodium											
Metal Halide											
Induction											
LED											
Florescent											

How are the parking structure lights controlled?
(Select any that may apply)

- ☐ None
- ☐ Day Lighting
- ☐ Occupancy Control
- ☐ Building Management System
- ☐ Manual Switch
- ☐ Timeclocks

When were these parking structure light fixtures last upgraded/retrofit?

○ None	○ 1997	○ 2005
○ 1990	○ 1998	○ 2006
○ 1991	○ 1999	○ 2007
○ 1992	○ 2000	○ 2008
○ 1993	○ 2001	○ 2009
○ 1994	○ 2002	○ 2010
○ 1995	○ 2003	○ 2011
○ 1996	○ 2004	○ 2012

Notes/Comments

Indoor Parking?

***Does the building have an indoor parking garage?**

- ○ Yes
- ○ No

Indoor Parking Lot Details

Total square footage of the indoor parking lot?

What amount (if any) of the total parking area is included in the Building Area (gsf, nsf or rsf) that you entered earlier?

Please indicate the type of the light fixtures:

	% of Parking Lot Served
None	
High-pressure sodium	
Metal Halide	
Induction	
LED	
Florescent	

How are the indoor parking lights controlled?

- ☐ None
- ☐ Day Lighting
- ☐ Occupancy Control
- ☐ Building Management System
- ☐ Manual Switch
- ☐ Timeclocks

When were these indoor parking lot light fixtures last upgraded/retrofit? (if applicable)

Notes/Comments

Alternative Energy?

***Is there alternative energy generated onsite (e.g. CHP, solar, wind etc)?**

- ○ Yes
- ○ No

Alternative Energy Details

Alternative Energy Source:

- ◯ Solar PV
- ◯ Solar Thermal
- ◯ Wind
- ◯ Congeneration
- ◯ Ice Storage
- ◯ Combined Heat and Power
- ◯ Fuel Cell

Size (please indicate units)

Please note any additional alternative energy source(s):

Size (include units) of additional alternative energy source?

Conclusion

Has the building undergone any retrofits in the past five years?

- ◯ Yes
- ◯ No

Conclusion 2

Please describe any recent retrofits.

Please add any additional information you think may be important to know about your building

EW-201261 FirstFuel RBA Project- Building Survey

***Please indicate how many minutes it took to complete this survey.**

Appendix D: Overview of Monitoring and Verification Methodologies: Options A, B, C and D

M&V Guidelines: Measurement and Verification for Federal Energy Projects

Version 3.0

FEMP

www.eere.energy.gov/femp

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

M&V Guidelines:
Measurement and Verification for Federal Energy Projects
Version 3.0

Prepared For:
U.S. Department of Energy
Federal Energy Management Program
www1.eere.energy.gov/femp/

Prepared By:
Nexant, Inc.
1401 Walnut Street, Suite 400
Boulder, CO 80302
Tel: 303.402.2480
www.nexant.com

Under Subcontract To:
EMP2, Inc.
www.emp2.com

April 2008

4.1 OVERVIEW OF M&V OPTIONS A, B, C, AND D

The measurement and verification (M&V) protocol mandated for projects conducted under the Super Energy Savings Performance Contract (Super ESPC) is the Federal Energy Management Program (FEMP) M&V Guidelines: Measurement and Verification for Federal Energy Projects. The FEMP Guidelines are an application of the International Performance Measurement and Verification Protocol[5] (IPMVP). Both of these guidelines group M&V methodologies into four general categories: Options A, B, C, and D. The options are generic M&V approaches for energy and water saving projects.

M&V approaches are divided into two general types: retrofit isolation and whole-facility. Retrofit isolation methods look only at the affected equipment or system independent of the rest of the facility; whole-facility methods consider the total energy use and de-emphasize specific equipment performance. One primary difference in these approaches is where the boundary of the energy conservation measure (ECM) is drawn, as shown in Figure 4-1. All energy used within the boundary must be considered. Options A and B are retrofit isolation methods; Option C is a whole-facility method; Option D can be used as either, but is usually applied as a whole-facility method.

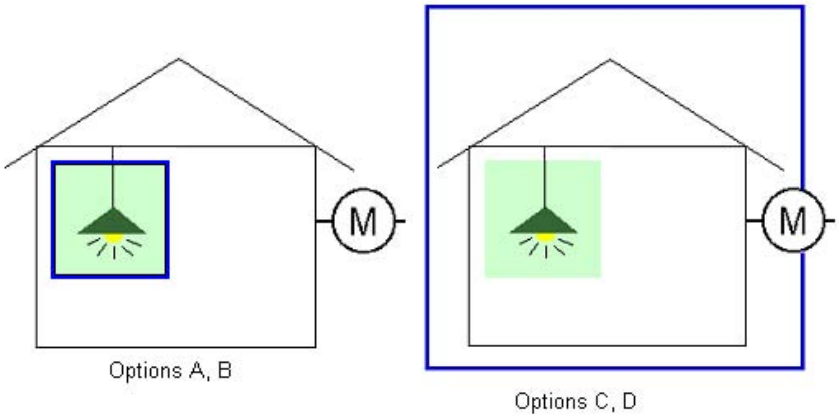


Figure 4-1 Retrofit Isolation (Options A and B) vs Whole-Facility M&V Methods (Options C and D)

The four generic M&V options are summarized in Table 4-1 and described in more detail below. Each option has advantages and disadvantages based on site-specific factors and the needs and expectations of the agency (see Chapter 5). While each option defines an approach to determining savings, it is important to realize that savings are not directly measured, and all savings are estimated values. The accuracy of these estimates, however, will improve with the number and quality of the measurements made. Although not required in Super ESPC projects, the accuracy of savings estimates can be quantified, as discussed in Section 5.4.

[5] *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings Volume I*, EVO-10000 -1.2007, Efficiency Valuation Organization.

Table 4-1 Overview of M&V Options A, B, C, and D

M&V Option	Performance[1] and Usage[2] Factors	Savings Calculation
Option A—Retrofit Isolation with Key Parameter Measurement	This option is based on a combination of measured and estimated factors when variations in factors are not expected. Measurements are spot or short-term and are taken at the component or system level, both in the baseline and post-installation cases. Measurements should include the key performance parameter(s) which define the energy use of the ECM. Estimated factors are supported by historical or manufacturer's data. Savings are determined by means of engineering calculations of baseline and post-installation energy use based on measured and estimated values.	Direct measurements and estimated values, engineering calculations and/or component or system models often developed through regression analysis Adjustments to models are not typically required.
Option B—Retrofit Isolation with All Parameter Measurement	This option is based on periodic or continuous measurements of energy use taken at the component or system level when variations in factors are expected. Energy or proxies of energy use are measured continuously. Periodic spot or short-term measurements may suffice when variations in factors are not expected. Savings are determined from analysis of baseline and reporting period energy use or proxies of energy use.	Direct measurements, engineering calculations, and/or component or system models often developed through regression analysis Adjustments to models may be required.
Option C – Utility Data Analysis	This option is based on long-term, continuous, whole-building utility meter, facility level, or sub-meter energy (or water) data. Savings are determined from analysis of baseline and reporting period energy data. Typically, regression analysis is conducted to correlate with and adjust energy use to independent variables such as weather, but simple comparisons may also be used.	Based on regression analysis of utility meter data to account for factors that drive energy use Adjustments to models are typically required.
Option D—Calibrated Computer Simulation	Computer simulation software is used to model energy performance of a whole-facility (or sub-facility). Models must be calibrated with actual hourly or monthly billing data from the facility. Implementation of simulation modeling requires engineering expertise. Inputs to the model include facility characteristics; performance specifications of new and existing equipment or systems; engineering estimates, spot-, short-term, or long-term measurements of system components; and long-term whole-building utility meter data. After the model has been calibrated, savings are determined by comparing a simulation of the baseline with either a simulation of the performance period or actual utility data.	Based on computer simulation model (such as eQUEST) calibrated with whole-building or end-use metered data or both. Adjustments to models are required.

[1] Performance factors indicate equipment or system performance characteristics, such as kW/ton for a chiller or watts/fixture for lighting.

[2] Operating factors indicate equipment or system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting.

4.2 DEVELOPING REGRESSION MODELS

All M&V options utilize models to predict the baseline and performance period energy use of the project or ECM based on the behavior of the appropriate independent variables. An independent variable is a parameter that is expected to change regularly and has a measurable effect on the energy use of a system or building. The models used to predict energy use, with the exception of Option D which utilizes simulation software, are often mathematical equations derived through regression analysis that incorporate key independent variables. Regression models involve an

evaluation of the energy behavior of a facility or system to determine how it relates to one or more independent variables (e.g., weather, occupancy, production rate). Regression models are a technique often used to adjust baseline or performance period energy use to account for changes in weather, occupancy, or other factors between the baseline and performance periods. Proper applications of these routine adjustments are discussed in Section 5.2.

IPMVP 2007 Appendix B-2 and ASHRAE Guideline 14-2002 Annex D both have additional details on developing models by means of regression analyses as well as techniques for validating these models.

4.2.1 Independent Variables

An independent variable is a parameter that is expected to change regularly and has a measurable effect on the energy use of a system or building. Typical independent variables that drive energy consumption that can be incorporated in regression models include outdoor temperature, other weather parameters (e.g., heating or cooling degree days), occupancy, operating hours, and other variable site conditions.

Data on independent variables may be from a third party or may be tracked using onsite data collection, depending on their nature. Weather data are typically more reliable when supplied by an independent source, but should be validated with site data to ensure applicability.

Once the data have been collected, the mathematical model that is used to predict the baseline (or performance period) energy use is developed. The model should make intuitive sense—the independent variables should be reasonable and the coefficients should have the expected sign (positive or negative) and be within an expected range or magnitude.

4.2.2 Choosing a Model

There are various forms of models used in standard statistical practice. Examples of multi-variant regression models are included in IPMVP 2007 and ASHRAE Guideline 14.

One example of a linear multi-variant regression model for a weather-dependent ECM is shown in Equation 4-1 below. In models using weather data, it can be beneficial to define a custom temperature base for calculating HDD and CDD data based on the actual behavior of the building.[6]

Equation 4-1: Multi-Variant Regression Model for a Weather-Dependent ECM

$$E = B_1 + (B_2 \times T_i - T_{i-1})) + (B_3 \times HDD_i) + (B_4 \times CDD_i) + (B_5 \times X_1) + (B_6 \times X_2) + (B_7 \times X_3)$$

where:

E	=	energy use
i	=	index for units of time for period
$B_{1\text{-}7}$	=	coefficients
T	=	ambient temperature
HDD	=	heating degree days using a base temperature of 60°F

[6] 2005 ASHRAE Handbook - Fundamentals, page 32.17.

CDD = cooling degree days using a base temperature of 65°F
X_n = independent steady-state variables

It is important that the best model type be used, which in turn will depend on the number of independent variables that affect energy use and the complexity of the relationships. Finding the best model often requires testing several models and comparing their statistical results. The number of coefficients should be appropriate for the number of observations. Similarly, the form of the polynomial should be suitable to number of independent variables. Additionally, the independent variables must be truly independent of one another. The model should be tested for possible statistical problems (e.g., autocolinearity[7]) and corrected.

Validation steps should include checks to make sure that statistical results meet acceptable standards. The statistical requirements outlined in Table 4-2 are examples of validation standards for mathematical models using typical statistical indicators. An example application of these indices is included in the Standard M&V Plan for Chiller Replacements (Appendix H). The statistical validity of models can be demonstrated using other published sources such as ASHRAE Guideline 14-2002. Specific goals should be set for validating mathematical models used in each project based on suitable levels of effort (see Chapter 5) and should be specified in the M&V Plan. Many analysis tools provide some of these statistical results, while others will need to be calculated.

Table 4-2 Statistical Validations Guidelines

Parameter Evaluated	Abbreviation	Suggested Acceptable Values	Purpose
Coefficient of determination	R^2	> 0.75	Indicates model's overall ability to account for variability in the dependent variable. Lower R^2 values may indicate independent variables may be missing or additional data is needed.
Coefficient of variation of root-mean squared error	C_V(RSME)	< 15%	Calculates the standard deviation of the errors, indicating overall uncertainty in the model
Mean Bias Error	MBE	+/- 7%	Overall indicator of bias in regression estimate. Positive values indicate higher than actual values; negative values indicate that regression under-predicts values.
t-statistic	t-stat	> 2.0	Absolute value >2 indicates independent variable is significant

4.2.3 Weather Data

If the energy savings model incorporates weather data, several issues should be considered:

- The relationship between temperature and energy use may vary depending upon the time of year. For example, an ambient temperature of 55°F in January has a different implication for energy usage than the same temperature in August. Thus, seasons may need to be addressed in the model.
- The relationship between energy use and weather may be nonlinear. For example, a 10°F change in temperature may result in a very different energy use impact if that change is from 75°F to 85°F rather than 35°F to 45°F.

[7] Autocolinearity can result when one or more important independent variables were left out of the model.

- Matching degree-day and other data with billing start and end dates.

4.2.4 Documentation

All models should be thoroughly documented including specifying model limits. Ideally, the range of values of the independent variables used to create the model span the entire range of possible conditions. Models are generally good only for the range of independent variables used in creating the regression model.

The criteria used for identifying and eliminating any available data must be documented. Outliers are data beyond the expected range of values (or two to three standard deviations away from the average of the data). The elimination of outliers, however, should be justified by abnormal or specific mitigating factors. If a reason for the unexpected data cannot be found, the data should be included in the analysis. Outliers should be defined using common sense as well as common statistical practice.

4.2.5 Savings Determination

In general, the procedure for determining energy savings with a regression model is as follows:

- Develop and validate an appropriate baseline model relating the baseline energy use during normal operations to key independent variables.
- Install ECMs and continuously measure the independent variables used in the baseline model. along with any additional variables that may be needed for performance period model development.
- Using the baseline model, estimate what the energy use would have been without the ECMs by driving the baseline model with the performance period weather or other independent variables.
- Calculate savings by comparing the predicted baseline energy use with the actual energy use of the performance period.

An alternative approach that is sometimes warranted includes creating a separate regression model to describe performance period energy use. Both the baseline and performance period models are then adjusted to the same period's conditions prior to comparison. This approach allows for calculation of normalized savings[8] based on a predefined set of parameters, such as typical weather. All independent variables and criteria for validating performance period models should be included in the M&V Plan.

The best regression model is one that is simple and yet produces accurate and repeatable savings estimates. Determining the best model often requires testing several models to find one that is easy enough to use and meets statistical requirements for accuracy (see Section 4.2).

[8] See Section 7.2.

4.3 OPTION A—RETROFIT ISOLATION WITH KEY PARAMETER MEASUREMENT

M&V Option A involves a retrofit or system level M&V assessment. The approach is intended for retrofits where key performance factors (e.g., end-use capacity, demand, power) or operational factors (e.g., lighting operational hours, cooling ton-hours) can be spot- or short-term-measured during the baseline and post-installation periods. Any factor not measured is estimated based on assumptions, analysis of historical data, or manufacturer's data.

All end-use technologies can be verified using Option A. However, the accuracy of this option is generally inversely proportional to the complexity of the measure. Thus, the savings from a simple lighting retrofit will typically be more accurately estimated with Option A than the savings from a more complicated chiller retrofit. If greater accuracy is required, Options B, C, or D may be more appropriate. Properly applied, an Option A approach:

- Ensures that baseline conditions have been properly defined
- Confirms that the proper equipment/systems were installed and that they have the potential to generate predicted savings
- Verifies that the installed equipment/systems continue to have the capacity to yield the predicted savings during the term of the contract

Option A can be applied when identifying that the potential to generate savings is the most critical M&V issue, including situations where:

- The magnitude of savings is low for the entire project or a portion of the project to which Option A is applied.
- The risk of not achieving savings is low.
- The independent variables that drive energy use are not difficult or expensive to measure, and are not expected to change.
- Interactive effects can be reasonably estimated or ignored
- Long-term measurements are not warranted
- The agency is willing to accept some uncertainty

4.3.1 Approach to Option A

Option A is an approach designed for projects in which the potential to generate savings must be verified, but the actual savings can be determined from short-term measurements, estimates, and engineering calculations. Performance period energy use is not measured throughout the term of the contract. Performance period energy use and baseline energy use are predicted using an engineering or statistical analysis of information that does not involve long-term measurements.

With Option A, savings are determined by measuring the key parameters such as capacity, efficiency, or operation of a system before and after a retrofit, and by multiplying the difference by an estimated factor. Using estimates is the easiest and least expensive method of determining savings. It can also be the least accurate and is typically the method with the greatest uncertainty in savings. This level of savings determination may suffice for certain types of projects where a single factor represents a significant portion of the savings uncertainty.

Option A is appropriate for projects in which both parties agree to a payment stream that is not subject to fluctuation due to changes in the operation or performance of the equipment. However, payments could be subject to change based on periodic measurements or non-routine adjustments.

4.3.1.1 Measurements

Within Option A, various methods and levels of accuracy determining savings are available. The level of accuracy depends on what measurements are made to verify equipment ratings, capacity, operating hours, and/or efficiencies; the quality of assumptions made; and the accuracy of the equipment inventory including nameplate data and quantity of installed equipment. There may be sizable differences between published information and actual operating data. Where discrepancies exist or are believed to exist, field-operating data should be obtained.

A key consideration in implementing Option A is identifying the parameters that will be measured and those that will be estimated. The key performance parameter(s) that the ESCO is responsible for should be measured in both the baseline and performance period cases, and savings should be calculated from these values. For example, the watts/fixture is the key performance parameter for a lighting retrofit.

Other parameters that affect energy use (e.g., operating hours) that the agency or no one controls, can be estimated and then stipulated in the contract. Where these other parameters are not known with sufficient certainty, they should be measured in the baseline case and then stipulated. The penalty associated with low accuracy is not achieving the estimated savings and the associated utility bill cost reductions. Appropriate sources of estimated values are discussed below.

4.3.1.2 Estimates

The estimated parameters will affect the reported savings over the entire contract term. All estimates should be based on reliable, documentable sources and should be known with a high degree of confidence. While direct measurements from short-term logging or existing EMCS records are the preferred information source, such information may not be available or may be costly to obtain. Sources of information on which estimations should be based include the following (in decreasing order of preference):

- Models derived from measurements and monitoring
- Manufacturer’s data or standard tables (such as lighting tables used in utility demand-side management programs)
- Manufacturer’s curves, such as pump, fan, and chiller performance curves
- Industry-accepted performance curves, such as standards published by the American National Standards Institute (ANSI), American Refrigeration Institute (ARI), and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
- Typical Meteorological Year (TMY) weather data
- Observations of building and occupant behavior
- Facility operations and maintenance logs

Estimated parameters should *not* come from the following:

- Undocumented assumptions or "rules-of-thumb"
- Proprietary "black-box" algorithms or other undocumented software
- Handshake agreements with no supporting documentation
- Guesses at operating parameters
- Equations that do not make mathematical sense or are derived from questionable data

4.3.1.3 Ongoing Verification

The potential to generate savings may be verified through spot/short-term metering and inspections conducted immediately before and immediately after installation. Annual (or some other regular interval) inspections must be conducted to verify that the proper equipment/systems are installed and the equipment/systems are performing to specification. If conditions have changed, additional performance period measurements or non-routine adjustments may be appropriate.

4.3.2 M&V Considerations

Option A is for projects in which the potential to generate savings must be verified and actual savings can be determined from short-term measurements, estimates, and engineering calculations. Some considerations when using Option A approaches include:

- Option A methods can vary in the level of accuracy in determining savings and verifying performance. The level of accuracy depends on the validity of estimates, the quality of the equipment inventory, and the measurements that are made.
- Verifying proper ongoing operation and potential to perform is an important aspect of Option A.
- Option A is appropriate for relatively simple ECMs whose baseline and post-installation conditions (e.g., equipment quantities and ratings such as lamp wattages or motor kW) represent a significant portion of the uncertainty associated with the project.
- Option A methods are not suitable for ECMs whose performance is uncertain or unpredictable.

4.4 OPTION B—RETROFIT ISOLATION WITH ALL PARAMETER MEASUREMENT

M&V Option B is a retrofit isolation or system-level approach. The approach is intended for retrofits with performance factors (e.g., end-use capacity, demand, power) and operational factors (lighting operational hours, cooling ton-hours) that can be measured at the component or system level and where long-term performance needs to be verified. It is similar to Option A, but uses periodic or continuous metering of all energy quantities, or all parameters needed to calculate energy, during the performance period. This approach provides the greatest accuracy in the calculation of savings, but increases the performance-period M&V cost.

The Option B approach ensures the same items as Option A, but also:

- Determines energy savings using periodic or continuous measurement of energy use or all parameters needed to calculate energy use during the term of the contract.

Option B is typically used when any or all of these conditions apply:

- For simple equipment replacement projects with energy savings that are less than 20% of total facility energy use as recorded by the relevant utility meter or sub-meter (Option C is not applicable)
- When energy savings values per individual measure are desired
- When interactive effects can be estimated using methods that do not involve long-term measurements
- When the independent variables that affect energy use are not complex and excessively difficult or expensive to monitor
- When operational data on the equipment is available through control systems
- When sub-meters already exist that record the energy use of subsystems under consideration (e.g., a separate sub-meter for heating ventilation and air-conditioning (HVAC) systems)

4.4.1 Approach to Option B

Option B verification procedures involve the same items as Option A, but require more end-use metering. Option B relies on the physical assessment of equipment change-outs to ensure that the installation is to specification. The potential to generate savings is verified through observations, inspections, and spot/short-term/continuous metering of energy or proven proxies of energy use, such as variable frequency drive speed for motor power. Baseline models are typically developed by correlating metered energy use with key independent variables. Depending on the ECM, spot or short-term metering may be sufficient to characterize the baseline condition, and the continuous metering of one or more variables may occur after retrofit installation. It is appropriate to use spot or short-term measurements in the performance period to determine energy savings when variations in performance are not expected, and may support some normalized savings approaches (Section 7.2) though adjustments to the baseline and/or the performance period model(s). When variations are expected, it is appropriate to measure factors continuously during the contract period. Continuous monitoring of information can be used to improve or optimize the operation of the equipment over time, thereby improving the performance of the retrofit.

4.4.2 M&V Considerations

Option B is for projects in which the potential to generate savings must be verified and actual energy use during the contract term needs to be measured for comparison with the baseline model for calculating savings. Option B involves procedures for verifying the same items as Option A plus the determination of energy savings during the contract term through short-term or continuous end-use metering. Some considerations when using Option B approaches include:

- All end-use technologies can be verified with Option B; however, the degree of difficulty and costs associated with verification increases as metering complexity increases.

- The task of measuring or determining energy savings using Option B can be more difficult and costly than that of Option A. However, results are typically more precise using Option B than the use of estimations as defined for Option A.
- Periodic spot or short-term measurements of factors are appropriate when variations in loads and operation are not expected. When variations are expected, it is appropriate to measure factors continuously.
- Performing continuous measurements or periodic measurements over the term of the contract will account for operating variations and will result in closer approximations of actual energy savings. Continuous measurements provide long-term persistence data on the energy use of the equipment or system.
- Data collected for energy savings calculations can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the retrofit. For constant-load retrofits, however, there may be no inherent benefit of continuous over short-term measurements.

4.5 OPTION C—WHOLE-BUILDING DATA ANALYSIS

M&V Option C involves whole-facility utility or sub-meter data analysis procedures to verify the performance of retrofit projects in which whole-facility baseline and performance period data are available. Option C usually involves collecting historical whole-facility baseline energy use and related data and continuously measuring whole-facility energy use after ECM installation. Baseline and periodic inspections of the equipment are also needed. Energy savings under Option C are estimated by developing statistically representative models of whole-facility or sub-metered energy consumption (i.e., therms and/or kWh). This method confirms total energy savings, but does not measure the savings from individual components.

In general, Option C should be used with complex equipment replacement and controls projects for which predicted savings are relatively large, i.e., greater than about 10% to 20% of the site's energy use, on a monthly basis. Option C regression methods are valuable for measuring interactions between energy systems or determining the impact of projects that cannot be measured directly, such as insulation or other building envelope measures. Regression analysis requires experienced, qualified analysts, and Option C methods should be employed only for projects that meet the following requirements:

- Savings are predicted to be greater than about 10% to 20% of the overall consumption measured by the utility or sub-meter.
- At least 12 and preferably 24 months or more of pre-installation data are used to calculate a baseline model.
- At least 9 and preferably 12 months of performance period data are used to calculate annual savings.
- Adequate data on independent variables are available to generate an accurate baseline model, and procedures are in place to track the variables required for performance period models.

- Significant operational or other changes are not planned for the facility during the performance period, and procedures are in place to document changes that do occur at the site.

4.5.1 Approach to Option C

With Option C, energy savings are determined using whole-building utility meter or facility-level metered data. Savings are determined through analysis of utility data (therms, fuel oil, kW, kWh, etc.) and the independent variables that affect energy consumption. Regression models are developed to predict energy use based on the appropriate independent variables for the project. Although simple mathematical techniques utilizing utility bill comparison are sometimes used, they are unreliable and not recommended on federal ESPC projects. Regression models can take into account the impacts of weather and other independent variables on energy use, whereas simple utility bill comparison techniques cannot. The analysis requires an evaluation of the behavior of the facility as it relates to one or more independent variables (e.g., weather, occupancy, production rate) using regression analysis.

Utility data analysis can take several approaches to calculate savings, as described in Section 4.2.5 and Section 7.2. The key elements of these approaches include developing an appropriate baseline model which relates the baseline energy use to key independent variables, and continuously measuring the performance period energy use and the key independent variables. Savings are often calculated by comparing the energy use predicted by the baseline model using measured conditions with the actual energy use of the performance period. Alternately, performance period models may be developed if the baseline and performance period models are to be adjusted to typical conditions prior to comparison. Performance period models may also be needed if there is not a full year's worth of data available for the performance period.

4.5.2 Data Collection

Collecting, validating, and properly applying data are important elements of using utility data analysis. Option C techniques utilize three types of data: utility billing data, independent variables, and information on unrelated changes at the site. These data elements are discussed below.

4.5.2.1 Utility Billing Data

Utility billing data provide the basis for savings calculations by allowing a comparison of adjusted baseline models with performance period energy use. Regardless of the type of utility data used, a key to properly applying the data is ensuring that all start and end dates of the utility data are aligned with those of the independent variables. Collecting data on independent variables more often than collecting billing data can help align time frames. Billing data can be:

- Monthly billing data. Billing data should be measured at least once a month. There are typically two types of monthly billing data: total usage for the month and usage aggregated by time-of-use periods. Although either type of data can be used with a regression model, time-of-use is preferable because it provides more insight into usage patterns. In many cases, the peak demand is also recorded.

- Interval demand billing data. This type of billing data records the average demand (or energy use) for a given interval (e.g., 15 minutes) associated with the billing period, and typically includes peak demand charges.
- Stored energy billing data. Inventory readings or delivery information can be used to determine historical consumption for resources such as fuel oil, although sub-metering is preferred.

4.5.2.2 Other Site Changes

One of the challenges in applying Option C is accounting for factors beyond the ECM that affect overall site energy use, such as changes in square footage or loads. Tracking site changes provides a means for accounting for changes in energy use not associated with ECM installation. Adequately tracking the information needed to make these non-routine baseline adjustments can be a challenging task for long-term contracts and sites that have significant operational changes.

4.5.3 M&V Considerations[9]

The following points should be considered when conducting Option C utility data analyses for M&V:

- All independent variables that affect energy consumption must be specified, whether or not they are accounted for in the model. Critical variables can include weather, building occupancy, set points, time of day, number of meals served, etc. The most common variable for many types of ECMs is outdoor air temperature.
- The form and content of any separate performance period model(s) (if used) should be specified, along with the statistical validation targets. Statistical validity of the final regression model(s) must be demonstrated.
- Independent variable data need to correspond to the time periods of the billing meter reading dates and intervals. A plan for data collection, including sources and frequencies, should be specified.
- It is best to develop models using data in whole-year sets (12, 24, 36, or 48 months) so that any seasonal variations are not overstated.
- It is necessary to specify how site changes unrelated to the installation of the ECMs will be tracked over the performance period and how these data will be used to perform savings adjustments.
- If baseline energy use needs to be adjusted to incorporate minimum energy or operating standards (such as minimum ventilation rates or lighting levels), any modification to the model needs to be detailed.

4.6 OPTION D—CALIBRATED SIMULATION

Option D involves whole facility or system analysis procedures to verify the performance of retrofit projects using calibrated computer simulation models. Computer simulation is a powerful tool that allows an experienced user to model the building and mechanical systems in order to

[9] See ASHRAE Guideline 14-2002 and IPMVP Volume 1 (EVO 10000-1.2007) for additional information on utility billing analysis.

predict building energy use both before and after the installation of ECMs. The accuracy of the models is ensured by using metered site data to describe baseline and/or performance period conditions. Carefully constructed models can provide savings estimates for the individual ECMs on a project. More elaborate models generally improve the accuracy of savings calculations, but increase costs. A calibrated simulation of a building, however, can be utilized to easily evaluate savings from other potential improvements.

Building simulation requires experienced, qualified analysts, and Option D methods should be used only for projects that meet any or all of the following requirements:

- For complex equipment replacement and controls projects with too many ECMs to cost-effectively use retrofit isolation methods A or B
- When interactive effects between ECMs are too complex for retrofit isolation approaches, but need to be quantified
- When the Option C utility data analysis approach is not viable due to the overall level of savings being less than 20% of metered use
- When complex baseline adjustments are expected during the performance period
- When energy savings values per individual measure are desired
- When new construction projects are involved
- When savings levels are sufficient to warrant the cost of simulation
- When either baseline or performance period energy data, but not both, are unavailable or unreliable.

Option D is especially useful where a baseline does not exist (e.g., new construction or major building modification) or the factors responsible for savings are not easily measured (e.g., reduced solar gain and heat loss through new windows).

Situations for which computer simulation is not appropriate include:

- Analysis of ECM savings that can be more cost-effectively determined with other methods
- Buildings that cannot be adequately modeled, such as those with complex geometries or other unusual features
- Building systems or ECMs that cannot be adequately modeled, such as radiant barriers or demand-response control algorithms that are important in comparing baseline and performance period scenarios
- Projects with limited resources that are not sufficient to support the effort required for data collection, simulation, calibration, and documentation

Even for the simplest projects simulation modeling and calibration are time-intensive activities and should be performed by an accomplished building simulation specialist. Calibrated simulation analysis is an expensive M&V procedure, and should be undertaken only on projects that generate enough savings to justify its use.

4.6.1 Approach to Option D

M&V Option D for an existing building typically follows five general steps: 1) collect data; 2) input data and test baseline model; 3) calibrate the baseline model; 4) create and refine the performance period model; and 5) verify performance and calculate savings. Each of these steps is discussed in detail below.

The methodology followed for new construction projects is somewhat different, and is detailed in IPMVP Volume III.[10] One primary difference between the methods used for existing and new buildings is the availability of utility data. In new construction, the performance period model would be calibrated to utility data, whereas the baseline model would not due to lack of data, although comparisons with similar buildings can be made. This approach would also apply to an existing building that does not have reliable baseline energy data.

4.6.1.1 Collecting the Data

The data required for simulating an existing building can be voluminous, and ensuring collection of all data required to develop the simulation models is key. Collecting comprehensive baseline data is advised. All data collected do not necessarily need to be incorporated into the model, but may be included to meet specific model accuracy requirements. All collected information and inputs need to be documented in a format that allows due-diligence review. Inadequate, disorganized, self-contradictory, or conflicting documentation can be grounds for rejecting a submittal.

To obtain end-use data for model calibration, building subsystem metering must be included in the project M&V activities for baseline and performance periods. The specific sub-systems selected for monitoring are in most cases the installed ECMs and related systems. For ECMs such as windows or insulation that cannot be monitored, the impacted HVAC system should be sub-metered. The model calibration will benefit the most from monitoring the energy end uses for which the least information is available.

Required data typically includes:

- Utility bill records: Collect a minimum of 12 (and preferably 24, 36, or 48) consecutive months of utility bills for the months immediately before installation of the ECMs. The billing data should include meter read date, kWh consumption, peak electric demand, and heating fuel use (e.g., natural gas). Additional data in hourly and 15-minute formats may be required.
- Architectural, mechanical, and electrical drawings: as-built drawings are preferred.
- Site survey data: Comprehensive equipment and system data, typically collected during an investment grade audit, including:
  - HVAC systems: primary equipment (e.g., chillers and boilers): capacities, number, model and serial numbers, age, condition, operating schedules, etc.

[10] International Performance Measurements and Verification Protocol: Concepts and Options for Determining Energy Savings in New Construction, Volume III, April 2003.

  - HVAC systems: secondary equipment (e.g., air-handling units, terminal boxes): characteristics, fan sizes and types, motor sizes and efficiencies, design-flow rates and static pressures, duct-system types, economizer operation, and type of controls
  - HVAC system controls, including location of zones, temperature set-points, control set-points and schedules, and any special control sequences
  - Lighting systems: number and types of lamps, with nameplate data for lamps and ballasts, lighting schedules, etc.
  - Building occupants: population counts, occupation schedules in different zones
  - Other major energy-consuming loads: type (industrial process, air compressors, water heaters, elevators), energy consumption, schedules of operation
- Site survey data that may be required in addition to data normally collected during an audit include:
  - Plug loads: summarize major and typical plug loads for assigning values per zone
  - Building envelope and thermal mass: dimensions and type of interior and exterior walls, properties of windows, and building orientation and shading from nearby objects. Infiltration rates are important, but are often difficult to determine
  - HVAC systems: ventilation air-flow rates can have a dramatic effect on energy use
- Short-term monitoring: The building energy management control system (EMCS) or data-logging equipment is set up to record system data as it varies over time. Typically, primary energy using systems and equipment involved in an ECM are monitored. These data may be required if particular subsystems (e.g., the chiller plant) need to be accurately modeled in order to determine savings. The data reveal how variable loads change with building operating conditions such as weather, occupancy, daily schedules, etc.
- Spot measurements of specific equipment: The power draw on lighting, plug load, HVAC equipment, and other circuits should be recorded to determine actual equipment operating powers.
- Operator interviews: Building operators can provide much of the above listed information and also any deviation in the intended operation of building equipment.
- Weather data: For calibration purposes, representative site weather data are required for the period in question, as outlined below (Section 4.6.3).
- Minimum code performance standards: For new construction projects and major renovations, minimum performance standards are often mandated for the baseline based on required codes.[11] If standards must be referenced in the baseline model, the minimum equipment efficiencies to represent the standards should be used.

[11] Minimum efficiency standards include CA Title 24, ASHRAE 90.1, IECC 2006, and state energy codes.

4.6.1.2 Inputting the Data and Running the Baseline Model

The data must be adapted as required to the baseline model and entered into the simulation program input files. Key data for inclusion are physical properties of the facility, equipment and system types and efficiencies, appropriate weather data, and control sequences. Specific attention should be given to systems that will be modified by ECMs.

The more site-specific data incorporated the more accurate the savings calculations, but the greater the costs. The simulation program's user guide and other resources should be consulted as needed to determine how to properly input the collected data into the model. From the volume of data collected, many decisions must be made to best represent the data in the simulation program's input file. This can be done most cost-effectively by an experienced building modeling specialist.

After the data have been inputted, a few simulations should be run to debug the model and the model output files should be checked to verify that there are no errors in running the program, such as:

- Does the HVAC system satisfy the heating and cooling loads?
- Are the equipment schedules correct?
- Are equipment efficiencies accurate?
- Are the model predictions reasonable?

4.6.1.3 Calibrating the Baseline Model

The baseline simulation model should be calibrated using the procedures described in Section 4.5.3 by comparing the energy usage and demand projected by the model with the usage and demand of the measured utility data. For new construction projects, the baseline energy use should be compared to other buildings that have similar operation and function. If required tolerances to the measured data are not met, the input data to the model should be refined until requirements are met.

The calibrated model should be documented by showing final input parameters for the model. This information, as well as the actual calibration results, needs to be provided in the M&V submittals.

4.6.1.4 Create and Refine the Performance Period Model

Starting with the calibrated baseline model, the model should be updated to include the building's ECMs to create the performance period model.

If individual savings levels from each ECM are desired, an approach that includes the interactive effects of the ECMs is to input the ECMs consecutively into the baseline model. Some software allows the modeler to create a rolling baseline by including the previous ECMs in the model. After each ECM has been modeled, the simulation is run. The first run is the baseline model, the second run is ECM 1, the third run is ECM 1 and ECM 2, the fourth run is ECM 1, ECM 2, and ECM 3, etc. After the final ECM has been inputted, the model should represent the performance

period condition with all ECMs installed. This approach includes interactive effects in the savings for each ECM.

Determining the sequence to input the ECMs into the model is an important consideration in managing interactive effects. Typically, measures that will affect the overall heating and cooling loads of the building (e.g., envelope improvements or lighting upgrades) should be inputted first. Secondary ECMs are those that affect the HVAC subsystems, and the final ECMs that should be inputted are those affecting the central plant.

Some simulation programs run each ECM against the original baseline, which neglects any interactive effects between the measures. These intermediate results are not always 100% additive, as two ECMs that save 2% alone, may not save 4% combined. Considering the interactive effects of ECMs, these ECMs combined may save 3%. When using this approach, a final run including all measures must be executed to determine the interactive effects of all the ECMs. This approach does not allocate interactive effects to the individual ECMs.

4.6.1.5 Verifying Performance and Calculating Savings

The method used to determine savings will depend upon the phase of the project. During project development, proposed savings are determined by subtracting the results of the performance period model from the results of the calibrated baseline model, both using the agreed-upon weather data and facility operating conditions.

As with all M&V methods, after implementation of the ECMs the proper installation and operation of the ECMs must be verified periodically. Performance data should be collected not only to calibrate the model, but to validate that the new equipment and systems are installed and operating properly.

After the first year of performance, there are two options to calculate verified savings: 1) calibrate the performance period model and subtract the results of baseline model using the same conditions; or 2) subtract measured utility data for the performance period from the results of baseline model that was updated to actual conditions.

The first option requires that the performance period model be calibrated using the procedures described in Section 4.6.3. Update the performance period model using data collected during the performance period from site surveys, spot measurements, short-term monitoring, and utility data. Effort can be minimized by focusing data collection on the installed ECMs.

If savings are to be estimated for a specific year, actual weather and other data from that year must be used. If savings are to be normalized to typical conditions (see Section 7.2), for example, then typical weather data (e.g., TMY data) should be used. In any case, both the baseline model and the performance period model must be run with the same weather data. The weather data to be used are specified in the site-specific M&V Plan. Although time-intensive, Option D approaches are well suited to adjust models when significant site changes occur during the performance period.

If savings for each ECM are to be determined including interactive effects, the ECMs must be inputted consecutively into the model and simulations run after each input, as described above.

Individual ECM savings are determined by the difference in energy or demand use between two consecutive runs. The savings determined for the individual ECMs should total the savings determined from the baseline and performance period runs. It is important that savings be determined with both models using the same conditions (weather, occupancy schedules, set points, etc.), except for the characteristics of the installed ECMs.

The energy values and rate structure specified in the M&V Plan are applied to the energy savings determined by the model. If utility rates are included in the model, sufficient information on the savings should be provided so that cost calculations can be verified. When time-of-use charges or other variable usage schedules are applied, the demand (kW) and energy (kWh) savings must be broken down into the proper categories to determine cost savings (see Section 7.2).

4.6.2 Simulation Software

The most frequently used type of building energy simulation program for energy analyses are whole-building programs that create customized models of buildings and their systems, and employ hourly weather data to predict energy use. Such programs are very versatile, allowing the accurate modeling of most buildings through custom input data. Two of the most common public domain programs of this type are eQUEST and EnergyPlus.[12] A complete list of available energy simulation programs is maintained by the DOE.[13]

These building simulation programs require extensive input data to accurately model the energy use of a building. Recently, user interfaces have been improved that simplify the input process with graphical formats, and libraries of typical building components have been added to facilitate model development.

Simulation programs acceptable for Option D should have the following characteristics[14]:

- The program is commercially available, supported, and documented.
- The program has the ability to adequately model the project site and ECMs.
- The model can be calibrated to an acceptable level of accuracy.
- The program allows the use of actual weather data in hourly format.

4.6.3 Model Calibration[15]

The model calibration for existing buildings is accomplished by linking simulation inputs to actual operating conditions and comparing simulation results with whole-building and/or end-use data. The simulation may be of a whole facility or just for the end use or system affected by the ECM. Both baseline and performance period models should be calibrated wherever possible. Model calibration is typically an iterative process of adjusting model inputs and re-comparing

---

[12] eQUEST is available through http://doe2.com/equest/ (current release is eQUEST 3.6 and 3.61b) and EnergyPlus is available through http://www.eere.energy.gov/buildings/energyplus/.

[13] See http://www.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm

[14] For more information on building simulation program elements See ASHRAE 90.1-2004 Energy Standard for Buildings Except Low-Rise Residential Buildings, Section G.2 or ASHRAE Guideline 14-2002.

[15] See ASHRAE Guideline 14-2002 and IPMVP Volume 1 (EVO 10000-1.2007) for additional information on simulation modeling and validation techniques.

the results to measured data. A model is considered in calibration when the statistical indices demonstrating calibration have been met. Expected calibration requirements should be specified in the project-specific M&V Plan, and industry standard guidelines are included in Table 4-3. These requirements should be adjusted as required to meet the needs of the project.

For most models, there are multiple levels of calibration that can be performed:

- System level calibration with hourly monitored data
- Whole-building level calibration with monthly utility data
- Whole-building level calibration with hourly utility data

Determining the level of calibration that is needed depends on the value of the project, the availability of data, and the need for certainty in the savings estimates. All models should be calibrated to monthly data at a minimum. Simulation models that focus on specific systems should be calibrated to system level data. Also, calibrating the models to hourly data will help ensure accuracy, especially for determining peak demand savings. Calibrating a computer simulation to measured utility data necessitates that actual weather data be used, as discussed below.

The calibration procedures should apply to all energy sources (demand, electricity, natural gas, etc.), but should focus on the primary source(s) of savings. Each of these model calibration strategies is discussed below.

4.6.3.1 Weather Data

The first step in calibrating a model is updating and running the model using weather data that correspond precisely to the same calendar days as each utility bill. Programs that allow the use of only average weather files or weather data from only a few representative periods per month or per season are not suitable for the calibration techniques required for Option D.

Obtaining weather data for the appropriate location and time-period is an important step in calibrating any simulation model. Several resources are available for getting real-time weather data and converting them into the proper format for use with the simulation software. DOE maintains a website[16] that provides weather data from 1998 to the present from up to 4,000 weather stations. Some data may be missing, but can be extrapolated from the DOE's database.[17] The database provides data in a format used by Energy Plus, but can be converted for use with eQUEST and other programs.[18] Since using actual weather data can be time consuming, it is sometimes appropriate to modify average weather to more closely match the actual weather.[19]

The time period and frequency of the weather data need to align with the utility data periods, which can require data manipulation. The measure-specific M&V Plan must specify which

---

16 The DOE website is http://www.eere.energy.gov/buildings/energyplus/cfm/weatherdata/weather_request.cfm .

17 Detailed information on the data can be found in *Real-Time Weather Data Access Guide, User's Guide NREL/BR-550-34303 March 2006*, National Renewable Energy Laboratory. The FAQ and instructions on this web page should be followed to fill in the missing data: http://www.eere.energy.gov/buildings/energyplus/cfm/weatherdata/faq.cfm

18 Weather file converter software is available through http://doe2.com/index_Wth.html .

19 See http://gundog.lbl.gov/ for discussion on simulation issues.

weather data sources will be used, including both the source of the data and the physical location of the weather station.

After the model has been calibrated using actual weather data, the building's energy use may be adjusted to average-year weather. Average weather data may be obtained from ASHRAE (WYEC2) and the National Renewable Energy Laboratory (TMY2).[20]

4.6.3.2 Statistical Indices

For all of these approaches, two prescribed statistical indices (described below) must be calculated in order to declare a model calibrated: the mean bias error (MBE) and the coefficient of variation of the root mean squared error C_v(RMSE).[21] The recommended calibration requirements are those specified by ASHRAE Guideline 14. Specific calibration goals should be set for each project based on appropriate level of effort (see Chapter 5). This process should be applied to electricity (kWh), demand (kW), and all other fuels used.

In addition to statistical indices, graphical comparison techniques can be an effective tool understanding the variances present in a model. Simple or advanced methods of graphical comparison techniques can be effective, and are detailed in ASHRAE Guideline 14.

As mentioned above, actual weather corresponding to the time period in question should be used in the model. Typically, the energy consumption predicted by the model and measured by the utility or sub-meter are determined for every month or interval in the data set, as well as for the whole year or period, and statistical analyses are performed on the results. The same techniques can be applied to hourly and subsystem data. The statistical values that need to be calculated are MBE and C_v (RMSE).

- MBE—mean bias error. The MBE indicates how well the energy consumption is predicted by the model as compared to the measured data. Positive values indicate that the model overpredicts actual values; negative values indicate that the model underpredicts actual values. However, it is subject to cancellation errors, where the combination of positive and negative values serves to reduce MBE. To account for cancellation errors, the C_V(RSME) is also needed.
- C_V(RSME)— coefficient of variation of the root-mean-squared error. This value indicates the overall uncertainty in the prediction of whole-building energy usage. The lower the C_V(RSME), the better the calibration. This value is always positive.

The mean bias error is calculated by subtracting the simulated energy consumption from the measured energy consumption for all the intervals over a given time period. The differences from each interval are summed and then divided by the sum of the measured energy consumption over the same time period. MBE is calculation is expressed in Equation 4-2.

---

[20] A comprehensive list of sources for weather data is available at http://www.eere.energy.gov/buildings/energyplus/weatherdata_sources.html.

[21] See ASHRAE Guideline 14-2002 and Section 4.2.2 for additional information.

Equation 4-2: Measured Energy Consumption

$$MBE(\%) = \frac{\sum_{Period} (S - M)_{Interval}}{\sum_{Period} M_{Interval}} \times 100$$

Where:

M is the measured kWh or fuel consumption during the time interval
S is the simulated kWh or fuel consumption during the same time interval

The C_v(RSME) is a normalized measure of variability between two sets of data. For calibrated simulation purposes, it is obtained by squaring the difference between paired data points, summing the squared differences over each interval through the period, and then dividing by the number of points, which yields the mean squared error. The square root of this quantity yields the root mean squared error (RMSE). The C_v(RMSE), is obtained by dividing the RMSE by the mean of the measured data for the period.

The root mean square error for the period is calculated using Equation 4-3.

Equation 4-3: Root Mean Square Error

$$RMSE_{Period} = \sqrt{\frac{\sum (S - M)_{Interval}^{2}}{N_{Interval}}}$$

Where:

$N_{Interval}$ are the number of time intervals in the monitoring period.

The mean of the measured data for the period is calculated using Equation 4-4.

Equation 4-4: Mean of the Measured Data

$$A_{Period} = \frac{\sum_{Period} M_{Interval}}{N_{Interval}}$$

The Cv(RSME) is calculated using Equation 4-5.

Equation 4-5: Cv(RSME)

$$Cv(RMSE_{Period}) = \frac{RMSE_{Period}}{A_{Period}} \times 100$$

The primary differences in applying these indices to the various data sets (monthly, hourly, sub-metered) are 1) the acceptable values of the indices and 2) the definition of “interval” and “period” in each of the equations above. The application of these statistical indices for each level of calibration is detailed in the sections below.

The recommended acceptable values for each approach are included in Table 4-3. These values have been adopted from ASHRAE Guideline 14. Specific calibration goals should be set for each project based on the appropriate level of effort (see Chapter 5) and should be specified in the project-specific M&V Plan. For existing buildings, the model calibration will occur prior to contract award, and both the calibration goals and results should be included in the IGA.

Table 4-3 Acceptable Calibration Tolerances[22]

Calibration Type	Index	Acceptable Value*
Monthly	MBE_{month}	± 5%
	$Cv(RMSE_{month})$	15%
Hourly	MBE_{Month}	±10 %
	$Cv(RMSE_{Month})$	30%

*Lower values indicate better calibration

4.6.3.3 Subsystem Level Calibration with Monitored Data

Calibration of a building model's subsystems to measured data may be required to enhance or ensure the overall accuracy of the model meets specified targets. The model's hourly predicted energy usage (kWh, therms, or Btu) is compared against measured hourly energy usage for the monitored building subsystems to determine whether the model accurately predicts subsystem level usage.

Most simulation programs, including eQUEST, output subsystem usage values minimally in 1-hour intervals. Therefore, for calibration, measured data must be averaged over each hour. For example, if 15-minute chiller demand (kW) data are collected, they must be averaged into hourly values.

When applying the statistical equations above to sub-metered data, the interval is an hour and the period can be defined by the user.

4.6.3.4 Whole-Building Level Calibration with Monthly Data

Comparing energy use projected by the building model with monthly utility bills is the minimum level of calibration that should be conducted on any model of an existing building with monthly utility data available. In the statistical equations above, the interval is a month and the period is a year.

When using monthly data, an additional check of the monthly variances should be made by calculating MBE by defining both the interval and the period as a month.

Example calibration calculations and results using monthly data are shown in Table 4-4. The results show that in addition to meeting the overall MBE and CV (RMSE) goals, the MBE for each month was also below the target value.

[22] ASHRAE Guideline 14-2002, Section 6.3.3.4.2.2.

4.6.3.5 Whole-Building Level Calibration with Hourly Data

When hourly data are applied, the interval is an hour and the period can be defined by the user, and often a 1-month billing period is used. These indices, however, may be calculated for the entire period or for weekdays, weekends, and holidays separately.[23]

Table 4-4 Example Calculations to Determine Monthly Model Calibration

Month	2,006 Measured kWh (M)	eQUEST Simulated kWh (S)	S-M	MBE	Squared Error
Jan	839,040	842,236	3,196	0%	10,212,435
Feb	814,080	774,882	(39,198)	5%	1,536,448,710
Mar	766,080	827,555	61,475	-8%	3,779,175,625
Apr	874,555	928,017	53,462	-6%	2,858,226,075
May	984,960	1,077,269	92,309	-9%	8,520,951,481
Jun	960,000	1,005,105	45,105	-5%	2,034,461,025
Jul	1,079,040	1,184,382	105,342	-10%	11,096,884,293
Aug	956,160	1,034,555	78,395	-8%	6,145,776,025
Sep	908,160	1,009,812	101,652	-11%	10,333,192,128
Oct	888,960	999,842	110,882	-12%	12,294,831,230
Nov	952,320	840,194	(112,126)	12%	12,572,295,939
Dec	871,680	822,511	(49,169)	6%	2,417,626,946
Total	10,895,035	11,346,360	451,325	-4%	73,600,081,912
	Overall Results:				
	MBE_{month}	-4%			
	Cv(RMSE):	9%			

4.6.4 M&V Considerations

Many issues must be considered and addressed in developing a project-specific M&V Plan using Option D. Some of the more common steps are outlined below.

- Use an experienced building modeling professional. Although new simulation software packages make much of the process easier, a program's capabilities and real data requirements cannot be fully understood by inexperienced users, and resulting models may not be accurate.
- Determine the availability of utility bill data.
- Determine whether hourly or monthly billing data are available and whether meters can be installed to collect hourly data. Calibrations to hourly data are generally more accurate than calibrations to monthly data because there are more points to compare. Hourly energy or demand data, however, are generally only available for a utility's largest customers or may be collected with portable data loggers. If only monthly billing data are available, conducting additional short-term monitoring of building sub-systems can improve the accuracy of the model.

[23] Bou-Saada, T.E. and J.S. Haberl, "An Improved Procedure for Developing Calibrated Hourly Simulation Models," International Building Performance Simulation Association, Report No. ESL-PA-95/08-01, 1995.

- Use actual equipment performance data in the simulation models. Many software packages have libraries of HVAC equipment that closely match actual system performance. Be cautious and investigate the library HVAC description to be sure it is a good representation of the real system and consider developing user-defined equipment performance curves based on field measurements or manufacturer's data.
- Specify spot measurements and short-term monitoring of key parameters for both the baseline and performance period models. Spot and short-term measurements augment the whole-building data and more accurately characterize building systems. It is recommended that an end use be monitored over a period that captures the full range of the equipment's operation (e.g., spring and summer for cooling systems. The data must also be collected in a way that facilitates sub-system level calibration. Careful selection of spot measurements and short-term monitoring is necessary because it can add significant cost and time to the project.
- Use trend data to determine actual controls. Sequencing of building controls is difficult to interpret from interviews, site surveys, manufacturer's data, and spot measurements. The best way to ascertain actual sequences is through trending data. Sometimes, the EMCS systems can be utilized to determine actual operating scenarios. However, the capability for data storage in many systems may be limited.
- Specify model calibration procedures that will be followed for monthly, hourly, or subsystem data for both the baseline and performance period models. Prescribe statistical calibration requirements based on the accuracy required for the project.
- Specify the simulation program and version and the source of weather data used (on-site, local weather station or typical weather data).
- Clearly explain how savings will be calculated after the first year. Keeping models up to date can be expensive. For projects without substantial site changes expected, an Option C utility billing analysis approach may be viable.[24] Regardless of how savings are calculated each year, the ongoing performance of the measures needs to be verified periodically.

[24] IPMVP Volume 1 2007, Section 4.10.4

Appendix E: Remote Building Audit Results

End Use Breakdown

				ELECTRICITY (KWH)							GAS (kBtu)		TOTAL (kBtu)							
Building Name	Location	Building Type	Building GSF	Cooling (kWh/sqft)	Heating (kWh/sqft)	Ventilation (kWh/sqft)	Misc-Electric (kWh/sqft)	Pumps (kWh/sqft)	Lighting (kWh/sqft)	Plug Load (kWh/sqft)	Gas Heating (kBtu/sqft)	Gas Other (kBtu/sqft)	Cooling (kBtu/sqft)	Heating (kBtu/sqft)	Ventiliation (kBtu/sqft)	Misc Electric (kBtu/sqft)	Pumps (kBtu/sqft)	Lighting (kBtu/sqft)	Plug Load (kBtu/sqft)	Thermal Other (kBtu/sqft)
Detroit Arsenal Building 249	Midwest	Warehouse (refrigerated and non-refrigerated)	48,564	0.12	0	0.64	0.29	0	1.89	0.4	0	0	0.42	0.01	2.18	0.98	0	6.45	1.36	0
Everett Building 1800 Location Exchange Aug 2012-July 2013	Northwest	Retail Store	18,623	1.62	0.01	1.39	1.84	0.29	6.02	4.3	0	0	5.52	0.02	4.76	6.28	0.98	20.54	14.66	0
Everett Building 1950 Fitness Center	Northwest	Fitness Center/Health Club/Gym	76,576	1.51	0.06	1.48	1.39	0.61	5.47	3.31	0	0	5.17	0.21	5.05	4.76	2.09	18.66	11.29	0
Everett Building 1980 Child Development Center	Northwest	Office	15,143	1.89	0.38	2.67	1.18	0.64	3.54	2.55	49.78	26.22	6.44	51.09	9.11	4.02	2.2	12.06	8.69	26.22
Everett Building 2000 Fleet HQ-Admin	Northwest	Office	61,263	2.48	0.4	2.35	0.79	0.22	3.45	2.72	11.49	1.58	8.45	12.84	8.01	2.68	0.73	11.76	9.27	1.58
Everett Building 2025 Galley	Northwest	Dining Facility	11,553	0	0	6.27	27.91	0.07	4.99	9.1	134.55	98.29	0	134.55	21.4	95.22	0.22	17.02	31.04	98.29
Everett Building 2026 BACHELOR ENLISTED QRTS I	Northwest	Barracks	53,091	0	0	0.64	0.66	0.12	1.85	3.54	13.88	6.02	0	13.88	2.2	2.26	0.42	6.32	12.09	6.02
Everett Building 2027 BACHELOR ENLISTED QTRS II	Northwest	Barracks	51,294	0	0	0.89	1.2	0.07	1.39	2.75	23.98	5.46	0	23.98	3.03	4.09	0.25	4.73	9.4	5.46
Everett Building 2028 BACHELOR ENLISTED QTRS III	Northwest	Barracks	61,942	0	0	1.33	0.54	0.11	0.99	2.82	30.43	7.78	0	30.43	4.55	1.85	0.36	3.37	9.61	7.78
Everett Building 2102 Redcom Northwest	Northwest	Office	15,950	0.73	1.7	2.09	1.43	0.83	3.29	2.48	11.66	1.45	2.48	17.45	7.12	4.89	2.85	11.24	8.45	1.45
Everett Building 2106 Reserve Center	Northwest	Office	12,344	0.88	0.55	2.65	1.31	0.97	3.87	3.97	43.65	0.77	3.01	45.54	9.04	4.47	3.3	13.21	13.53	0.77
Everett Building 2108 Support Building	Northwest	Office	10,860	1.16	2.17	3.04	1.26	0.98	3.74	3.81	44.03	5.39	3.95	51.42	10.36	4.29	3.33	12.76	12.99	5.39
Everett Building 2114 Security	Northwest	Fire Station	14,070	0.02	1.07	3.24	15.49	0	2.99	3.61	0	0	0.07	3.64	11.06	52.86	0	10.22	12.31	0
Everett Building 2120 Fleet Region Readiness Ctr	Northwest	Office	21,917	2.36	0	2.05	2.94	0.35	2.51	2.14	0	0	8.04	0	6.99	10.03	1.2	8.56	7.31	0
Everett Building 2125 Port Operations	Northwest	Office	6,183	0.05	4.19	1.85	2.55	0	3.19	2.21	0	0	0.16	14.28	6.31	8.71	0	10.88	7.54	0
Everett Building 2130 GSE Shop	Northwest	Retail Store	26,828	0	0.09	4.25	0.79	0.74	2.91	1.34	894.23	0.83	0	894.52	14.49	2.69	2.52	9.92	4.56	0.83
Everett Building 2132 Public Works - Transportation	Northwest	Transportation	27,675	0	0.47	1.6	0.24	0.42	3.49	0.29	0	0	0.01	1.6	5.45	0.82	1.43	11.9	0.98	0
Everett Building 2134 Security	Northwest	Office	17,085	0	0	1.4	4.19	0.04	4.12	1.46	0	0	0	0	4.79	14.29	0.14	14.06	4.99	0
Everett Building 2153 Nex Mini Mart	Northwest	Retail Store	3,370	0.71	10.22	3.6	32.65	0	13.93	17.18	0	0	2.42	34.85	12.29	111.39	0	47.54	58.61	0
Everett Building 2200 Logistics Complex (FISC)	Northwest	Data Center	95,435	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Everett Building 2202 Transit Shed	Northwest	Distribution Center	78,964	0.33	0	1.9	0.73	0	2.93	1.5	0	0	1.12	0	6.49	2.49	0	9.99	5.12	0
Everett Building 2220 Small Arms Range (Indoor)	Northwest	Training Facility	4,150	0.31	6.32	1.5	1.47	0	3.12	5.23	49.1	2.91	1.07	70.65	5.1	5.01	0	10.64	17.84	2.91
Everett Building 2320 Ships Hose Maint Facility	Northwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	3,772	0.31	0.12	1.18	0.05	0	2.57	0.99	0	0	1.07	0.4	4.04	0.19	0	8.77	3.38	0
Everett Building 2600 Pierside Laundromat	Northwest	Office	5,184	12.15	13.44	2.63	16.73	0.59	4.77	10.13	0	0	41.44	45.87	8.98	57.1	2.02	16.28	34.57	0
FB 224 Warehouse	Southeast	Warehouse (refrigerated and non-refrigerated)	42,465	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB 234 Warehouse	Southeast	Warehouse (refrigerated and non-refrigerated)	28,861	2.93	0	1.78	2.56	0	1.49	2.36	0	0	9.99	0	6.09	8.74	0	5.08	8.07	0
FB 2653 Child Development Center	Southeast	Office	24,657	1.91	0.02	2.05	1.16	0.45	2.29	1.44	0	0	6.53	0.07	7	3.96	1.55	7.8	4.91	0
FB 2784 ENL OPEN DINING	Southeast	Dining Facility	30,805	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB 2827 HQ 11TH ENGINEER BN	Southeast	Office	9,843	1.76	0	1.11	1.4	0.87	0.58	0.15	0	0	6.02	0.01	3.77	4.79	2.96	1.97	0.52	0
FB 2889 ENLISTED UPH	Southeast	Barracks	40,678	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB 2898 ENLISTED UPH	Southeast	Barracks	30,053	1.77	0	0.72	0	0.68	1.24	0.6	0	0	6.03	0	2.47	0	2.33	4.25	2.06	0
FB 2931 REGIMENTAL HQ BLDG	Southeast	Office	67,705	0.94	0	2.19	1.05	0.49	4.03	3.54	0	0	3.2	0.01	7.47	3.59	1.67	13.74	12.06	0
FB 3035 TRAINEE BKS	Southeast	Barracks	96,505	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB 3308 Recreation Center	Southeast	Office	16,094	0.42	0.09	2.24	0.75	0	4.75	1.95	0	0	1.43	0.31	7.63	2.56	0	16.21	6.65	0
FB 336 Warehouse	Southeast	Warehouse (refrigerated and non-refrigerated)	15,140	3.56	0	4.12	7.73	0	7.13	2.56	0	0	12.14	0	14.07	26.38	0	24.33	8.74	0
FB 3565 TRAINEE BKS	Southeast	Barracks	65,346	1.03	0	1.24	0.54	0	1.02	0.13	0	0	3.52	0	4.22	1.83	0	3.47	0.46	0
FB 3570 TRAINEE BKS	Southeast	Barracks	65,570	0.88	0	1.41	0.12	0	1.29	0.51	0	0	3.02	0	4.83	0.41	0	4.41	1.73	0
FB 3575 TRAINEE BKS	Southeast	Barracks	65,346	1.05	0	1.62	0	0	1.04	0.48	0	0	3.57	0	5.53	0	0	3.54	1.63	0
FB 3580 TRAINEE BKS	Southeast	Barracks	65,346	0.73	0	1.3	0	0	1.33	0.56	0	0	2.5	0	4.42	0	0	4.54	1.92	0
FB 3585 TRAINEE BKS	Southeast	Barracks	65,346	1.04	0	1.26	0	0	1.32	0.5	0	0	3.55	0	4.3	0	0	4.51	1.7	0
FB 4105 General Instruction Building	Southeast	Office	163,000	1.73	0	1.67	1.16	0.69	2.84	3.19	0	0	5.9	0.01	5.71	3.96	2.35	9.69	10.87	0
FB 4320 DFAC (Dining Facility)	Southeast	Dining Facility	54,521	2.26	0	4.21	1	0	3.86	2.45	0	0	7.72	0	14.38	3.43	0	13.17	8.38	0
FB 4323 CO OPS BARRACKS	Southeast	Barracks	65,346	0.96	0	1.26	0.13	0	1.25	0.54	0	0	3.26	0	4.3	0.46	0	4.28	1.85	0
FB 4324 CO OPS BARRACKS	Southeast	Barracks	65,346	0.42	0	0.97	0.13	0	1.23	0	0	0	1.42	0	3.32	0.43	0	4.19	0	0
FB 4325 CO OPS BARRACKS	Southeast	Barracks	65,346	1.01	0	1.13	0	0	1.39	0.54	0	0	3.43	0	3.87	0	0	4.76	1.84	0
FB 4326 CO OPS BARRACKS	Southeast	Barracks	56,526	0.66	0	1.31	0.14	0	1.42	0.34	0	0	2.26	0	4.47	0.49	0	4.83	1.17	0
FB 4327 CO OPS BARRACKS	Southeast	Barracks	65,346	0.95	0	1.3	0.53	0	1.46	0.55	0	0	3.24	0	4.42	1.81	0	4.99	1.86	0
FB Building 200 Dining Facility	Southeast	Dining Facility	31,005	5.88	0	2.87	6.85	0.82	4.94	10.56	0	0	20.06	0	9.79	23.36	2.8	16.84	36.02	0
FB Building 2745 Dining Facility	Southeast	Dining Facility	28,400	8.25	0	3.1	14.24	0.94	5.47	12.56	0	0	28.16	0	10.59	48.58	3.22	18.65	42.86	0
FB Building 2818 Audie Murphy Gym	Southeast	Fitness Center/Health Club/Gym	23,142	4.16	0.01	1.03	0.87	0	4.45	2.27	0	0	14.2	0.02	3.53	2.97	0	15.19	7.75	0
FB Building 2878 Simulator Facility	Southeast	Office	46,524	4.39	0.01	2.63	1.56	0.48	3.79	3.93	0	0	14.98	0.02	8.98	5.34	1.63	12.94	13.41	0
FB Building 3350 Santiago Gym	Southeast	Fitness Center/Health Club/Gym	23,728	3.38	0.01	1.28	0.49	0	4.47	2.53	0	0	11.55	0.02	4.35	1.66	0	15.25	8.62	0
FB Building 4350 PN 67468 EST Trainer	Southeast	Office	68,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB Building 5122 Barracks	Southeast	Barracks	39,723	3.29	0	2.31	3.91	0.92	1.83	1.02	0	0	11.22	0.01	7.88	13.33	3.14	6.23	3.46	0
FB Building 5123 Barracks	Southeast	Barracks	41,659	2.51	0	1.79	2.76	0.9	1.28	0.65	0	0	8.58	0	6.12	9.42	3.09	4.37	2.22	0
FB Building 5124 Barracks	Southeast	Barracks	41,659	0	0	1.21	3.54	0.3	4.27	1.94	0	0	0	0	4.14	12.08	1.02	14.56	6.62	0

End Use Breakdown

				ELECTRICITY (KWH)							GAS (kBtu)		TOTAL (kBtu)							
Building Name	Location	Building Type	Building GSF	Cooling (kWh/sqft)	Heating (kWh/sqft)	Ventilation (kWh/sqft)	Misc-Electric (kWh/sqft)	Pumps (kWh/sqft)	Lighting (kWh/sqft)	Plug Load (kWh/sqft)	Gas Heating (kBtu/sqft)	Gas Other (kBtu/sqft)	Cooling (kBtu/sqft)	Heating (kBtu/sqft)	Ventiliation (kBtu/sqft)	Misc Electric (kBtu/sqft)	Pumps (kBtu/sqft)	Lighting (kBtu/sqft)	Plug Load (kBtu/sqft)	Thermal Other (kBtu/sqft)
FB Building 5130 Barracks	Southeast	Barracks	96,154	1.74	0	1.29	0.1	0.48	1.28	0.25	0	0	5.95	0	4.4	0.35	1.65	4.38	0.87	0
FB Building 5140 Dining Facility	Southeast	Dining Facility	26,079	10.85	0	3.37	11.81	1.49	5.09	9.57	0	0	37.02	0.02	11.49	40.28	5.09	17.38	32.66	0
FB Building 6 Meloy Hall	Southeast	Office	100,433	2.34	0	1.04	1.09	0.54	1.94	1.85	0	0	7.99	0	3.55	3.72	1.85	6.64	6.32	0
FB Building 70 Admin	Southeast	Office	146,872	2.32	0	1.86	2.56	0.6	4.44	3.53	0	0	7.92	0.01	6.35	8.72	2.06	15.17	12.04	0
FB Building 9079 Rec Center	Southeast	Recreation Center	31,632	6.47	0.06	1.54	1	0.84	4.65	2.03	0	0	22.06	0.19	5.25	3.4	2.86	15.88	6.94	0
FB Building 9232 Bowling Center	Southeast	Office	20,442	6.34	0.07	2.2	3.73	0.24	6.38	2.92	0	0	21.62	0.22	7.52	12.74	0.83	21.78	9.96	0
FB Building 9236 Rec Center	Southeast	Recreation Center	3,000	13.18	1.65	2.69	2.68	0	7.36	10.26	0	0	44.98	5.63	9.18	9.14	0	25.1	35	0
Fort Bliss Building 11251 Phys Fit Center	Southwest	Fitness Center/Health Club/Gym	22,648	13.02	0.26	2.67	0.72	0.08	7.32	3.06	0	0	44.43	0.89	9.12	2.46	0.29	24.98	10.43	0
Fort Bliss Building 2 Televideo Center	Southwest	Office	241,909	1.19	0.07	2.07	0.52	0.1	1.63	0.59	0	0	4.05	0.23	7.06	1.78	0.35	5.56	2.02	0
Fort Bliss Building 20105 CO HQ Bldg	Southwest	Training Facility	45,651	2.74	0	1.1	0.41	0.02	2.15	0.82	0	0	9.36	0	3.75	1.41	0.07	7.33	2.8	0
Fort Bliss Building 20107 VEH MAINT SHOP	Southwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fort Bliss Building 20117 VEH MAINT SHOP	Southwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	1.44	0.51	3.04	2.82	0	2.65	1.56	0	0	4.92	1.75	10.36	9.63	0	9.03	5.34	0
Fort Bliss Building 20157 VEH MAINT SHOP	Southwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,091	1.1	0.16	0.41	1.04	0	2.54	1.16	0	0	3.75	0.56	1.41	3.54	0	8.68	3.95	0
Fort Bliss Building 20355 Barracks	Southwest	Barracks	50,991	2.13	0.61	3.03	0.16	0	1.02	0.22	0	0	7.27	2.08	10.32	0.56	0	3.49	0.76	0
Fort Bliss Building 20457 VEH MAINT SHOP	Southwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,153	0.88	0.24	0.65	0.12	0.19	1.79	0.44	0	0	3.02	0.83	2.23	0.41	0.64	6.11	1.5	0
Fort Bliss Building 2527 Org Str Building	Southwest	Distribution Center	65,589	0.93	0	0.74	0.07	0	4.05	0.28	0	0	3.18	0.01	2.51	0.25	0	13.81	0.95	0
Fort Bliss Building 2592 VEH MAINT SHOP	Southwest	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	1.28	0.28	2.24	0.63	0.1	3.21	1.27	0	0	4.36	0.97	7.64	2.15	0.35	10.94	4.34	0
Fort Bliss Building 2930 Phys Fit Ctr	Southwest	Fitness Center/Health Club/Gym	61,322	6.39	0.02	4.16	0.44	0.43	7.64	3.61	0	0	21.8	0.05	14.21	1.51	1.47	26.05	12.32	0
Fort Bliss Building 724 Training Aids Ctr	Southwest	Training Facility	22,439	3.61	0.18	0.62	0.07	0.3	0.46	0.25	0	0	12.32	0.61	2.11	0.23	1.03	1.57	0.85	0
Fort Carson Building 1218	West	Office	46,113	2.21	1.19	1.83	1.24	0.95	2.29	2.29	0	0	7.54	4.07	6.24	4.23	3.24	7.81	7.8	0
Fort Carson Building 1552 Barracks	West	Barracks	123,860	1.09	0	2.04	1.77	0.48	1.97	0.84	0	0	3.71	0	6.95	6.05	1.65	6.71	2.86	0
Fort Carson Building 2135 Simulator Facility	West	Training Facility	48,180	25.15	1.76	6.55	6.17	0.68	5.9	6.81	0	0	85.81	6.01	22.33	21.06	2.31	20.13	23.23	0
Fort Carson Building 2600 Company Ops Facility	West	Office	66,673	0.72	0	1.86	0.89	0.15	1.22	0.64	0	0	2.45	0	6.35	3.03	0.52	4.16	2.2	0
Fort Carson Building 330 Large Warehouse	West	Warehouse (refrigerated and non-refrigerated)	139,596	0.18	0.79	1	0.69	0	2.83	1.56	0	0	0.61	2.7	3.41	2.34	0	9.65	5.33	0
Fort Carson Building 520 Small Warehouse	West	Warehouse (refrigerated and non-refrigerated)	35,702	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fort Carson Building 756 Barracks	West	Barracks	95,858	0.75	0	1.78	1.8	0.39	1.87	0.44	0	0	2.56	0	6.09	6.14	1.35	6.37	1.5	0
Fort Carson Building 758 Barracks	West	Barracks	95,858	0.92	0	1.88	1.26	0.41	1.56	0.92	0	0	3.15	0	6.4	4.3	1.39	5.32	3.14	0
Fort Carson Building 9439 Dining Facility	West	Dining Facility	26,500	2.19	0	2.92	7.59	0.31	2.38	5.68	0	0	7.47	0	9.97	25.91	1.06	8.12	19.39	0
JBLM 1236 Auto Aid Institute	Northwest	Training Facility	17,136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JBLM 3369 Company HQ Building	Northwest	Office	59,534	0	0.01	1.67	2.26	0.3	2.61	1.7	13.96	2.19	0	13.98	5.68	7.7	1.02	8.92	5.81	2.19
JBLM 9136 Enlisted UPH	Northwest	Barracks	25,281	0	0	2.33	1.73	0	4.94	1.42	88.84	10.69	0	88.84	7.94	5.92	0	16.86	4.86	10.69
ORARNG Anderson Readiness Center	Northwest	Office	121,841	0.9	0	1.93	10.5	0.12	5.12	4.32	0	0	3.08	0.01	6.57	35.81	0.4	17.49	14.75	0
ORARNG Joint Force Headquarters	Northwest	Office	85,840	1.41	0.14	2.11	6.78	0.26	4.6	4.77	0	0	4.8	0.49	7.21	23.13	0.88	15.7	16.28	0
Picatinny Building 65 Admin	Northeast	Office	66,000	0.36	1.24	1.74	0.8	0.2	3.6	2.81	0	0	1.23	4.23	5.93	2.73	0.68	12.27	9.59	0
Picatinny Building 92 Admin	Northeast	Office	35,300	1.82	1.15	1.8	0.56	1.04	3.51	1.75	0	0	6.22	3.93	6.14	1.92	3.54	11.97	5.99	0
Picatinny Building 95 Admin & Shop	Northeast	Office	94,000	3.38	0.62	2.42	1.59	0.49	5.91	3.85	0	0	11.52	2.11	8.24	5.42	1.66	20.16	13.12	0
Picatinny Buildings 93 & 94	Northeast	Office	208,000	0.88	0.03	1.04	1.35	0.48	3.92	3.03	0	0	3.02	0.1	3.55	4.59	1.63	13.37	10.33	0
Port Hueneme 850 Admin Space	Westcoast	Office	16,920	0.27	0.11	2.25	2.58	1.02	2	2.42	0	0	0.91	0.39	7.69	8.79	3.48	6.82	8.26	0
Port Hueneme Building 1100 Admin & General Use Lab	Westcoast	Office	190,818	0.77	0	0.71	1.19	0.14	2.2	1.24	0	0	2.64	0	2.43	4.06	0.46	7.51	4.22	0
Port Hueneme Building 1444 Admin Space & Classrooms	Westcoast	Office	60,000	0.97	0.19	1.66	0.8	0.34	2.58	1.7	0	0	3.31	0.65	5.67	2.72	1.15	8.82	5.81	0
Port Hueneme Building 2 (Mar-12 to Feb-13)	Westcoast	Office	51,000	3.98	0.16	3.31	24.4	0.76	5.41	3.16	0	0	13.59	0.53	11.28	83.27	2.6	18.45	10.78	0
Tobyhanna Building 11 Administration Building	Northeast	Office	196,000	0.88	0.57	2.37	8.75	0.19	4.29	3.44	0	0	3.02	1.93	8.08	29.84	0.64	14.64	11.74	0
Tobyhanna Building 18 DPW Engineering Office	Northeast	Office	12,947	1.83	5.72	1.93	1.27	0	4.54	6.59	0	0	6.25	19.51	6.59	4.33	0	15.49	22.5	0
US Naval Observatory - Building 52B	Northeast	Office	49,423	0.43	0.4	1.61	3.21	0	3.06	1.78	0	0	1.46	1.38	5.51	10.96	0	10.45	6.06	0

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Detroit Arsenal Building 249	Warehouse (refrigerated and non-refrigerated)	48,564	33,362	-	113,831	HVAC Scheduling Control	Operational	2,408	-	8,216
Detroit Arsenal Building 249	Warehouse (refrigerated and non-refrigerated)	48,564	33,362	-	113,831	Lighting Retrofit	Retrofit	29,801	-	101,681
Detroit Arsenal Building 249	Warehouse (refrigerated and non-refrigerated)	48,564	33,362	-	113,831	Plug Load Management	Retrofit	1,153	-	3,934
Everett Building 1800 Location Exchange Aug 2012-July 2013	Retail Store	18,623	32,494	-	110,870	HVAC Scheduling Control	Operational	8,924	-	30,449
Everett Building 1800 Location Exchange Aug 2012-July 2013	Retail Store	18,623	32,494	-	110,870	Lighting Controls	Retrofit	6,213	-	21,199
Everett Building 1800 Location Exchange Aug 2012-July 2013	Retail Store	18,623	32,494	-	110,870	Lighting Retrofit	Retrofit	11,805	-	40,279
Everett Building 1800 Location Exchange Aug 2012-July 2013	Retail Store	18,623	32,494	-	110,870	Plug Load Management	Retrofit	5,552	-	18,943
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	HVAC Unoccupied Setback	Operational	24,369	-	83,147
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	Lighting Controls	Retrofit	29,317	-	100,030
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	Lighting Retrofit	Retrofit	44,874	-	153,110
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	Plug Load Management	Retrofit	15,204	-	51,876
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	Schedule Modifications	Operational	11,750	-	40,091
Everett Building 1950 Fitness Center	Fitness Center/Health	76,576	133,971	-	457,109	VFDs on Pumps	Retrofit	8,457	-	28,855
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Convert constant flow hot and chilled water pumping systems to variable flow-rate.	Retrofit	2,923	-	9,973
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Evaluate the existing chilled water production and pumping system components for replacement.	Retrofit	5,715	-	19,500
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	11,224	-	38,296
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Evaluate the existing occupied/unoccupied building automation schedules	Operational	19,162	225,804	297,959
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Investigate thermal end use ECMs	Retrofit	-	112,903	116,290
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	4,555	112,903	131,832
Everett Building 1980 Child Development Center	Office	15,143	51,360	451,610	640,399	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	7,781	-	26,549
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Convert constant flow hot water pumping systems to variable flow-rate.	Retrofit	3,953	-	13,488
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	35,288	-	120,403
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Evaluate the existing Rooftop Units for Replacement	Retrofit	81,567	-	278,307
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	16,171	71,965	129,299
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	33,584	-	114,589
Everett Building 2000 Fleet HQ-Admin	Office	61,263	206,361	71,965	778,228	Review control sequences and temperature setback programming to eliminate unnecessary simultaneous heating and cooling.	Operational	35,798	-	122,143
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Evaluate the central heating plant and heating distribution system for upgrades	Retrofit	-	328,416	338,268

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Kitchen Equipment related Water and Thermal Savings Measures	Retrofit	-	136,840	140,945
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Kitchen Hood - VFD on Exhaust Fan	Retrofit	16,121	-	55,005
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Lighting retrofits and occupancy controls.	Retrofit	12,606	-	43,012
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Refrigeration Controls	Retrofit	9,672	-	33,001
Everett Building 2025 Galley	Dining Facility	11,553	43,992	684,200	854,827	Unoccupied temperature setback.	Operational	5,593	218,944	244,596
Everett Building 2026 BACHELOR ENLISTED QRTS I	Barracks	53,091	31,930	-	108,945	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	27,650	-	94,342
Everett Building 2026 BACHELOR ENLISTED QRTS I	Barracks	53,091	31,930	-	108,945	Thermal savings measures	Retrofit	-	-	-
Everett Building 2026 BACHELOR ENLISTED QRTS I	Barracks	53,091	31,930	-	108,945	Variable Frequency Drives for Air Handler Fan Motors	Retrofit	3,064	-	10,454
Everett Building 2026 BACHELOR ENLISTED QRTS I	Barracks	53,091	31,930	-	108,945	Variable Frequency Drives for Hot Water Heating Pumps	Retrofit	1,216	-	4,149
Everett Building 2027 BACHELOR ENLISTED QTRS II	Barracks	51,294	37,764	-	128,851	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	28,654	-	97,767
Everett Building 2027 BACHELOR ENLISTED QTRS II	Barracks	51,294	37,764	-	128,851	Thermal savings measures	Retrofit	-	-	-
Everett Building 2027 BACHELOR ENLISTED QTRS II	Barracks	51,294	37,764	-	128,851	Variable Frequency Drives for Air Handler Fan Motors	Retrofit	6,817	-	23,260
Everett Building 2027 BACHELOR ENLISTED QTRS II	Barracks	51,294	37,764	-	128,851	Variable Frequency Drives for Hot Water Heating Pumps	Retrofit	2,293	-	7,824
Everett Building 2028 BACHELOR ENLISTED QTRS III	Barracks	61,942	34,341	-	117,171	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	28,725	-	98,010
Everett Building 2028 BACHELOR ENLISTED QTRS III	Barracks	61,942	34,341	-	117,171	Thermal savings measures	Retrofit	-	-	-
Everett Building 2028 BACHELOR ENLISTED QTRS III	Barracks	61,942	34,341	-	117,171	Variable Frequency Drives for Air Handler Fan Motors	Retrofit	3,574	-	12,194
Everett Building 2028 BACHELOR ENLISTED QTRS III	Barracks	61,942	34,341	-	117,171	Variable Frequency Drives for Hot Water Heating Pumps	Retrofit	2,042	-	6,967
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Convert constant flow hot and chilled water pumping systems to variable flow-rate.	Retrofit	3,992	-	13,621
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Evaluate the existing chilled water production and pumping system components for replacement.	Retrofit	2,893	-	9,871
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	10,343	-	35,290
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Implement personal space heater education and removal program.	Operational	27,053	-	92,305
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	5,105	9,950	27,667
Everett Building 2102 Redcom Northwest	Office	15,950	57,323	9,950	205,835	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	7,937	-	27,081
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Convert constant flow hot and chilled water pumping systems to variable flow-rate	Retrofit	3,580	-	12,215
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	13,438	-	45,850
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Investigate thermal end use ECMs	Retrofit	-	63,006	64,896
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	-	26,252	27,040
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Personal computer and plug load power management practices should be evaluated during unoccupied periods	Operational	9,277	-	31,653
Everett Building 2106 Reserve Center	Office	12,344	34,510	194,266	317,842	Review control sequences and temperature setback programming to eliminate unnecessary unoccupied heating and cooling	Operational	8,215	105,008	136,188
Everett Building 2108 Support Building	Office	10,860	31,706	-	108,181	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls	Retrofit	11,420	-	38,965

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Everett Building 2108 Support Building	Office	10,860	31,706	-	108,181	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	2,080	-	7,097
Everett Building 2108 Support Building	Office	10,860	31,706	-	108,181	Personal computer and plug load power management practices should be evaluated during unoccupied periods	Retrofit	8,035	-	27,415
Everett Building 2108 Support Building	Office	10,860	31,706	-	108,181	Review control sequences and temperature setback programming to eliminate unnecessary unoccupied heating and cooling	Operational	10,171	-	34,703
Everett Building 2114 Security	Fire Station	14,070	37,492	-	127,923	HVAC Unoccupied Setback	Operational	17,656	-	60,242
Everett Building 2114 Security	Fire Station	14,070	37,492	-	127,923	Lighting Retrofit	Retrofit	8,607	-	29,367
Everett Building 2114 Security	Fire Station	14,070	37,492	-	127,923	Plug Load Management	Retrofit	2,097	-	7,155
Everett Building 2114 Security	Fire Station	14,070	37,492	-	127,923	VFDs and DCV on Fans	Retrofit	9,132	-	31,158
Everett Building 2120 Fleet Region Readiness Ctr	Office	21,917	47,632	-	162,520	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	10,820	-	36,918
Everett Building 2120 Fleet Region Readiness Ctr	Office	21,917	47,632	-	162,520	Evaluate the existing occupied/unoccupied building automation schedules.	Operational	15,614	-	53,275
Everett Building 2120 Fleet Region Readiness Ctr	Office	21,917	47,632	-	162,520	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	7,628	-	26,027
Everett Building 2120 Fleet Region Readiness Ctr	Office	21,917	47,632	-	162,520	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	9,501	-	32,417
Everett Building 2120 Fleet Region Readiness Ctr	Office	21,917	47,632	-	162,520	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.	Operational	4,069	-	13,883
Everett Building 2125 Port Operations	Office	6,183	24,489	-	83,556	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	7,250	-	24,737
Everett Building 2125 Port Operations	Office	6,183	24,489	-	83,556	Evaluate the existing occupied/unoccupied building automation schedules.	Operational	3,215	-	10,970
Everett Building 2125 Port Operations	Office	6,183	24,489	-	83,556	Implement personal space heater education and removal program	Operational	8,500	-	29,002
Everett Building 2125 Port Operations	Office	6,183	24,489	-	83,556	Perform a building envelope audit to identify and address the apparent building shell integrity issues	Retrofit	3,700	-	12,624
Everett Building 2125 Port Operations	Office	6,183	24,489	-	83,556	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	1,824	-	6,223
Everett Building 2130 GSE Shop	Retail Store	26,828	35,852	10,134	132,765	HVAC Scheduling Control	Operational	9,402	5,073	37,305
Everett Building 2130 GSE Shop	Retail Store	26,828	35,852	10,134	132,765	HVAC Unoccupied Setback	Operational	9,385	5,061	37,234
Everett Building 2130 GSE Shop	Retail Store	26,828	35,852	10,134	132,765	Lighting Retrofit	Retrofit	17,065	-	58,226
Everett Building 2132 Public Works - Transportation	Transportation	27,675	26,557	-	90,612	HVAC Unoccupied Setback	Operational	3,697	-	12,614
Everett Building 2132 Public Works - Transportation	Transportation	27,675	26,557	-	90,612	Lighting Retrofit	Retrofit	19,904	-	67,912
Everett Building 2132 Public Works - Transportation	Transportation	27,675	26,557	-	90,612	Parking Lot Lighting Retrofit	Retrofit	1,761	-	6,009
Everett Building 2132 Public Works - Transportation	Transportation	27,675	26,557	-	90,612	Plug Load Management	Operational	1,195	-	4,077
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Demand Controlled Ventilation	Retrofit	5,976	-	20,390
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Door & Window Weatherization	Retrofit	141	-	481
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Lighting Controls	Retrofit	19,223	-	65,589
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Lighting Retrofit	Retrofit	7,523	-	25,668
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Miscellaneous Loads	Retrofit	7,138	-	24,355
Everett Building 2134 Security	Office	17,085	42,211	-	144,024	Plug Load Management	Retrofit	2,210	-	7,541
Everett Building 2153 Nex Mini Mart	Retail Store	3,370	19,264	-	65,729	HVAC Setpoints and Schedules	Operational	2,447	-	8,349
Everett Building 2153 Nex Mini Mart	Retail Store	3,370	19,264	-	65,729	Lighting Controls	Retrofit	1,568	-	5,350
Everett Building 2153 Nex Mini Mart	Retail Store	3,370	19,264	-	65,729	Lighting Retrofit	Retrofit	13,189	-	45,001
Everett Building 2153 Nex Mini Mart	Retail Store	3,370	19,264	-	65,729	Plug Load Management	Retrofit	2,060	-	7,029
Everett Building 2200 Logistics Complex (FISC)	Data Center	95,435	-	-	-	HVAC Unoccupied Setback	Operational	-	-	-
Everett Building 2200 Logistics Complex (FISC)	Data Center	95,435	-	-	-	Lighting Retrofit	Retrofit	-	-	-
Everett Building 2200 Logistics Complex (FISC)	Data Center	95,435	-	-	-	Plug Load Management	Retrofit	-	-	-
Everett Building 2202 Transit Shed	Distribution Center	78,964	122,831	-	419,099	HVAC Scheduling Control	Operational	5,772	-	19,694

100 Building RBA Energy Conservation Measures										
Portal Building Name	**Building Type**	**Building GSF**	**Total Electric Savings (kWh)**	**Total Gas Savings (CF)**	**Total kbTu Savings**	**ECM Name**	**ECM Type**	**ECM Electric Savings (kWh)**	**ECM Gas Savings (CF)**	**ECM kBtu Savings**
Everett Building 2202 Transit Shed	Distribution Center	78,964	122,831	-	419,099	Lighting Retrofit	Retrofit	106,750	-	364,231
Everett Building 2202 Transit Shed	Distribution Center	78,964	122,831	-	419,099	Plug Load Management	Retrofit	10,309	-	35,174
Everett Building 2220 Small Arms Range (Indoor)	Training Facility	4,150	6,639	-	22,652	Lighting Retrofit	Retrofit	4,760	-	16,241
Everett Building 2220 Small Arms Range (Indoor)	Training Facility	4,150	6,639	-	22,652	Plug Load Management	Retrofit	1,879	-	6,411
Everett Building 2320 Ships Hose Maint Facility	Repair Services (Vehicle, Shoe, Locksmith, etc)	3,772	5,003	-	17,070	HVAC Unoccupied Setback	Retrofit	2,052	-	7,001
Everett Building 2320 Ships Hose Maint Facility	Repair Services (Vehicle, Shoe, Locksmith, etc)	3,772	5,003	-	17,070	Lighting Controls	Retrofit	860	-	2,934
Everett Building 2320 Ships Hose Maint Facility	Repair Services (Vehicle, Shoe, Locksmith, etc)	3,772	5,003	-	17,070	Lighting Retrofit	Retrofit	2,091	-	7,134
Everett Building 2600 Pierside Laundromat	Office	5,184	13,984	-	47,713	Evaluate Heat Recovery Systems for Process Loads	Operational	-	-	-
Everett Building 2600 Pierside Laundromat	Office	5,184	13,984	-	47,713	HVAC Scheduling Control	Operational	8,950	-	30,537
Everett Building 2600 Pierside Laundromat	Office	5,184	13,984	-	47,713	Lighting Retrofit	Retrofit	5,034	-	17,176
FB 224 Warehouse	Warehouse (refrigerated and non-refrigerated)	42,465	560,966	-	-	HVAC Scheduling Control	Operational	-	-	-
FB 234 Warehouse	Warehouse (refrigerated and non-refrigerated)	28,861	33,741	-	115,124	HVAC Scheduling Control	Operational	3,124	-	10,659
FB 234 Warehouse	Warehouse (refrigerated and non-refrigerated)	28,861	33,741	-	115,124	HVAC Unoccupied Setback	Operational	23,108	-	78,844
FB 234 Warehouse	Warehouse (refrigerated and non-refrigerated)	28,861	33,741	-	115,124	Plug Load Management	Retrofit	7,509	-	25,621
FB 2653 Child Development Center	Office	24,657	26,936	-	91,906	Investigate the opportunity for solar photovoltaic array.	Retrofit	6,527	-	22,270
FB 2653 Child Development Center	Office	24,657	26,936	-	91,906	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Operational	10,678	-	36,433
FB 2653 Child Development Center	Office	24,657	26,936	-	91,906	Review control schedules, sequences, and temperature setback programming to eliminate unnecessary cooling during unoccupied periods.	Operational	9,731	-	33,202
FB 2784 ENL OPEN DINING	Dining Facility	30,805	-	-	-	Demand-controlled Ventilation	Retrofit	-	-	-
FB 2784 ENL OPEN DINING	Dining Facility	30,805	-	-	-	Lighting retrofits and occupancy controls.	Retrofit	-	-	-
FB 2784 ENL OPEN DINING	Dining Facility	30,805	-	-	-	Refrigeration Controls	Retrofit	-	-	-
FB 2784 ENL OPEN DINING	Dining Facility	30,805	-	-	-	Water and Thermal Savings Measures	Retrofit	-	-	-
FB 2827 HQ 11TH ENGINEER BN	Office	9,843	3,570	-	12,181	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	700	-	2,388
FB 2827 HQ 11TH ENGINEER BN	Office	9,843	3,570	-	12,181	O&M Measures	Operational	1,660	-	5,664
FB 2827 HQ 11TH ENGINEER BN	Office	9,843	3,570	-	12,181	Parking Lot Lighting Retrofit with Controls	Retrofit	1,210	-	4,129
FB 2889 ENLISTED UPH	Barracks	40,678	-	-	-	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	-	-	-
FB 2889 ENLISTED UPH	Barracks	40,678	-	-	-	Plug Load Management	Retrofit	-	-	-
FB 2889 ENLISTED UPH	Barracks	40,678	-	-	-	Schedule Modifications	Operational	-	-	-
FB 2889 ENLISTED UPH	Barracks	40,678	-	-	-	Variable Frequency Drives for Chilled Water Pumps	Retrofit	-	-	-
FB 2898 ENLISTED UPH	Barracks	30,053	25,529	-	87,105	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	10,883	-	37,133
FB 2898 ENLISTED UPH	Barracks	30,053	25,529	-	87,105	Schedule Modifications	Operational	13,000	-	44,356

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
FB 2898 ENLISTED UPH	Barracks	30,053	25,529	-	87,105	Variable Frequency Drives for Chilled Water Pumps	Retrofit	1,646	-	5,616
FB 2931 REGIMENTAL HQ BLDG	Office	67,705	160,822	-	548,725	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	72,913	-	248,779
FB 2931 REGIMENTAL HQ BLDG	Office	67,705	160,822	-	548,725	Investigate the opportunity for solar photovoltaic array.	Retrofit	19,580	-	66,807
FB 2931 REGIMENTAL HQ BLDG	Office	67,705	160,822	-	548,725	Perform a building envelope audit to identify and address the apparent building shell integrity issues.	Retrofit	-	-	-
FB 2931 REGIMENTAL HQ BLDG	Office	67,705	160,822	-	548,725	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Operational	51,824	-	176,823
FB 2931 REGIMENTAL HQ BLDG	Office	67,705	160,822	-	548,725	Review control schedules, sequences, and temperature setback programming to eliminate unnecessary cooling during unoccupied periods.	Operational	16,505	-	56,315
FB 3035 TRAINEE BKS	Barracks	96,505	-	-	-	Demand-controlled Ventilation	Retrofit	-	-	-
FB 3035 TRAINEE BKS	Barracks	96,505	-	-	-	Lighting retrofits and occupancy controls.	Retrofit	-	-	-
FB 3035 TRAINEE BKS	Barracks	96,505	-	-	-	Parking Lot Lighting Retrofit with Controls	Retrofit	-	-	-
FB 3035 TRAINEE BKS	Barracks	96,505	-	-	-	Water and Thermal Savings Measures	Retrofit	-	-	-
FB 3308 Recreation Center	Office	16,094	56,785	-	193,750	HVAC Scheduling Control	Operational	3,900	-	13,307
FB 3308 Recreation Center	Office	16,094	56,785	-	193,750	Lighting Retrofit	Retrofit	43,694	-	149,084
FB 3308 Recreation Center	Office	16,094	56,785	-	193,750	Parking Lot Lighting Retrofit	Retrofit	5,894	-	20,110
FB 3308 Recreation Center	Office	16,094	56,785	-	193,750	Plug Load Management	Retrofit	3,297	-	11,249
FB 336 Warehouse	Warehouse (refrigerated and non-refrigerated)	15,140	33,684	-	114,930	HVAC Scheduling Control	Operational	7,860	-	26,818
FB 336 Warehouse	Warehouse (refrigerated and non-refrigerated)	15,140	33,684	-	114,930	Lighting Controls	Retrofit	19,280	-	65,783
FB 336 Warehouse	Warehouse (refrigerated and non-refrigerated)	15,140	33,684	-	114,930	Plug Load Management	Retrofit	6,544	-	22,328
FB 3565 TRAINEE BKS	Barracks	65,346	36,447	-	124,357	Adjust ventilation controls and air distribution.	Retrofit	14,966	-	51,064
FB 3565 TRAINEE BKS	Barracks	65,346	36,447	-	124,357	Lighting retrofits and occupancy controls.	Retrofit	21,481	-	73,293
FB 3565 TRAINEE BKS	Barracks	65,346	36,447	-	124,357	Thermal savings measures.	Retrofit	-	-	-
FB 3570 TRAINEE BKS	Barracks	65,570	44,184	-	150,756	Adjust ventilation controls and air distribution.	Retrofit	17,017	-	58,062
FB 3570 TRAINEE BKS	Barracks	65,570	44,184	-	150,756	Lighting retrofits and occupancy controls.	Retrofit	27,167	-	92,694
FB 3570 TRAINEE BKS	Barracks	65,570	44,184	-	150,756	Thermal savings measures	Retrofit	-	-	-
FB 3575 TRAINEE BKS	Barracks	65,346	41,454	-	141,441	Adjust ventilation controls and air distribution.	Retrofit	19,552	-	66,711
FB 3575 TRAINEE BKS	Barracks	65,346	41,454	-	141,441	Lighting retrofits and occupancy controls.	Retrofit	21,902	-	74,730
FB 3575 TRAINEE BKS	Barracks	65,346	41,454	-	141,441	Thermal savings measures	Retrofit	-	-	-
FB 3580 TRAINEE BKS	Barracks	65,346	43,699	-	149,101	Adjust ventilation controls and air distribution.	Retrofit	15,690	-	53,534
FB 3580 TRAINEE BKS	Barracks	65,346	43,699	-	149,101	Lighting retrofits and occupancy controls.	Retrofit	28,009	-	95,567
FB 3580 TRAINEE BKS	Barracks	65,346	43,699	-	149,101	Thermal savings measures	Retrofit	-	-	-
FB 3585 TRAINEE BKS	Barracks	65,346	43,006	-	146,736	Adjust ventilation controls and air distribution.	Retrofit	15,207	-	51,886
FB 3585 TRAINEE BKS	Barracks	65,346	43,006	-	146,736	Lighting retrofits and occupancy controls.	Retrofit	27,799	-	94,850
FB 3585 TRAINEE BKS	Barracks	65,346	43,006	-	146,736	Thermal savings measures	Retrofit	-	-	-
FB 4105 General Instruction Building	Office	163,000	202,212	-	689,947	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	99,724	-	340,258
FB 4105 General Instruction Building	Office	163,000	202,212	-	689,947	Investigate the opportunity for solar photovoltaic array.	Retrofit	26,106	-	89,074
FB 4105 General Instruction Building	Office	163,000	202,212	-	689,947	Review control schedules, sequences, and temperature setback programming to eliminate unnecessary cooling during unoccupied periods.	Operational	76,382	-	260,615
FB 4320 DFAC (Dining Facility)	Dining Facility	54,521	114,599	-	391,012	Kitchen Hood - VFD on Exhaust Fan	Retrofit	16,031	-	54,698
FB 4320 DFAC (Dining Facility)	Dining Facility	54,521	114,599	-	391,012	Lighting retrofits and occupancy controls.	Retrofit	66,260	-	226,079
FB 4320 DFAC (Dining Facility)	Dining Facility	54,521	114,599	-	391,012	Refrigeration Controls	Retrofit	5,455	-	18,612

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
FB 4320 DFAC (Dining Facility)	Dining Facility	54,521	114,599	-	391,012	Unoccupied temperature setback.	Operational	26,853	-	91,622
FB 4320 DFAC (Dining Facility)	Dining Facility	54,521	114,599	-	391,012	Water and Thermal Savings Measures	Retrofit	-	-	-
FB 4323 CO OPS BARRACKS	Barracks	65,346	41,532	-	141,707	Adjust ventilation controls and air distribution.	Retrofit	15,207	-	51,886
FB 4323 CO OPS BARRACKS	Barracks	65,346	41,532	-	141,707	Lighting retrofits and occupancy controls.	Retrofit	26,325	-	89,821
FB 4323 CO OPS BARRACKS	Barracks	65,346	41,532	-	141,707	Thermal savings measures	Retrofit	-	-	-
FB 4324 CO OPS BARRACKS	Barracks	65,346	37,610	-	128,325	Adjust ventilation controls and air distribution.	Retrofit	11,707	-	39,944
FB 4324 CO OPS BARRACKS	Barracks	65,346	37,610	-	128,325	Lighting retrofits and occupancy controls.	Retrofit	25,903	-	88,381
FB 4324 CO OPS BARRACKS	Barracks	65,346	37,610	-	128,325	Thermal savings measures	Retrofit	-	-	-
FB 4325 CO OPS BARRACKS	Barracks	65,346	42,911	-	146,412	Adjust ventilation controls and air distribution.	Retrofit	13,638	-	46,533
FB 4325 CO OPS BARRACKS	Barracks	65,346	42,911	-	146,412	Lighting retrofits and occupancy controls.	Retrofit	29,273	-	99,879
FB 4325 CO OPS BARRACKS	Barracks	65,346	42,911	-	146,412	Thermal savings measures	Retrofit	-	-	-
FB 4326 CO OPS BARRACKS	Barracks	56,526	45,716	-	155,983	Adjust ventilation controls and air distribution.	Retrofit	15,811	-	53,947
FB 4326 CO OPS BARRACKS	Barracks	56,526	45,716	-	155,983	Lighting retrofits and occupancy controls.	Retrofit	29,905	-	102,036
FB 4326 CO OPS BARRACKS	Barracks	56,526	45,716	-	155,983	Thermal savings measures	Retrofit	-	-	-
FB 4327 CO OPS BARRACKS	Barracks	65,346	46,437	-	158,443	Adjust ventilation controls and air distribution.	Retrofit	15,690	-	53,534
FB 4327 CO OPS BARRACKS	Barracks	65,346	46,437	-	158,443	Lighting retrofits and occupancy controls.	Retrofit	30,747	-	104,909
FB 4327 CO OPS BARRACKS	Barracks	65,346	46,437	-	158,443	Thermal savings measures	Retrofit	-	-	-
FB Building 200 Dining Facility	Dining Facility	31,005	72,506	-	247,390	Lighting Retrofit (T-8 to Super T-8)	Retrofit	33,670	-	114,882
FB Building 200 Dining Facility	Dining Facility	31,005	72,506	-	247,390	HVAC Scheduling Control	Operational	4,424	-	15,095
FB Building 200 Dining Facility	Dining Facility	31,005	72,506	-	247,390	Kitchen Hood Exhaust and Make-Up Air Controls	Retrofit	14,835	-	50,617
FB Building 200 Dining Facility	Dining Facility	31,005	72,506	-	247,390	Refrigeration Controls	Retrofit	19,577	-	66,797
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	HVAC Setpoints and Schedules	Operational	25,288	-	86,283
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	Lighting Controls	Retrofit	9,632	-	32,864
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	Lighting Retrofit	Retrofit	16,634	-	56,755
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	Refrigeration Controls	Retrofit	40,438	-	137,974
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	VFD for Kitchen Ventilation	Retrofit	17,466	-	59,594
FB Building 2745 Dining Facility	Dining Facility	28,400	133,912	-	456,908	VFDs and DCV on Fans	Retrofit	24,454	-	83,437
FB Building 2818 Audie Murphy Gym	Fitness Center/Health Club/Gym	23,142	31,872	-	108,747	HVAC Unoccupied Setback	Operational	13,219	-	45,103
FB Building 2818 Audie Murphy Gym	Fitness Center/Health Club/Gym	23,142	31,872	-	108,747	Lighting Controls	Retrofit	3,472	-	11,846
FB Building 2818 Audie Murphy Gym	Fitness Center/Health Club/Gym	23,142	31,872	-	108,747	Lighting Retrofit	Retrofit	15,181	-	51,798
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	HVAC Unoccupied Setback	Operational	21,766	-	74,266
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	Investigate Control Improvements - Demand Controlled Ventilation	Operational	34,931	-	119,185
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	Lighting Retrofit	Retrofit	30,185	-	102,991
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	Optimize Control of Chilled Water Plant	Operational	33,635	-	114,763
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	Parking Lot Lighting Retrofit with Controls	Retrofit	21,941	-	74,863
FB Building 2878 Simulator Facility	Office	46,524	153,343	-	523,206	Plug Load Management	Retrofit	10,885	-	37,140
FB Building 3350 Santiago Gym	Fitness Center/Health Club/Gym	23,728	37,839	-	129,107	Air Cooled Condenser Retrofit with Evaporative	Retrofit	14,643	-	49,962
FB Building 3350 Santiago Gym	Fitness Center/Health Club/Gym	23,728	37,839	-	129,107	Lighting Retrofit	Retrofit	23,196	-	79,145
FB Building 4350 PN 67468 EST Trainer	Training Facility	68,000	-	-	-	HVAC Scheduling Control	Operational	-	-	-
FB Building 4350 PN 67468 EST Trainer	Training Facility	68,000	-	-	-	HVAC Unoccupied Setback	Operational	-	-	-
FB Building 4350 PN 67468 EST Trainer	Training Facility	68,000	-	-	-	Lighting Retrofit	Retrofit	-	-	-
FB Building 4350 PN 67468 EST Trainer	Training Facility	68,000	-	-	-	Plug Load Management	Operational	-	-	-
FB Building 5122 Barracks	Barracks	39,723	30,387	-	103,680	Air Cooled Condenser Retrofit with Evaporative	Retrofit	9,867	-	33,666
FB Building 5122 Barracks	Barracks	39,723	30,387	-	103,680	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	10,434	-	35,601
FB Building 5122 Barracks	Barracks	39,723	30,387	-	103,680	Plug Load Management	Operational	10,086	-	34,413
FB Building 5123 Barracks	Barracks	41,659	50,050	-	170,771	Lighting Retrofit	Retrofit	50,050	-	170,771
FB Building 5124 Barracks	Barracks	41,659	19,473	-	66,442	Lighting Controls	Retrofit	13,435	-	45,840
FB Building 5124 Barracks	Barracks	41,659	19,473	-	66,442	Miscellaneous Loads	Operational	-	-	-

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
FB Building 5124 Barracks	Barracks	41,659	19,473	-	66,442	Occupancy Controls of Fan Coil Units	Retrofit	3,542	-	12,085
FB Building 5124 Barracks	Barracks	41,659	19,473	-	66,442	VFDs on Hot Water Pumps	Retrofit	2,496	-	8,516
FB Building 5130 Barracks	Barracks	96,154	44,907	-	153,223	HVAC Economizer Operation	Operational	12,582	-	42,930
FB Building 5130 Barracks	Barracks	96,154	44,907	-	153,223	Lighting Retrofit	Retrofit	19,744	-	67,367
FB Building 5130 Barracks	Barracks	96,154	44,907	-	153,223	VFDs and DCV on Fans	Retrofit	12,581	-	42,926
FB Building 5140 Dining Facility	Dining Facility	26,079	153,636	-	524,206	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	16,400	-	55,957
FB Building 5140 Dining Facility	Dining Facility	26,079	153,636	-	524,206	HVAC Unoccupied Setback	Operational	87,063	-	297,059
FB Building 5140 Dining Facility	Dining Facility	26,079	153,636	-	524,206	Kitchen Hood Exhaust and Make-Up Air Controls	Retrofit	20,058	-	68,438
FB Building 5140 Dining Facility	Dining Facility	26,079	153,636	-	524,206	Refrigeration Controls	Retrofit	30,115	-	102,752
FB Building 6 Meloy Hall	Office	100,433	178,480	-	608,974	Evaluate the existing chilled water production equipment and pumping system components for replacement and upgraded control strategies.	Operational	47,035	-	160,483
FB Building 6 Meloy Hall	Office	100,433	178,480	-	608,974	Implement Demand Control Ventilation to modulate the amount of outside air supplied to the building.	Retrofit	39,419	-	134,498
FB Building 6 Meloy Hall	Office	100,433	178,480	-	608,974	Investigate the potential for night setback during the cooling season.	Operational	63,669	-	217,239
FB Building 6 Meloy Hall	Office	100,433	178,480	-	608,974	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	28,357	-	96,754
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	HVAC Setpoints and Schedules	Operational	136,606	-	466,100
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	Lighting Controls	Retrofit	42,887	-	146,330
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	Lighting Retrofit	Retrofit	66,810	-	227,956
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	Plug Load Management	Retrofit	31,972	-	109,088
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	VFDs and DCV on Fans	Retrofit	49,607	-	169,259
FB Building 70 Admin	Office	146,872	336,744	-	1,148,970	VFDs on Pumps	Retrofit	8,862	-	30,237
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	Chilled Water Plant Optimization	Retrofit	28,155	-	96,065
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	HVAC Scheduling Control	Operational	3,198	-	10,912
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	HVAC Unoccupied Setback	Operational	22,040	-	75,200
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	Lighting Controls	Retrofit	8,336	-	28,442
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	Lighting Retrofit	Retrofit	22,991	-	78,445
FB Building 9079 Rec Center	Recreation Center	31,632	87,743	-	299,379	Plug Load Management	Retrofit	3,023	-	10,314
FB Building 9232 Bowling Center	Recreation Center	20,442	65,963	-	225,066	HVAC Economizer Operation	Operational	25,905	-	88,388
FB Building 9232 Bowling Center	Recreation Center	20,442	65,963	-	225,066	HVAC Unoccupied Setback	Operational	14,336	-	48,914
FB Building 9232 Bowling Center	Recreation Center	20,442	65,963	-	225,066	Lighting Controls	Retrofit	6,367	-	21,724
FB Building 9232 Bowling Center	Recreation Center	20,442	65,963	-	225,066	Lighting Retrofit	Retrofit	15,351	-	52,378
FB Building 9232 Bowling Center	Recreation Center	20,442	65,963	-	225,066	Plug Load Management	Operational	4,004	-	13,662
FB Building 9236 Rec Center	Recreation Center	3,000	17,853	-	60,914	HVAC Economizer Operation	Operational	2,408	-	8,216
FB Building 9236 Rec Center	Recreation Center	3,000	17,853	-	60,914	HVAC Unoccupied Setback	Operational	4,980	-	16,992
FB Building 9236 Rec Center	Recreation Center	3,000	17,853	-	60,914	Lighting Controls	Retrofit	3,474	-	11,853
FB Building 9236 Rec Center	Recreation Center	3,000	17,853	-	60,914	Lighting Retrofit	Retrofit	2,839	-	9,687
FB Building 9236 Rec Center	Recreation Center	3,000	17,853	-	60,914	Plug Load Management	Retrofit	4,152	-	14,167

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Fort Bliss Building 11251 Phys Fit Center	Fitness Center/Health Club/Gym	22,648	155,129	-	529,300	Demand Controlled Ventilation	Retrofit	3,013	-	10,280
Fort Bliss Building 11251 Phys Fit Center	Fitness Center/Health Club/Gym	22,648	155,129	-	529,300	HVAC Scheduling Control	Operational	103,393	-	352,777
Fort Bliss Building 11251 Phys Fit Center	Fitness Center/Health Club/Gym	22,648	155,129	-	529,300	Lighting Retrofit (T-8 to Super T-8)	Retrofit	36,576	-	124,797
Fort Bliss Building 11251 Phys Fit Center	Fitness Center/Health Club/Gym	22,648	155,129	-	529,300	Miscellaneous Loads	Operational	1,644	-	5,609
Fort Bliss Building 11251 Phys Fit Center	Fitness Center/Health Club/Gym	22,648	155,129	-	529,300	Plug Load Management	Retrofit	10,503	-	35,836
Fort Bliss Building 2 Televideo Center	Office	241,909	204,695	-	698,419	HVAC Scheduling Control	Operational	90,180	-	307,694
Fort Bliss Building 2 Televideo Center	Office	241,909	204,695	-	698,419	Lighting Controls	Operational	30,180	-	102,974
Fort Bliss Building 2 Televideo Center	Office	241,909	204,695	-	698,419	Lighting Retrofit	Retrofit	62,360	-	212,772
Fort Bliss Building 2 Televideo Center	Office	241,909	204,695	-	698,419	Plug Load Management	Retrofit	15,550	-	53,057
Fort Bliss Building 2 Televideo Center	Office	241,909	204,695	-	698,419	VFDs on AHU Fans	Retrofit	6,425	-	21,922
Fort Bliss Building 20105 CO HQ Bldg	Training Facility	45,651	22,219	-	75,811	HVAC Economizer Operation	Retrofit	4,855	-	16,565
Fort Bliss Building 20105 CO HQ Bldg	Training Facility	45,651	22,219	-	75,811	HVAC Scheduling Control	Operational	6,135	-	20,933
Fort Bliss Building 20105 CO HQ Bldg	Training Facility	45,651	22,219	-	75,811	Lighting Controls	Operational	4,095	-	13,972
Fort Bliss Building 20105 CO HQ Bldg	Training Facility	45,651	22,219	-	75,811	Plug Load Management	Retrofit	7,134	-	24,341
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Air Cooled Condenser Retrofit with Evaporative Cooling	Retrofit	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Air Side Economizer Maintenance	Operational	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Eliminate Unnecessary Simultaneous Heating and Cooling	Operational	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Lighting Retrofit (T-8 to Super T-8)	Retrofit	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Parking Lot Lighting Retrofit with Controls	Retrofit	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Plug Load Management	Retrofit	-	-	-
Fort Bliss Building 20107 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	34,087	-	-	-	Schedule Modifications	Operational	-	-	-
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Air Cooled Condenser Retrofit with Evaporative Cooling	Retrofit	20,744	-	70,779
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Air Side Economizer Maintenance	Operational	7,225	-	24,652
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Eliminate Unnecessary Simultaneous Heating and Cooling	Operational	50,755	-	173,176
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Lighting Retrofit (T-8 to Super T-8)	Retrofit	8,340	-	28,456
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Parking Lot Lighting Retrofit with Controls	Retrofit	29,293	-	99,948

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Fort Bliss Building 20117 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	33,450	129,633	-	442,308	Plug Load Management	Retrofit	13,276	-	45,298
Fort Bliss Building 20157 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,091	35,404	-	120,798	Eliminate Unnecessary Simultaneous Heating and Cooling	Operational	8,014	-	27,344
Fort Bliss Building 20157 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,091	35,404	-	120,798	Parking Lot Lighting Retrofit with Controls	Retrofit	27,390	-	93,455
Fort Bliss Building 20355 Barracks	Barracks	50,991	93,989	-	320,690	Lighting Controls	Operational	3,681	-	12,560
Fort Bliss Building 20355 Barracks	Barracks	50,991	93,989	-	320,690	Lighting Retrofit	Retrofit	11,482	-	39,177
Fort Bliss Building 20355 Barracks	Barracks	50,991	93,989	-	320,690	Plug Load Management	Operational	1,696	-	5,787
Fort Bliss Building 20355 Barracks	Barracks	50,991	93,989	-	320,690	Schedule Modifications	Operational	77,130	-	263,168
Fort Bliss Building 20457 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,153	15,988	1,248	55,836	Eliminate Unnecessary Simultaneous Heating and Cooling	Retrofit	6,843	1,107	24,489
Fort Bliss Building 20457 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,153	15,988	1,248	55,836	HVAC Scheduling Control	Operational	4,380	141	15,090
Fort Bliss Building 20457 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	55,153	15,988	1,248	55,836	Lighting Retrofit	Retrofit	4,765	-	16,258
Fort Bliss Building 2527 Org Str Building	Distribution Center	65,589	131,947	-	450,203	HVAC Scheduling Control	Operational	17,800	-	60,734
Fort Bliss Building 2527 Org Str Building	Distribution Center	65,589	131,947	-	450,203	Lighting Controls	Operational	45,147	-	154,042
Fort Bliss Building 2527 Org Str Building	Distribution Center	65,589	131,947	-	450,203	Lighting Retrofit	Retrofit	69,000	-	235,428
Fort Bliss Building 2592 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	300,280	-	1,024,555	Eliminate Unnecessary Simultaneous Heating and Cooling	Operational	8,050	-	27,467
Fort Bliss Building 2592 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	300,280	-	1,024,555	HVAC Operating and Maintenance Measures	Operational	26,070	-	88,951
Fort Bliss Building 2592 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	300,280	-	1,024,555	HVAC Scheduling Control	Operational	148,060	-	505,181
Fort Bliss Building 2592 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	300,280	-	1,024,555	Lighting Retrofit	Retrofit	109,300	-	372,932
Fort Bliss Building 2592 VEH MAINT SHOP	Repair Services (Vehicle, Shoe, Locksmith, etc)	115,742	300,280	-	1,024,555	Upgrade to EE Motors	Retrofit	8,800	-	30,026
Fort Bliss Building 2930 Phys Fit Ctr	Fitness Center/Health Club/Gym	61,322	372,781	-	1,271,929	Chilled Water Supply Temperature Reset	Operational	15,671	-	53,469
Fort Bliss Building 2930 Phys Fit Ctr	Fitness Center/Health Club/Gym	61,322	372,781	-	1,271,929	Evaporative Retrofit for Air-cooled Condensers	Retrofit	93,846	-	320,203
Fort Bliss Building 2930 Phys Fit Ctr	Fitness Center/Health Club/Gym	61,322	372,781	-	1,271,929	Lighting Retrofit	Retrofit	174,294	-	594,691
Fort Bliss Building 2930 Phys Fit Ctr	Fitness Center/Health Club/Gym	61,322	372,781	-	1,271,929	Schedule Modifications	Operational	7,269	-	24,802
Fort Bliss Building 2930 Phys Fit Ctr	Fitness Center/Health Club/Gym	61,322	372,781	-	1,271,929	VFDs and DCV on Fans	Retrofit	81,701	-	278,764
Fort Bliss Building 724 Training Aids Ctr	Training Facility	22,439	27,506	-	93,850	Air Cooled Condenser Retrofit with Evaporative	Retrofit	19,658	-	67,073
Fort Bliss Building 724 Training Aids Ctr	Training Facility	22,439	27,506	-	93,850	Air Side Economizer Maintenance	Operational	1,014	-	3,460
Fort Bliss Building 724 Training Aids Ctr	Training Facility	22,439	27,506	-	93,850	Lighting Retrofit	Retrofit	2,256	-	7,697

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Fort Bliss Building 724 Training Aids Ctr	Training Facility	22,439	27,506	-	93,850	Tune-up of Air-Cooled Air Conditioning Equipment	Operational	3,293	-	11,236
Fort Bliss Building 724 Training Aids Ctr	Training Facility	22,439	27,506	-	93,850	Upgrade to EE Motors	Retrofit	1,285	-	4,384
Fort Carson Building 1218	Office	46,113	107,799	-	367,810	Implement a Personal Computer and Plug Load Power Management System	Retrofit	27,667	-	94,400
Fort Carson Building 1218	Office	46,113	107,799	-	367,810	Investigate erratic energy consumption.	Operational	14,256	-	48,641
Fort Carson Building 1218	Office	46,113	107,799	-	367,810	Review existing building control system	Retrofit	65,876	-	224,769
Fort Carson Building 1552 Barracks	Barracks	123,860	67,008	-	228,631	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	48,800	-	166,506
Fort Carson Building 1552 Barracks	Barracks	123,860	67,008	-	228,631	Plug Load Management\n	Retrofit	18,208	-	62,126
Fort Carson Building 1552 Barracks	Barracks	123,860	67,008	-	228,631	Schedule Modifications	Operational	-	-	-
Fort Carson Building 2135 Simulator Facility	Training Facility	48,180	205,888	-	702,490	Air Cooled Condenser Retrofit with Evaporative Cooling	Retrofit	30,722	-	104,823
Fort Carson Building 2135 Simulator Facility	Training Facility	48,180	205,888	-	702,490	HVAC Unoccupied Setback	Operational	51,802	-	176,748
Fort Carson Building 2135 Simulator Facility	Training Facility	48,180	205,888	-	702,490	Lighting Retrofit	Retrofit	39,616	-	135,170
Fort Carson Building 2135 Simulator Facility	Training Facility	48,180	205,888	-	702,490	Parking Lot Lighting Retrofit	Retrofit	16,971	-	57,905
Fort Carson Building 2135 Simulator Facility	Training Facility	48,180	205,888	-	702,490	Plug Load Management	Retrofit	66,777	-	227,843
Fort Carson Building 2600 Company Ops Facility	Office	66,673	35,041	-	119,560	Implement a Personal Computer and Plug Load Power Management System	Retrofit	9,316	-	31,786
Fort Carson Building 2600 Company Ops Facility	Office	66,673	35,041	-	119,560	Investigate erratic energy consumption.	Operational	9,113	-	31,094
Fort Carson Building 2600 Company Ops Facility	Office	66,673	35,041	-	119,560	Review control schedules, sequences, and temperature setback programming	Operational	16,612	-	56,680
Fort Carson Building 330 Large Warehouse	Warehouse (refrigerated and non-refrigerated)	139,596	195,277	-	666,285	HVAC Scheduling Control	Operational	28,526	-	97,331
Fort Carson Building 330 Large Warehouse	Warehouse (refrigerated and non-refrigerated)	139,596	195,277	-	666,285	Lighting Retrofit	Retrofit	118,092	-	402,930
Fort Carson Building 330 Large Warehouse	Warehouse (refrigerated and non-refrigerated)	139,596	195,277	-	666,285	Parking Lot Lighting Retrofit with Controls	Retrofit	39,322	-	134,167
Fort Carson Building 330 Large Warehouse	Warehouse (refrigerated and non-refrigerated)	139,596	195,277	-	666,285	Plug Load Management	Retrofit	9,337	-	31,858
Fort Carson Building 520 Small Warehouse	Warehouse (refrigerated and non-refrigerated)	35,702	-	-	-	HVAC Scheduling Control	Operational	-	-	-
Fort Carson Building 520 Small Warehouse	Warehouse (refrigerated and non-refrigerated)	35,702	-	-	-	Lighting Retrofit	Retrofit	-	-	-
Fort Carson Building 520 Small Warehouse	Warehouse (refrigerated and non-refrigerated)	35,702	-	-	-	Plug Load Management	Retrofit	-	-	-
Fort Carson Building 756 Barracks	Barracks	95,858	43,233	-	147,511	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	35,851	-	122,324
Fort Carson Building 756 Barracks	Barracks	95,858	43,233	-	147,511	Plug Load Management	Retrofit	7,382	-	25,187
Fort Carson Building 756 Barracks	Barracks	95,858	43,233	-	147,511	Schedule Modifications	Operational	-	-	-
Fort Carson Building 758 Barracks	Barracks	95,858	45,341	-	154,703	Investigate and Remediate the cause of Cycling Load	Operational	-	-	-
Fort Carson Building 758 Barracks	Barracks	95,858	45,341	-	154,703	Lighting Retrofit (T-8 to Super T-8) with Occupancy Sensors	Retrofit	29,908	-	102,046
Fort Carson Building 758 Barracks	Barracks	95,858	45,341	-	154,703	Plug Load Management	Retrofit	15,433	-	52,657
Fort Carson Building 758 Barracks	Barracks	95,858	45,341	-	154,703	Schedule Modifications	Operational	-	-	-
Fort Carson Building 9439 Dining Facility	Dining Facility	26,500	29,555	-	100,842	Kitchen Hood - VFD on Exhaust Fan	Retrofit	15,480	-	52,818
Fort Carson Building 9439 Dining Facility	Dining Facility	26,500	29,555	-	100,842	Refrigeration Controls	Retrofit	14,075	-	48,024

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Fort Carson Building 9439 Dining Facility	Dining Facility	26,500	29,555	-	100,842	Water and Thermal Savings Measures	Retrofit	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	Boiler Replacement	Retrofit	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	HVAC Efficiency Testing & Air-Fuel Ratio	Operational	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	Lighting Retrofit	Operational	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	Plug Load Management	Retrofit	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	VFDs and DCV on Fans	Retrofit	-	-	-
JBLM 1236 Auto Aid Institute	Training Facility	17,136	-	-	-	VFDs on Hot Water Pumps	Retrofit	-	-	-
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Evaluate the existing lighting assets for the deployment of occupancy controls.	Retrofit	17,687	-	60,348
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Investigate the implementation Optimal Start/Stop control	Operational	4,811	194	16,615
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Investigate the weekend consumption	Operational	8,506	390	29,424
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Perform a building envelope audit to identify and address the apparent building shell integrity issues.	Retrofit	12,566	487	43,377
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Operational	30,589	-	104,370
JBLM 3369 Company HQ Building	Office	59,534	79,909	1,071	273,753	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.	Operational	5,750	-	19,619
JBLM 9136 Enlisted UPH	Barracks	25,281	45,065	3,810	157,686	Adjust ventilation controls and air distribution	Retrofit	14,725	3,810	54,166
JBLM 9136 Enlisted UPH	Barracks	25,281	45,065	3,810	157,686	Lighting occupancy controls	Retrofit	30,340	-	103,520
ORARNG Anderson Readiness Center	Office	121,841	394,459	-	1,345,894	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.\n	Retrofit	164,472	-	561,178
ORARNG Anderson Readiness Center	Office	121,841	394,459	-	1,345,894	Investigate the opportunity for solar photovoltaic array.	Retrofit	21,545	-	73,512
ORARNG Anderson Readiness Center	Office	121,841	394,459	-	1,345,894	Investigate the potential for night setback during the cooling season.	Operational	17,483	-	59,652
ORARNG Anderson Readiness Center	Office	121,841	394,459	-	1,345,894	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	49,014	-	167,236
ORARNG Anderson Readiness Center	Office	121,841	394,459	-	1,345,894	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.\n	Operational	141,945	-	484,316
ORARNG Joint Force Headquarters	Office	85,840	174,530	-	595,496	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	85,267	-	290,931
ORARNG Joint Force Headquarters	Office	85,840	174,530	-	595,496	Investigate the opportunity for solar photovoltaic array.	Retrofit	16,159	-	55,135
ORARNG Joint Force Headquarters	Office	85,840	174,530	-	595,496	Investigate the potential for night setback during the cooling season.\n	Operational	15,177	-	51,784
ORARNG Joint Force Headquarters	Office	85,840	174,530	-	595,496	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.\n	Operational	57,927	-	197,647
Picatinny Building 65 Admin	Office	66,000	137,416	-	468,863	Determine and remediate the causes of uncontrolled electric heating.	Operational	47,206	-	161,067
Picatinny Building 65 Admin	Office	66,000	137,416	-	468,863	Evaluate a Building Automation System (BAS) upgrade for optimal scheduling.	Operational	21,745	-	74,194
Picatinny Building 65 Admin	Office	66,000	137,416	-	468,863	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	50,720	-	173,057
Picatinny Building 65 Admin	Office	66,000	137,416	-	468,863	Investigate cause of demand on June 11th, 2012 to prevent future demand spikes.	Operational	-	-	-
Picatinny Building 65 Admin	Office	66,000	137,416	-	468,863	Investigate the opportunity for solar photovoltaic array.	Retrofit	17,745	-	60,546
Picatinny Building 92 Admin	Office	35,300	69,681	-	237,752	Determine and remediate the causes of uncontrolled electric heating.	Operational	12,178	-	41,551
Picatinny Building 92 Admin	Office	35,300	69,681	-	237,752	Evaluate a Building Automation System (BAS) upgrade for optimal scheduling.	Operational	12,131	-	41,391
Picatinny Building 92 Admin	Office	35,300	69,681	-	237,752	Evaluate evening electric consumption during the heating season.	Operational	7,199	-	24,563

100 Building RBA Energy Conservation Measures										
Portal Building Name	Building Type	Building GSF	Total Electric Savings (kWh)	Total Gas Savings (CF)	Total kbTu Savings	ECM Name	ECM Type	ECM Electric Savings (kWh)	ECM Gas Savings (CF)	ECM kBtu Savings
Picatinny Building 92 Admin	Office	35,300	69,681	-	237,752	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	26,343	-	89,882
Picatinny Building 92 Admin	Office	35,300	69,681	-	237,752	Investigate the opportunity for solar photovoltaic array.	Retrofit	11,830	-	40,364
Picatinny Building 95 Admin & Shop	Office	94,000	410,324	-	1,400,025	Evaluate a Building Automation System (BAS) upgrade for optimal scheduling.	Operational	16,005	-	54,609
Picatinny Building 95 Admin & Shop	Office	94,000	410,324	-	1,400,025	Evaluate the existing lighting assets for the possibility of fixture retrofits.\n	Retrofit	193,424	-	659,963
Picatinny Building 95 Admin & Shop	Office	94,000	410,324	-	1,400,025	Investigate the opportunity for solar photovoltaic array.	Retrofit	17,745	-	60,546
Picatinny Building 95 Admin & Shop	Office	94,000	410,324	-	1,400,025	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Operational	35,881	-	122,426
Picatinny Building 95 Admin & Shop	Office	94,000	410,324	-	1,400,025	Review control sequences and temperature setback programming to eliminate unnecessary simultaneous heating and cooling.	Operational	147,269	-	502,482
Picatinny Buildings 93 & 94	Office	208,000	379,312	-	1,294,212	Adjust Computer Room or Data Center cooling practices.	Operational	28,912	-	98,648
Picatinny Buildings 93 & 94	Office	208,000	379,312	-	1,294,212	Building Automation System (BAS) upgrade for optimal scheduling.\n	Operational	45,925	-	156,696
Picatinny Buildings 93 & 94	Office	208,000	379,312	-	1,294,212	Evaluate the existing lighting assets for the possibility of fixture retrofits.	Retrofit	195,821	-	668,141
Picatinny Buildings 93 & 94	Office	208,000	379,312	-	1,294,212	Personal computer and plug load power management.	Operational	67,249	-	229,454
Picatinny Buildings 93 & 94	Office	208,000	379,312	-	1,294,212	Solar photovoltaic array.	Retrofit	41,405	-	141,274
Port Hueneme 850 Admin Space	Office	16,920	4,600	-	15,695	Building Start-Up	Operational	4,600	-	15,695
Port Hueneme Building 1100 Admin & General Use Lab	Office	190,818	70,814	-	241,617	Investigate the weekend consumption	Operational	28,401	-	96,904
Port Hueneme Building 1100 Admin & General Use Lab	Office	190,818	70,814	-	241,617	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	42,413	-	144,713
Port Hueneme Building 1444 Admin Space & Classrooms	Office	60,000	46,170	-	157,532	Evaluate HVAC setpoints	Operational	6,240	-	21,291
Port Hueneme Building 1444 Admin Space & Classrooms	Office	60,000	46,170	-	157,532	Lighting Retrofit	Retrofit	25,870	-	88,268
Port Hueneme Building 1444 Admin Space & Classrooms	Office	60,000	46,170	-	157,532	Plug Load Management	Operational	14,060	-	47,973
Port Hueneme Building 2 (Mar-12 to Feb-13)	Office	51,000	234,262	-	799,302	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	54,300	-	185,272
Port Hueneme Building 2 (Mar-12 to Feb-13)	Office	51,000	234,262	-	799,302	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	27,918	-	95,256
Port Hueneme Building 2 (Mar-12 to Feb-13)	Office	51,000	234,262	-	799,302	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.	Operational	61,896	-	211,189
Port Hueneme Building 2 (Mar-12 to Feb-13)	Office	51,000	234,262	-	799,302	Review control schedules, sequences, and temperature setback programming to eliminate unnecessary unoccupied conditioning	Operational	90,148	-	307,585
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	147,207	-	502,270
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Perform a building envelope audit to identify and address the apparent building shell integrity issues.	Retrofit	-	-	-
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	132,997	-	453,786
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.	Operational	116,353	-	396,996
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Review control sequences and temperature setback programming to eliminate unnecessary unoccupied heating and cooling	Operational	84,241	-	287,430
Tobyhanna Building 11 Administration Building	Office	196,000	550,458	-	1,878,162	Review Control Sequences of all Ventilation Equipment	Operational	69,660	-	237,680

100 Building RBA Energy Conservation Measures										
Portal Building Name	**Building Type**	**Building GSF**	**Total Electric Savings (kWh)**	**Total Gas Savings (CF)**	**Total kbTu Savings**	**ECM Name**	**ECM Type**	**ECM Electric Savings (kWh)**	**ECM Gas Savings (CF)**	**ECM kBtu Savings**
Tobyhanna Building 18 DPW Engineering Office	Office	12,947	83,243	-	284,025	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	10,028	-	34,216
Tobyhanna Building 18 DPW Engineering Office	Office	12,947	83,243	-	284,025	Investigate the weekend consumption	Operational	37,469	-	127,844
Tobyhanna Building 18 DPW Engineering Office	Office	12,947	83,243	-	284,025	Perform a building envelope audit to identify and address the apparent building shell integrity issues.	Retrofit	-	-	-
Tobyhanna Building 18 DPW Engineering Office	Office	12,947	83,243	-	284,025	Personal computer and plug load power management practices should be evaluated during both the occupied and unoccupied periods.	Retrofit	12,062	-	41,156
Tobyhanna Building 18 DPW Engineering Office	Office	12,947	83,243	-	284,025	Review control sequences and temperature setback programming to eliminate unnecessary simultaneous heating and cooling.	Operational	23,684	-	80,810
US Naval Observatory - Building 52B	Office	49,423	71,344	-	243,426	Evaluate the existing lighting assets for the possibility of fixture retrofits and a deployment of occupancy controls.	Retrofit	26,070	-	88,951
US Naval Observatory - Building 52B	Office	49,423	71,344	-	243,426	Personal computer and plug load power management practices should be evaluated during unoccupied periods.	Retrofit	19,483	-	66,476
US Naval Observatory - Building 52B	Office	49,423	71,344	-	243,426	Review Computer Room or Data Center cooling practices and readjust settings to reduce power consumption.	Operational	9,807	-	33,461
US Naval Observatory - Building 52B	Office	49,423	71,344	-	243,426	Review control sequences and temperature setback programming to eliminate unnecessary unoccupied heating and cooling.	Operational	15,984	-	54,537

Appendix F: Chapter 6 "Metering Communications and Data Storage" from *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency*

Source: Sullivan, G.D.; Hunt, WD; Pugh, R.; Sandusky, W.F.; Koehler, TM; *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency;* Release 2.0. Prepared by Pacific Northwest Laboratory for the Federal Energy Management Program, U.S. Department of Energy. August 2001. http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf

Chapter 6 Metering Communications and Data Storage

An integral part of the overall metering system is the mode of communications from the sensors to the meter and then from the meter to the point of data storage, analysis, and archiving. The communication from sensor to meter is usually handled internal to the meter and largely transparent to the user. The communication from the meter to the ultimate storage, analysis, and archiving is the focus of this chapter.

Regardless of the meter type, once data are collected they need a communication pathway to a location where the data will be processed, stored, and used. This pathway should be amenable to the various meter output types – some of the more common output types include:

- Analog output – typically, 4 to 20 mA or 0 to 5 volts dc
- Contact closure – pulse type output
- Digital output – digital pulse
- Digital signal – outputs using networked communications (e.g., Ethernet, Modbus, HART).

Many of the newer digital-signal output meters can output multiple signal types offering a variety of communications options. These meters can be serially addressed, affording a lowered installed cost through reduced wiring installation and expense (i.e., multiple meters communicating on one pair of wires back to the data-collection terminal). Often these outputs can be viewed on local displays integral to the meter. These displays are quite useful for field set-up, calibration, verification of function, and troubleshooting. Developments in wireless technologies have resulted in lower meter cost and improved ease of installation.

Modern meter systems benefit from recent developments in communications technologies.

6.1 Traditional Communications Options – Non-Automated

Modern meter systems benefit from recent developments in communications technologies. Over the past 20 years, communications have moved from requiring a hand-written recording of the metered value to a manually entered electronic recording to a locally transmitted electronic value. These data collection/ communications modes are still in practice and are described below.

- ***Sneaker-net Data Collection***. A largely outdated, yet still practiced, method of manual meter reading involving writing down or keying in to a hand recorder the metered data. This data collection practice is inefficient, inaccurate, and discouraged in most applications.
- ***Mobile-Radio Data Collection***. This technology makes use of close-proximity radio frequency (RF) communications where by data are transmitted by the meter to a receiver – usually located in a slowly moving vehicle. While more accurate than sneaker-net, it still has an in-field manual collection component – driver and vehicle.

With the enactment of EPAct 2005, which explicitly states that metered data will be collected automatically, via automated meter reading (AMR) and made available at least daily, Federal agencies are now required to use AMR – where practicable. As such, the following section presents the AMR systems that

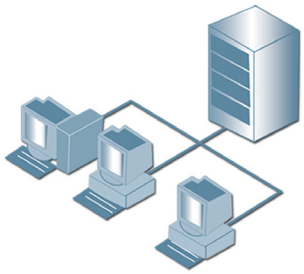
are more common and applicable to the Federal sector. Section 2.3 highlights the various legislative requirements and agency directives related to metering and communications.

Phone Modem

Advantages:
- Proven technology
- A secure and private network
- Usually available

Challenges:
- Can be expensive
- No access to real-time data
- Wired installation (hardwire solution) using additional equipment (modem)

Local Area Network



Advantages:
- Proven technology
- Increasing availability
- Always connected
- Data sharing opportunities

Challenges:
- Network/IT security concerns
- Wired installation – need for network connectivity

6.2 Modern Metering Communications – Automated Meter Reading (AMR)

AMR systems, both wired and wireless, are increasingly being used because of their availability, reliability, and decreasing cost. Many utilities, large corporate campuses, and universities are finding AMR not only to be convenient, but also to make good business sense. When developing the communications portion of your metering program, it is important to consider what existing communications infrastructure you can take advantage of (e.g., building automation system, local area network) to potentially lower the cost of AMR. In addition, if you have a large site with distributed buildings, you may find benefit in considering multiple communications technologies (e.g., networks in one area, phone lines in another, and wireless in a third) to gain the necessary communications coverage.

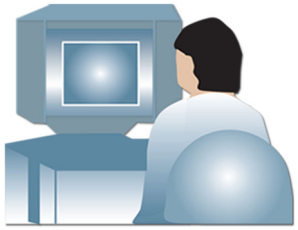
Below are the predominant AMR technologies along with some of the benefits and challenges of each.

Phone Modem. Taking advantage of telephone modem technology in both hardwire and wireless (i.e., cellular), this communications solution is the oldest and traditionally most reliable of the technologies. In typical applications, automated software (usually from the metering equipment vendor) is used to dial (phone-in) the modem daily to retrieve accumulated data. In addition to the phone-in systems, there are meters that can phone-out at preset times or at specified data accumulation levels. It should be noted that phone lines do not have to be dedicated to the meter(s) they serve; there is no reason meters cannot share a phone line with other applications – even personal office phones. Shared phone line applications can use off-hours for data communications and, therefore, do not interfere with other business-related uses.

Local Area Network. Using an existing building or site's computer network to serve as the communications path for the metering system can be very economic. When properly configured, meters can communicate over this network using a variety of open protocols, including Modbus, HART, transmission control protocol/internet protocol (TCP/IP), BACnet, etc. In addition, these meters usually can be serially addressed and linked together (daisy-chained) to minimize wiring installation and expense.

Beyond the local area network (LAN), wide-area networks (WANs) can be developed by linking more than one of these networks together. This becomes useful to large sites with many distributed buildings and locations. Additional benefits to the LAN solution include the ability to share data throughout the network and view data in real time. Prevalent concerns with using a LAN for data communications stem from perceived security issues with transferring data over secure networks and potential access to the LAN via the metering points. In both cases, these concerns can be addressed with typical LAN security protocols. As is often the case, some level of education on the system, its operation, and security may be necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

Building Automation System

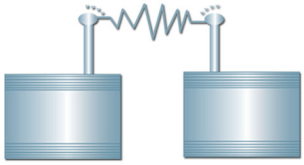


Advantages:
- Usually available
- Fast communications
- Always connected

Challenges:
- Potential system compatibility issues
- Potential data availability issues

Building Automation System. By using an existing building automation system (BAS), we again take advantage of a site's previous investment in existing infrastructure. In this case, the wiring used for BAS communication becomes the metering communications path. In this case, the meters are treated as other "points" on the BAS and function much as other sensors or points on the system (i.e., communicate to and from the central host computer). The BAS is a workable solution only when there is excess capacity to add points and system software is capable of using the meter's data output protocol – both of these factors need be verified with the BAS and metering equipment vendors. An additional constraint to the BAS solution relates to the host computer's ability to allocate memory for these data and offer an ability to retrieve data sets in an automated fashion.

Wireless

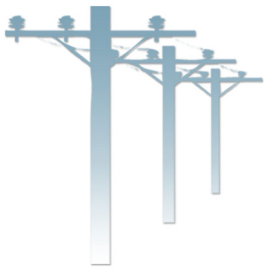


Advantages:
- No communication wiring to install
- Fast communications
- Always connected

Challenges:
- System cost – though prices are coming down
- Perceived RF interference issues
- Distance and materials limitations
- New system, new infrastructure

Radio Frequency/Wireless Networks. Becoming increasingly available and economic, wireless radio frequency (RF) communications makes use of wireless transmitters and receivers to communicate metered data. Wireless communication (FEMP 2007) offers the benefits of lowered installation cost, flexibility in metering locations, and minimizes disruption in service when compared to other options. Some of the limitations to wireless communications include the effective distance of communication (typically less than 300 feet) and the building's materials of construction that may impede or block the RF signal. Both situations can be mitigated by using a repeater or mesh network configuration. Similar to the LAN solution, wireless communications has perceived challenges including security issues and potential for interference with other sensitive communications equipment. In many cases these concerns are unfounded, yet some level of education on the system, its operation, and security may be

Power Line Carrier



Advantages:
- Uses existing infrastructure
- Always connected

Challenges:
- Speed of data transfer
- Technical issues with transferring data past transformers

necessary – a small demonstration of the system may help convince skeptical IT or information-security staff.

Power Line Carrier. This technology uses existing electrical wiring, both internal and external to buildings, as the communications conduit. While making use of the existing infrastructure gives this technology and economic advantage, limitations related to speed and quantity of data transfer and the ability to transfer data across standard electrical transformers can occur. Organizations making productive use of this technology, notably utilities and sites with many distributed buildings, do so by spreading the considerable installed cost over many metering points, or utilizing available communications technology that overcome this barrier.

As noted in the data output/communications considerations sections under each of the metering technologies in Chapter 5, many meters offer more than one communication output option. Most meters are a pulse or other protocol (e.g., Bacnet, Lonworks, or Modbus), whereby these data are either collected at the meter for future upload or sent (pushed by meter/pulled by collector) in real-time to the data collection point.

6.3 Data Storage Software

Assuming proper data collection and communication, some form of data storage system will be needed. Data storage needs will depend on the number of meters connected, the number of parameters metered, the data interval, and the expected need for access to historic data. In most cases, one of any number of commercially available database software systems will function well for data storage and software interface.

The specific requirements of the data storage/database system should be decided with assistance from site IT staff or others knowledgeable, or those who will be using the system. Below are draft specifications based on work done for the California Energy Commission Public Interest Energy Research Program (PIER) and the Building Technologies Program of the U.S. Department of Energy (CEC 2007).

6.3.1 Data Storage Specification Considerations

Sufficient data storage capacity will be able to store at least two years of data for all data points.

- Data shall be stored in a structured query language (SQL) compliant database format or time series format. Minimum requirements are a SQL server or equivalent.

- The database shall allow other application programs to read and access the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added.

- Trend, or interval, data shall be archived in a database from field equipment in time intervals no less than once per day.
- Storage on the field equipment will be reset once data are exported to allow for trending if communication is disrupted. Data will be uploaded once communication is re-established.
- Blank or null values in the database will be replaced with actual data. Calculations and other metrics will be updated once controller data are uploaded. This overall system update to check for new data should be automated to run once a day.
- All data shall be stored in database file format for direct use by third-party application programs (e.g., an energy information system [EIS] as discussed in Chapter 7).
- Sufficient data storage capacity will be able to store at least two years of data for all data points. In addition, storage capacity will also allow for compression of one year of data for historic trends and archiving.
- Time stamps shall be collected on all data. The time stamp, depending on system architecture, will be captured at the field controller or system controller and directed to the database archive.
- Exported data shall contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point shall be unique. The export query shall be for a specific point or multiple points in a defined group.
- Date/Time fields shall be in a single column in a format automatically recognized by common spreadsheet, database software tools, or EIS.
- The data shall be fully contained in a single file or table for each point. Data shall not span multiple files or database tables. Users can have the option to modify export file start and end file date span depending on third-party program requirements to evaluate the data.

Key to productive use of data is the access for analysis, whether done in-house or as part of a third-party EIS package or agreement – see Chapter 7 for more details.

The computer hardware for data storage and software execution should have ample processing power and memory to run the chosen database system and to process, store, and archive all collected data.

6.4 Data Storage Hardware

The computer hardware for data storage and software execution should have ample processing power and memory to run the chosen database system and to process, store, and archive all collected data. Fortunately, such activities can be handled quite easily with modern stand-alone personal computers and/or workstations. One key recommendation is that whatever system is chosen, it be dedicated to this activity. It is also recommended that this system have an automated back-up function (typically daily) to a separate system/server for data protection and archiving.

An increasingly popular option for data storage involves an agreement with a third-party organization (e.g., an EIS vendor or other data-hosting entity) whereby all data are collected, stored, and backed-up on vendor computer servers. In this case, the client is given access, usually over the web, to all data and analyses for addition processing, reporting, and downloading.

6.5 References

California Energy Commission (CEC). 2007. *Continuous Performance Monitoring Systems, Specification Guide for Performance Monitoring Systems*. Available at: http://cbs.lbl.gov/performance-monitoring/specifications.

Energy Policy Act of 2005 (EPAct 2005). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

Energy Independence and Security Act of 2007 (EISA 2007). 2007. Public Law 110-140, as amended, Section 434(b).

Federal Energy Management Program (FEMP). 2007. *Wireless Temperature Sensors for Improved HVAC Control*. DOE/EE-0319, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/pdfs/tir_wirelesstempsensors.pdf.