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Economic Energy Savings Potential in Federal Buildings

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Preface

The mission of the U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP) is to reduce the cost of government by advancing energy efficiency, water conservation, and the use of renewable technologies. This is accomplished by creating partnerships, leveraging resources, transferring technology, and providing training, technical guidance, and assistance to agencies. Each of these activities is directly related to achieving the requirements set forth in the Energy Policy Act of 1992 and the goals that have been established in Executive Order 13123 (June 1999), as well as supporting activities that promote sound management of Federal financial and personnel resources. The Pacific Northwest National Laboratory (PNNL) supports the mission of FEMP in all activity areas.

This document provides findings and recommendations from an analysis by PNNL to estimate the available economic energy savings potential in Federal facilities. Understanding this savings potential will help FEMP develop programmatic strategies aimed at meeting the Federal energy efficiency goals. This analysis relied on data from previously completed DOE SAVEnergy audits, as well as modeling of facilities with the Facility Energy Decision System (FEDS).

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Summary

The Federal Energy Management Program (FEMP) and Federal agencies have been working for years towards achieving mandated and legislated energy efficiency goals for Federal buildings. Recently, Executive Order 13123 extended prior requirements to a 35% reduction in energy use per square foot by 2010 relative to 1985. Since 1985, energy use at Federal buildings has dropped from 139.8 MBtu/ksf/yr (million Btu per thousand square feet) to 113.7 MBtu/ksf/yr in 1998[1]. Thus, significant additional energy savings will be required to meet the future goal of 90.9 MBtu/ksf.

The primary objective of this study was to estimate the current life-cycle cost-effective (i.e., economic) energy savings potential in Federal buildings and the corresponding capital investment required to achieve these savings, with Federal financing. Estimates were developed for major categories of energy efficiency measures such as building envelope, heating system, cooling system, and lighting. The analysis was based on conditions (building stock and characteristics, retrofit technologies, interest rates, energy prices, etc.) existing in the late 1990s. The potential impact of changes to any of these factors in the future was not considered.

The analysis relied on results from a sampling of SAVEnergy audits and modeling with the Facility Energy Decision System (FEDS). Although both auditing approaches consider a broad range of technologies, neither of these two approaches, or any other practical approach is 100% comprehensive. Thus, the estimated energy savings potential is most likely on the low side. In addition, the analysis was limited to consideration of savings captured via investment in capital improvements. Potential savings from changes in the building stock (e.g., demolition, new construction) or operation and maintenance practices, or replacement of equipment upon failure were not evaluated.

EO 13123 applies to owned buildings and leased buildings where energy costs are paid directly by the government. This includes foreign as well as domestic property. Certain types of energy intensive operations are excluded from the energy savings goals described above. The remaining buildings are commonly referred to as the "goal inventory." *This study focused on the energy savings potential in domestic, owned, goal inventory buildings, which represent about 86% of the total goal inventory square footage.*

Overall, the potential annual energy savings were estimated to be 25 MBtu/ksf/yr or 0.066 Quads/yr. This is 19% of the actual Federal goal inventory building energy consumption in FY98 or 22% of the per square foot consumption[2]. The estimated investment required to achieve these savings is \$5.2 billion, while annual dollar savings are estimated to be \$0.95 billion. The resulting net present value of the investment is \$9.3 billion. The energy savings potential, if captured, would result in the Federal government nearly meeting its goal of reducing energy consumption per square foot by 35% relative to 1985 figures, even without including the energy savings potential in foreign and leased property.

Lighting was the energy efficiency measure (EEM) category with the greatest energy savings potential, accounting for about one-fourth of the total. The most commonly recommended lighting measure was the conversion of T-12 fluorescent lights to T-8s with electronic ballasts. Other

[1] Excluding facilities that house energy intensive operations.

[2] The energy savings expressed as a percent of total energy consumption (19%) is less than the energy savings expressed as a percent of the per square foot energy consumption (22%) because the savings potential was only estimated for the domestic, owned, goal inventory square footage, which is 86% of the total goal inventory square footage.

common lighting measures were compact fluorescence lamps (CFLs), occupancy sensors or other controls, and light emitting diode (LED) exit signs. Other important categories indicated by the analysis are cooling systems, ventilation and controls, building envelope, service hot water, and heating systems. The frequencies of recommended energy efficiency measures from the sample of SAVEnergy audits evaluated and the FEDS modeling results are presented in Appendix D.

The clear evidence of substantial cost-effective lighting retrofit potential in both civilian and military agencies suggests that FEMP should continue to emphasize its lighting support programs. However, with 75% of the energy savings opportunity within other energy efficiency categories, a comprehensive energy efficiency program is clearly needed as well.

Although the total estimated energy savings per square foot were approximately the same for civilian and military agencies, the mix of energy efficiency measures was estimated to be significantly different. This result is mostly attributed to differences in analytical approach, which relied on a statistical extrapolation of SAVEnergy audit results for civilian agencies and simulation of selected Army installations with FEDS. Resolution of these differences is recommended to improve the accuracy of the estimates and better understand significant differences, if any, between civilian and military agencies.

Additional analysis of potential savings associated with central energy plants and thermal distribution systems is also recommended for the military. Energy savings estimates for these facilities were derived from SAVEnergy audit results for civilian agencies with similarly sized sites, but the savings could be several times greater based on the condition of a handful of military sites known by the authors.

The cost-effective energy savings potential noted above is based on Federal financing and declines if higher, private financing costs are assumed. A recent investigation conducted by the authors yielded an estimate of 0.040 to 0.048 Quads/yr of cost-effective energy savings potential via alternative financing [energy saving performance contracting (ESPC) or utility energy service contracts] or about two-thirds of the estimate in this study via Federal financing.[3] This range of alternative financing energy savings potential corresponds to required investments of $2.0 to $3.0 billion[4]. Even if all of the cost-effective alternative financing projects are implemented, the savings will leave the Federal government about 7 MBtu/ksf short of achieving the 35% reduction goal. Therefore, direct Federal funding of energy efficiency projects will also be required if the goal is to be met[5].

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[3] Dirks, J.A., D.R. Brown, and J.W. Currie. 1999. *Sensitivity of ESPC Projects to Changes in Interest Rates and Energy Prices*. An informal letter report from PNNL to DOE.

[4] Energy savings and investment figures from Dirks, Brown, and Currie (see footnote 3) were adjusted to correspond to the domestic, owned portion of the goal-inventory property only.

[5] Again, all conclusions are subject to the key limitations of this study described on the previous page, e.g., the estimated savings are based on currently available technologies being retrofit to the current building stock.

Glossary of Abbreviations and Other Terms

CFL	compact fluorescent lamps
DoD	Department of Defense
DOE	Department of Energy
EEM	energy efficiency measure
ESPC	energy saving performance contracting
EO	executive order
EPA	Environmental Protection Agency
FCC	Federal Communication Commission
FEDS	Facility Energy Decision System
FEMA	Federal Emergency Management Administration
FEMP	Federal Energy Management Program
FORSCOM	(Army) Forces Command
GSA	General Services Administration
HHS	Health and Human Services
ksf	thousand square feet
LED	light emitting diode
MBtu	million British thermal units
NARA	National Archives and Records Administration
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
NPV	net present value (of an investment)
PNNL	Pacific Northwest National Laboratory
PTAC	packaged terminal air conditioner
Quad	quadrillion Btu
sf	square feet
USIA	United States Information Agency[6]
VA	Veterans Affairs

[6] Incorporated into the State Department as of October 1, 1999.

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1.0 Introduction

FEMP and Federal agencies have been working for years towards achieving mandated and legislated energy efficiency goals for Federal buildings. Prior goals required energy consumption per square foot of building floor space to be reduced by 10%, 20%, and 30% relative to a 1985 baseline by the years 1995, 2000, and 2005, respectively. Recently, Executive Order 13123 extended the requirement to a 35% reduction by 2010 relative to 1985.

Since 1985, energy use at Federal buildings has dropped from 139.8 MBtu/ksf/yr to 113.7 MBtu/ksf/yr in 1998. This 18.7% drop in 13 years puts the Federal government on pace to meet the energy consumption goals for both 2005 (97.9 MBtu/ksf/yr) and 2010 (90.9 MBtu/ksf/yr). Still, significant additional energy savings will be required to meet the future goals.

The primary objective of this study was to estimate the life-cycle cost-effective (i.e., economic) energy savings potential in Federal buildings and the corresponding capital investment required to achieve these savings. Total estimates were aggregated from estimates prepared for major categories of energy efficiency measures such as building envelope, heating system, cooling system, and lighting. The results indicate (among other things) whether the economic energy savings potential is adequate to meet future goals, the magnitude of investment required to achieve the savings and meet the goals, and target energy efficiency measures that represent the greatest opportunity.

Over the years several estimates of the potential cost-effective energy savings and the corresponding required capital investment have been made. In general, these estimates must be updated periodically as changes occur in:

- the demand for energy services
- building stock and energy equipment characteristics[7]
- replacement or retrofit technology characteristics
- energy prices
- interest rates.

While prior estimates of the cost-effective energy savings potential have become dated, data collected from a few hundred SAVEnergy audits over the last few years has created a new source of information. This information can be used for characterizing the types of energy efficiency measures and estimating the cost-effective energy savings available for a significant portion of the Federal building inventory. The combination of these events suggested that new estimates of the potential cost-effective energy savings should be developed.

[7] Including previous retrofits, if any.

2.0 Previous Savings Estimates

The origins of the current Federal energy efficiency mandate of Executive Order 13123 stretches all the way back to the passage of the Federal Energy Management Improvement Act of 1988 (FEMIA). This law established for Federal agencies a 10% facility energy reduction goal by 1995 relative to 1985 facility energy use. The Federal agencies were successful in achieving this goal; through FY95 DOE reported a 14.2% reduction in energy use relative to the 1985 baseline. Since the FEMIA goal, additional energy efficiency goals have been established for Federal agencies:

- Executive Order 12759 of April 17, 1991, "Federal Energy Management" – mandated an energy reduction of 20% by 2000 relative to 1985

- Energy Policy Act of 1992 – legislated an energy reduction of 20% by 2000 relative to 1985

- Executive Order 12902 of March 6, 1994, "Energy Efficiency and Water Conservation at Federal Facilities" – mandated an energy reduction of 30% by 2005 relative to 1985

- Executive Order 13123 of June 8, 1999, "Greening the Government Through Efficient Energy Management" – mandated an energy reduction of 35% by 2010 relative to 1985.

Along the way there have been a number of estimates developed and made available regarding the potential level of cost-effective savings and/or investments to either meet or exceed the legislated and mandated goals. There are several reasons why these estimates may have been developed. One reason is to develop policy and influence legislation and executive guidance. From the perspective of FEMP, estimates of savings potential are valuable for a number of reasons. First, it is desirable to verify whether or not the energy goals are actually attainable. Note that the assessment described in this document takes the approach that efficiency improvements will be realized primarily through investments in building retrofits. Second, if the efficiency goal is attainable, the next question is what level of investment is necessary to attain the goal. Third, and most important, FEMP is able to make informed programmatic decisions and develop strategies based on these estimated funding requirements, ultimately assisting Federal agencies in meeting all the energy efficiency goals.

Below is a summary of several estimates of cost-effective potential energy savings and or investments. These estimates are presented in chronological order.

Alliance to Save Energy, 1991 (Hopkins 1991): "The Alliance estimates that 25 percent savings are a realistic potential… To reduce energy use by 25 percent, we estimate that $4.2 billion in Federal building efficiency improvements should be made by the year 2000." It appears the estimate of a 25 percent savings potential was based on a number of different studies on general building energy savings potential available at that time. The Alliance also assumed that an average energy efficiency measure would carry a simple payback period of 5 years (or, put another way, 1 dollar in energy savings per year for 5 dollars in capital investment). The total investment potential was then estimated by determining the total annual savings amount (25% of the annual facilities energy bill) and dividing that by 0.2 (the quotient of the simple payback period above).

Office of Technology Assessment (OTA), May 1991 (OTA 1991): "The best information available (which is only very approximate) indicates that a reduction in energy use of at least 25 percent is technically feasible and economically attractive for both federally owned and federally assisted buildings. This represents an annual savings of nearly $900 million in federally owned buildings, although achieving those savings could require initial investments on the order of $2 to $3 billion." The basis for the investment and savings estimates are not provided in the assessment.

Testimony by J. William Currie (PNNL) before the Senate Subcommittee on Governmental Affairs, February 1992 (Currie 1992): "... we estimate that over $2 billion in annual net savings would accrue to the taxpayers from installing all life-cycle cost effective technologies in Federal buildings and facilities." Also, "We estimate that an immediate investment of $5 to $10 billion for energy-efficient technologies in Federal buildings and facilities can be justified ..." This investment range was based on a rule-of-thumb, developed at PNNL through field experiences at Federal sites, that a government facility could invest one to two times its annual energy bill in energy efficient technologies.

Office of Technology Assessment, May 1994 (OTA 1994): There is widespread agreement that commercially available technologies could profitably reduce the Federal government's $4 billion annual building costs by at least 25 percent." As in 1991, the OTA did not provide a basis for their estimate.

Pacific Northwest Laboratory, August 1994 (Currie et al. 1994): "The lower-bound estimates show that we would save ... approximately 21% of the energy now used in buildings, facilities, and processes. ... Our analysis indicates that at least 33% of the annual bill, $1.5 billion, could be saved." The report went on to estimate a cost effective investment potential of $5.9 billion [1991 dollars] of which $1.0 billion would be in process energy improvement. This estimate, which appears to be the first estimate developed analytically, was developed by applying thorough analysis of new technologies to the Federal building inventory data. Assumptions regarding actual equipment and systems in the Federal building inventory was enhanced by the application of field observations by Pacific Northwest Laboratory staff.

FEMP, undated (FEMP): "Based on an evaluation of the life-cycle cost-effective energy and water conservation projects required to meet the [National Energy Conservation Policy Act] and Executive Order [12902] goals, the best estimate of the total investment required between 1996 and 2005 is $5.7 billion. This value could vary from a low of $4.4 billion to a high of $7.1 billion given the variability in both energy and water investment requirements." These estimates of investment were based upon two sources: data from the 1993 U.S. Army Corps of Engineers Renewables and Energy Efficiency Planning Model and the 1994 PNL assessment noted above.

Alliance to Save Energy, 1998 (Loper, Miller and Hopkins 1998): "In order to meet the President's 30-percent energy reduction goal by 2005, we estimate that Federal agencies will need to invest $4.7 billion over the next eight years [fiscal years 1998 through 2005] in energy saving projects." Calculations demonstrating how this estimate was developed were not included in the report.

Note that in addition to achieving the 1995 reduction goal of 10%, the 2000 reduction goal of 20% also appears to have been met in 1999 (FEMP 2000a). Also, from 1985 to 1999, an estimated $3.4 billion was invested in energy efficiency retrofits in Federal facilities.[8]

[8] Total estimated investment is the sum of the following: $2.502 billion in investments via agency appropriations (FEMP 2000b), $484 million from energy savings performance contracts (Reicher 2000 – Briefing by Assistant Secretary for Energy Efficiency and Renewable Energy on March 30, 2000 to DOE super-ESPC energy services companies), and $378 million in utility energy services investments (Reicher 2000 - Briefing by Assistant Secretary for Energy Efficiency and Renewable Energy on March 30, 2000 to DOE super-ESPC energy services companies).

It would be desirable to be able to identify emerging trends from and/or similarities between all these estimates/analyses; however, any such trends are likely the result of coincidence more than anything else because most of these estimates appear to be developed by using independent, simplified, assumption-driven calculations. In general, many of the estimates call for total capital investments in energy efficient retrofits in the neighborhood of $5 billion, as well as potential efficiency improvements in the neighborhood of 25%.

It is not really surprising that nearly 10 years after the initial savings potential estimate, an estimated investment opportunity on the order of $5.2 billion remains. Even though significant investments have been made since 1985, new and improved technologies continue to find their way onto the market resulting in increased savings potential. It is these new and improved technologies that boost the Federal agencies in their efforts to clear an increasingly higher bar.

3.0 Approach

The Federal government owns or leases more than 3 billion square feet of floor space in more than 400,000 buildings worldwide [General Services Administration (GSA) 1999a,b]. Responsibilities for reducing energy consumption per Executive Order 13123 apply to worldwide, owned property and worldwide leased property, where the Federal government directly pays the energy bills. EO 13123 does not apply to leased buildings, where energy costs are included in a fixed lease payment. EO 13123 also allows the exclusion of buildings with certain energy-intensive operations from the general requirements for reducing energy consumption. Estimates of Federal property square footage covered by EO 13123 as of FY 1998 are listed in Table 1.

Table 1. Federal Building Floor Space Governed by EO 13123[9]

Federal Building Subset	Thousands of Square Feet
Civilian Agencies, "Goal Inventory"	1,059,600
Civilian Agencies, "Energy Intensive Operations"	115,700
Civilian Agencies, Total	1,175,300
DoD, "Goal Inventory"	2,014,700
DoD, "Energy Intensive Operations"	203,900
DoD, Total	2,218,600
Federal, "Goal Inventory"	3,074,300
Federal, "Energy-Intensive Operations"	319,600
Federal, Total	3,393,900

While the data in Table 1 clearly identify the Federal building inventory, where the EO 13123 savings goals apply (i.e., the "goal inventory"), the data do not separate leased property from owned property, or foreign property from domestic property. The former is particularly important when evaluating the cost-effective energy savings potential. While Federal investment in leased facilities is possible, the investment must "payoff" within the remaining lease period, which is typically shorter than the period allowed under Federal ownership. Even so, the lease agreement may preclude such investments or at least make investments subject to lessor approval. Collectively, these restrictions reduce the potential cost-effective savings in this portion of the Federal building population. Foreign property should also be considered separately because of potential significant differences in weather, retrofit costs, and energy prices.

Data provided by the GSA (GSA 1999a,b; see Table 2) help identify the domestic, owned portion of the "goal inventory" buildings. GSA tracks domestic and foreign, owned and leased civilian buildings, but only domestic, owned and leased DoD buildings. Note that all leased buildings are included in GSA's data and not just the leased buildings where the Federal government directly pays for energy costs. Thus, the GSA figure for total civilian square footage (1,240,700 ksf) is greater than the corresponding figure in Table 1 (1,175,300 ksf). The square footage of domestic, owned "goal inventory" property can be estimated by subtracting an estimate of the domestic, owned energy intensive operations from the GSA figures for domestic, owned property. Domestic, owned

[9] Source: Chris Tremper, McNeil Technologies and Annual Report to Congress on Federal Government Energy Management and Conservation Programs Fiscal Year 1998.

civilian and DoD property is 86% of total Federal property shown in Table 1. The characteristics of energy -intensive operations (e.g., printing money by the Treasury, processing nuclear materials by DOE, munitions production by the Army) make them seem more likely to be domestically owned than the typical Federal building. Thus, the population of domestic, owned "goal inventory" property was estimated by subtracting 100% of the population of energy-intensive operations from the GSA figures for domestic, owned property. Exceptions to this rule were necessary for a few civilian agencies that have more energy intensive property than domestic, owned property.

Table 2. Domestic and Foreign, Owned and Leased Property

Federal Building Subset	Thousands of Square Feet
Civilian Agencies, Domestic, Owned Property	916,100
Civilian Agencies, Foreign, Owned Property	34,900
Civilian Agencies, Domestic, Leased Property	255,400
Civilian Agencies, Foreign, Leased Property	34,300
Civilian Agencies, Total	1,240,700
DoD, Domestic, Owned Property	1,994,600
DoD, Domestic, Leased Property	20,400
DoD, Domestic Total	2,015,000
Estimated Civilian Domestic, Owned "Goal Inventory"	847,100
Estimated DoD Domestic, Owned "Goal Inventory"	1,790,700
Estimated Federal Domestic, Owned "Goal Inventory"	2,637,800

Even with an analytical focus on domestic, owned, "goal inventory" buildings, a comprehensive evaluation of energy savings potential aggregated from building-level analyses is practically impossible. Thus, an analytical approach based on extrapolation from a sampling of buildings is required. As noted in the Introduction, FEMP-sponsored SAVEnergy audits have created a significant new source of information describing the energy infrastructure characteristics and prospective energy efficiency measures in Federal buildings. Approximately 310 SAVEnergy audits have been conducted for the six DOE Regional Offices located in Boston, Philadelphia, Atlanta, Chicago, Denver, and Seattle. For most SAVEnergy audits, auditors evaluated all or most of the buildings at each of the 310 sites to identify cost-effective energy efficiency measures that should be implemented. Thus, the audits developed the information of specific interest to this study, i.e., estimates of cost-effective energy savings and the corresponding investment required by energy efficiency measure type.

The SAVEnergy audit results were assumed to be representative of buildings of the same type, vintage, and DOE region. Unfortunately, from the perspective of this study, the SAVEnergy audits have not been conducted for a representative mix of Federal agency square footage. For example, the audits cover 6% of civilian building floor area, but only 0.6% of military floor area. In addition, the representation of civilian agency floor area in the audits is significantly different than the representation for the entire civilian agency building population, as indicated in Table 3. Finally, the mix of different building types audited within an agency was also often not representative of the population. Thus, it was not prudent to simply aggregate the results of the audits and multiply the totals by the ratio of Federal square footage to audit square footage. Therefore, an alternative approach was developed that segregated the evaluation of Federal buildings into civilian and military agencies.

Table 3. Distribution of Civilian Agency Floor Space in Population and Audits

Agency	% of Domestic, Owned Population Floor Space	% of Audit Floor Space[10]
General Services Admin.	23.59	25.66
Postal Service	17.53	0.68
Veterans Affairs	14.70	32.68
Energy	12.59	2.12
Interior	7.44	3.23
National Aeronatics and Space Administration	4.78	2.30
Justice	4.68	2.17
Agriculture	4.00	3.99
Transportation	2.73	13.07
Health and Human Services	2.45	1.59
Corps of Engineers[11]	1.22	0.00
Dept. of Labor	1.07	3.12
Dept. of Treasury	0.66	2.54
Dept. of Commerce	0.61	4.67
Dept. of Education	0.55	0.00
Others	1.40	2.19
Total Domestic, Owned ksf	916,100	
Total SAVEnergy Audit ksf		59,179

Civilian Agencies

As described above and shown in Table 3, the distribution of Federal building floor space in the audits was not representative of the civilian population. In addition, limited resources would not allow review and use of data from all 310 audits, but only about 90 audits. Therefore, an approach was developed based on reviewing a selected portion of the audits with statistical techniques used to extrapolate from the set of audits reviewed to the population of civilian buildings.

Of the 310 audits available, 36 were for military facilities, so these were excluded from further consideration. Selection of about 90 audits from the remainder was made on the basis of applying the following rules-of-thumb with the objective of selecting a set that would best represent the range of civilian facility characteristics and allow better extrapolation of characteristics to the population of civilian facilities.

[10] Based on all 310 SAVEnergy audits.

[11] Although the Corp of Engineers is not a civilian agency, its property is similar to civilian agencies, so is reported and evaluated separately from the rest of DoD in this study.

- Select audit square footage proportional to civilian square footage by agency
- Select audit regional square footage proportional to total regional civilian square footage
- Select at least one audit for each agency audited
- Avoid lower cost audits presumed to be less detailed or technology limited
- Select audits to cover a wide range of building sizes
- Select audits to cover many different types of buildings
- Select larger facilities (not necessarily larger buildings) to cover more total square footage.

As one might expect, it was not possible to exactly follow all of these rules-of-thumb. Where conflicts existed, preference was generally given to the rule-of-thumb closer to the top of the above list. Several requested audits, for various reasons, were typically unavailable from each of the six regional DOE offices, so substitutes were selected from available audits with further consideration of the rules-of-thumb. The resulting collection of audits reviewed is listed in Appendix A.

Each of the audits was reviewed and data were extracted and recorded in a database for subsequent statistical analysis. Data were collected at the building level, where available, but were only available at the site or facility level (i.e., for all buildings or all audited buildings at a single location) for about one-half of the audits. Data collection categories included site identification, energy prices, building type, size, and vintage (i.e., year built), and types of energy efficiency measures (EEMs) considered. For each EEM recommended in the Audits, the annual energy savings (MBtu and $), annual non-energy savings ($), implementation (investment) cost, and investment net present value were recorded. A complete listing of the data collected (if available) from each audit is presented in Appendix B.

The GSA's Owned Property Database identifies the square footage, number of buildings, vintage, and location for each of the 12 Federal building types for every Federal site in the nation. Thus, the objective of the statistical analysis was to develop valid correlations for predicting EEM energy savings, energy dollar savings, investment, and net present value based on the site characteristics available in the GSA database. The correlations were then applied to the GSA Owned Property Database (adjusted to exclude foreign and energy-intensive operation property) to estimate the cost-effective energy savings potential for civilian domestic, owned, "goal-inventory" buildings.

No adjustments were made to the audit data results, except to exclude recommended EEMs that were described in the audits as having a negative net present value (but were recommended anyway). Savings estimated for the civilian population were not adjusted to reflect any audit recommendations that have since been implemented. Additional details regarding the statistical analysis of the SAVEnergy audit data is presented in Appendix C.

Military Agencies

As noted above, only 36 or 12% of the audits were conducted for military facilities, and these represented only 0.6% of total military square footage or a factor of 10 less than the fraction of total civilian square footage covered by the SAVEnergy audits. Therefore, an alternative approach was developed for the military sector.

Over the past decade, PNNL has conducted an ongoing energy management program for the Army's Forces Command (FORSCOM). This work has allowed PNNL to develop detailed building characterizations for each of the 11 major FORSCOM sites. Together, these sites account for 180 million square feet of building floor space or about 9% of the military total. Typical of many Forts, Ports, and Bases, FORSCOM sites are a collection of housing, commercial, and light-industrial type buildings serving tens of thousands of military and civilian personnel. PNNL characterizations of these sites were assumed to already exclude energy intensive operations. In addition to directly representing a substantial fraction of military floor space, the characteristics of FORSCOM sites should be a reasonable proxy for the balance of the military's non-energy intensive building square footage. Thus, estimates of cost-effective EEMs developed for FORSCOM were assumed to be the same for the entire military on a per square foot basis.

The Facility Energy Decision System (FEDS) Model was used to simulate building energy use and determine cost-effective energy efficiency measures for each FORSCOM site (PNNL 1998). FEDS is a user-friendly, Windows-based, menu-driven software program for assessing the energy efficiency resource potential of facilities ranging from single buildings to large Federal installations, such as those within FORSCOM. FEDS determines the optimum set of cost-effective retrofits from a current database of hundreds of proven technologies. These include retrofits for heating, cooling, lighting, motors, building shell, and hot water. Replacement or modification of the equipment for a retrofit operation varies from complete replacement to functional enhancements to fuel switching.

4.0 Results

The results of the analysis are presented in Table 4 through Table 14. The first two tables show results for the SAVEnergy audit sample. The next four tables show results for the statistical extrapolation of the SAVEnergy audit sample to civilian Federal buildings. Tables 10 and 11 show results for DoD, while integrated results for civilian and military government buildings are shown in Tables 12 and 13. Finally, Table 14 compares historical and prospective energy use per square foot for the Federal government and civilian and military components.

Table 4 shows that annual energy savings for the SAVEnergy audit sample ranged from 6 to 54 MBtu/ksf for the various agencies, with an average of about 27 MBtu/ksf. The actual energy consumption at civilian agencies for FY98 was 122 MBtu/ksf[12]. Energy savings by energy efficiency measure (EEM) category are shown in Table 5. Ventilation and HVAC control measures accounted for 55% of the potential savings in the SAVEnergy audit sample. Other significant EEM categories were lighting, heating systems, and cooling systems.

Table 4. Results by Agency for SAVEnergy Audit Sample Data
Results per Thousand Square Feet (ksf) of Audit Sample Buildings

Agency	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Agriculture	21.48	372.23	1749.44	990.37
Commerce	16.30	213.63	882.18	2451.20
Energy	43.22	228.93	552.94	1506.53
Env. Protection Agency	18.00	212.00	966.51	1976.57
GSA	14.44	281.39	1387.04	1985.38
HHS	53.79	621.64	3953.91	1978.19
Interior	42.58	636.72	3288.11	4043.10
Justice	14.46	190.80	1142.06	1639.45
Labor	45.10	251.89	1410.96	2840.85
NASA	18.58	234.17	765.72	1726.22
National Archives and Records Adm	15.02	199.82	1238.21	1129.86
Gallery of Art	44.72	1606.25	9086.37	6546.03
Postal Service	6.04	208.41	1327.49	82.95
Transportation	30.91	398.98	1692.03	2670.38
Treasury	37.40	498.13	947.61	6764.52
Veterans Adm	29.56	430.97	2257.28	4008.20
Average	**26.77**	**403.79**	**1948.11**	**2886.86**

[12] FY98 Annual Report to Congress on Federal Government Energy Management and Conservation Programs.

Table 5. Results by EEM Category for SAVEnergy Audit Sample Data
Results per Thousand Square Feet (ksf) of Audit Sample Buildings

EEM Category[13]	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Building Envelope	0.50	3.21	26.10	27.90
Heating System	3.17	65.65	235.80	321.96
Cooling System	1.47	20.32	105.01	137.75
Ventilation and Controls	14.70	142.12	715.12	1,071.77
Lighting	4.30	102.18	551.99	760.48
Service Hot Water	0.03	4.72	20.03	48.91
Plug Loads	0.00	0.07	0.53	0.56
Process Drive Systems	0.16	2.70	11.49	27.08
Compressed Air Systems	0.00	0.00	0.03	0.00
Other Process Loads	0.17	7.67	7.96	82.91
Central Boilers	0.76	20.63	41.88	247.53
Central Chillers	0.79	28.17	207.35	122.79
Steam/Hot Water Distribution	0.47	2.04	2.59	21.27
Chilled Water Distribution	0.24	4.32	22.21	15.95
Total	**26.77**	**403.79**	**1,948.11**	**2,886.86**

Estimated annual energy savings and implementation costs for civilian agencies, shown in Table 6, are very close to the Table 4 SAVEnergy audit sample; only the net present value (NPV) is significantly different. The NPV difference between the audit sample and the estimate is primarily the result of differences in the mix of building types and climate regions. The difference attributable to building type was because the "other" building type was under represented in the audit sample and had substantially greater NPV/ft^2 than the "commercial" building type, which comprised the majority of the floor area[14].

Differences between the sample and estimated NPV also occurred because the Southeast and Central regions with relatively large NPV/ft^2 are under-represented in the sample, and the West region, with a relatively small NPV/ft^2, is over-represented in the sample. Estimates ranged from 17 to 37 MBtu/ksf/yr with an average of 26 MBtu/ksf/yr for the various agencies; a narrowing of the range compared to the results of Table 4 would be expected because many of the samples are not representative of an individual agency's building stock.

Table 7 shows that 22 trillion Btu/yr or 0.022 Quads/yr of energy savings could be achieved in domestic, owned, goal-inventory, civilian agency buildings for an investment of $1.5 billion. The annual monetary savings would be $330 million. Nearly three-quarters of the civilian energy savings potential is associated with four agencies: GSA, Postal Service, DOE, and Veterans Affairs.

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[13] See Appendix D for discussion of EEM categorization.
[14] See Appendix C for definitions of "other" and "commercial" building categories and other details regarding the statistical analysis of the SAVEnergy audit data.

Table 6. Regression Analysis Results by Agency for Civilian Population

Results per Thousand Square Feet (ksf) for Domestic, Owned, Goal-Inventory Buildings

Agency	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Agriculture	23.74	356.08	1,787.36	2,873.62
Commerce	26.99	450.77	2,012.53	3,686.46
Corp of Engineers	25.90	488.36	2,346.40	4,104.63
Education	24.63	382.56	1,581.56	3,614.26
Energy	33.19	437.00	1,681.09	4,748.51
EPA	30.35	474.01	2,107.08	4,071.20
Federal Communications Commission (FCC)	24.91	571.71	2,696.63	4,413.76
Federal Emergency Management Adm (FEMA)	28.62	489.90	2,153.42	4,042.61
Govt. Printing	37.23	559.74	2,501.49	4,667.58
GSA	26.60	379.97	1,902.48	3,148.76
HHS	28.21	424.43	2,143.27	3,299.05
Interior	22.31	428.28	1,983.96	3,525.02
Justice	23.95	381.10	1,590.09	3,570.39
Labor	23.11	409.16	1,741.71	3,778.69
NASA	26.97	410.39	1,728.02	3,794.64
National Science Foundation (NSF)	20.95	406.55	1,675.31	3,529.94
Postal Service	24.04	361.45	1,674.22	3,235.31
State	16.91	374.86	1,437.80	3,487.52
Transportation	22.50	367.37	1,793.93	3,028.95
Treasury	28.37	408.74	1,734.52	3,829.88
United States Information Agency (USIA)	26.46	661.92	3,271.79	5,301.28
Veterans Affairs	24.52	357.99	1,708.00	3,183.97
Average	**26.02**	**388.55**	**1,790.32**	**3,476.33**

Table 7. Regression Analysis Results by Agency for Civilian Population
Total Results for Domestic, Owned, Goal-Inventory Buildings

Agency	Annual Energy Savings, TBtu	Annual Energy Savings, $M	Implementation Cost, $M	Net Present Value, $M
Agriculture	0.566	8.49	42.61	68.51
Commerce	0.031	0.52	2.33	4.27
Corp of Engineers	0.293	5.53	26.56	46.46
Education	0.127	1.97	8.13	18.59
Energy	3.434	45.22	173.95	491.34
EPA	0.080	1.25	5.57	10.77
FCC	0.003	0.06	0.28	0.46
FEMA	0.014	0.24	1.04	1.95
Govt. Printing	0.069	1.04	4.63	8.65
GSA	5.454	77.92	390.14	645.71
HHS	0.640	9.63	48.62	74.84
Interior	1.539	29.53	136.80	243.06
Justice	0.930	14.80	61.77	138.69
Labor	0.229	4.05	17.24	37.39
NASA	1.094	16.65	70.10	153.93
NSF	0.020	0.39	1.63	3.43
Postal Service	3.909	58.77	272.20	526.01
State	0.003	0.06	0.23	0.55
Transportation	0.179	2.92	14.27	24.09
Treasury	0.080	1.16	4.91	10.84
USIA	0.005	0.13	0.65	1.05
Veterans Affairs	3.344	48.82	232.92	434.20
Total	**22.044**	**329.14**	**1,516.57**	**2,944.80**

Energy savings estimated for civilian agencies by EEM category are shown in Tables 8 and 9. Savings from ventilation and controls still dominate, but are a slightly lower fraction of the total compared to the SAVEnergy audit sample. The contributions of lighting, cooling system, and building envelope EEMs have increased, while that for heating systems has decreased. The ratio of dollar savings to Btu savings varies significantly. This variation is the result of two factors:

- The relative costs of fossil fuels and electricity (including both energy and demand charges).
- EEMs that switch fuels (e.g., switching from electric water heating to gas will often save a lot of money but will result in an increase in site energy consumption).

Table 8. Regression Analysis Results by EEM Category for Civilian Population
Results per Thousand Square Feet (ksf) for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Building Envelope	2.05	12.39	67.11	116.92
Heating System	1.24	51.19	153.64	500.31
Cooling System	2.41	30.95	175.58	211.60
Ventilation and Controls	13.25	136.39	601.54	1306.81
Lighting	6.40	121.32	674.29	955.22
Service Hot Water	-0.14	8.16	42.09	86.16
Plug Loads	0.00	1.08	3.69	9.10
Process Drive Systems	0.19	2.69	12.28	27.60
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.15	5.38	9.60	74.65
Central Boiler	0.18	14.44	23.30	150.61
Central Chiller	0.19	3.60	22.99	30.83
Steam/Hot Water Distribution	0.05	0.15	0.78	1.00
Chilled Water Distribution	0.06	0.82	3.41	5.52
Totals	**26.02**	**388.55**	**1790.32**	**3476.33**

Table 9. Regression Analysis Results by EEM Category for Civilian Population
Total Results for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, TBtu	Annual Energy Savings, $M	Implementation Cost, $M	Net Present Value, $M
Building Envelope	1.74	10.49	56.85	99.04
Heating System	1.05	43.37	130.15	423.82
Cooling System	2.04	26.22	148.73	179.24
Ventilation and Controls	11.22	115.53	509.56	1107.00
Lighting	5.42	102.77	571.19	809.17
Service Hot Water	-0.12	6.91	35.65	72.98
Plug Loads	0.00	0.91	3.13	7.71
Process Drive Systems	0.16	2.28	10.41	23.38
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.13	4.56	8.13	63.23
Central Boiler	0.15	12.23	19.74	127.58
Central Chiller	0.16	3.05	19.47	26.12
Steam/Hot Water Distribution	0.04	0.12	0.66	0.84
Chilled Water Distribution	0.05	0.70	2.89	4.68
Totals	**22.04**	**329.14**	**1516.57**	**2944.80**

Results for DoD properties are presented in Tables 10 and 11. The contribution of individual EEM categories are significantly different than estimated for civilian agencies. The most important difference is for ventilation and controls, which accounts for nearly half of the civilian agency savings, but none of the savings estimated for DoD buildings. Significant differences exist for every EEM category that was evaluated via a different methodology, with the exception of lighting.[15]

These difference are not all together unexpected. Generally, there are obvious reasons for these differences; some are the result of dissimilarities in the approach and others occur because of fundamental differences in how the buildings are supplied and consume energy.

- Accurately determining envelope savings is nearly impossible without running some kind of building energy simulation. Simulations are usually more costly and time consuming than SAVEnergy audit resources allow; hence, they are not often done and few if any envelope measures are recommended. However, FEDS provides a method for quickly and accurately identifying cost-effective retrofits.

- Heating provided by central systems is much more common in DoD than it is in civilian agencies. Hence, one would expect lower DoD savings in building heating systems and greater savings in central boilers as the data indicate.

- Cooling savings on the DoD side are somewhat elevated because all savings (heating and cooling) associated with heat pump retrofits are included in the cooling category.

- Ventilation and controls retrofits are not considered in FEDS. EMCSs are not considered for three reasons. First, even when operating perfectly, the projected savings are almost never realized. Second, trained operators are required to monitor and adjust the systems; these people are rarely available in the Federal sector. Finally, EMCSs require a fair amount of maintenance using trained personnel, and these people are generally unavailable. Ventilation retrofits are also not considered for two primary reasons. First, the change required is really more of a renovation than a retrofit (i.e., this generally requires major building modifications). Second, the costs and savings are difficult to estimate with any accuracy.

- The large differences seen for service hot water are associated with significant housing stock in military agencies.

Civilian agency and DoD results are integrated in Tables 12 and 13. Overall, the potential annual energy savings were estimated to be about 25 MBtu/ksf or 66 trillion Btu. This is roughly one-fifth of the actual Federal building energy consumption in FY98. The investment required to achieve these savings is $5.2 billion, resulting in annual dollar savings of $0.95 billion and a net present value of $9.3 billion.

If these savings were achieved, the Federal government would nearly meet the goal of reducing energy consumption per square foot of building floor space by 35% relative to consumption in 1985. Table 14 identifies energy consumption per square foot in 1985, 1998, and in the future if the cost-effective savings potential estimated above are achieved.

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[15] As described in the Approach, FEDS was used to estimate the energy savings potential for DoD within building envelope, heating system, cooling system, ventilation and controls, lighting, and service hot water categories. DoD energy savings for the other EEM categories were based on results for the civilian population or subsets of the civilian population.

Table 10. Results by EEM Category for DoD FEDS Analysis
Results per Thousand Square Feet (ksf) for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Building Envelope	4.70	46.89	331.55	365.22
Heating System	0.80	28.66	115.04	199.98
Cooling System	6.06	41.75	488.19	225.77
Ventilation and Controls	0.00	0.00	0.00	0.00
Lighting	6.62	104.03	884.98	1623.75
Service Hot Water	5.01	73.67	96.61	561.35
Plug Loads	0.00	1.08	3.69	9.10
Process Drive Systems	0.19	2.69	12.28	27.60
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.15	5.38	9.60	74.65
Central Boilers	0.34	35.50	54.81	374.29
Central Chillers	0.32	5.83	38.96	50.03
Steam/Hot Water Distribution	0.02	0.11	0.59	0.57
Chilled Water Distribution	0.12	1.78	7.61	12.94
Totals	**24.34**	**347.39**	**2043.91**	**3525.26**

Table 11. Results by EEM Category for DoD FEDS Analysis
Total Results for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, TBtu	Annual Energy Savings, $M	Implementation Cost, $M	Net Present Value, $/M
Building Envelope	8.42	83.97	593.72	654.01
Heating System	1.44	51.33	206.01	358.11
Cooling System	10.85	74.77	874.22	404.30
Ventilation and Controls	0.00	0.00	0.00	0.00
Lighting	11.86	186.29	1,584.77	2,907.72
Service Hot Water	8.98	131.93	173.00	1,005.23
Plug Loads	0.01	1.93	6.61	16.30
Process Drive Systems	0.33	4.82	22.00	49.43
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.27	9.64	17.19	133.68
Central Boilers	0.61	63.58	98.15	670.25
Central Chillers	0.58	10.45	69.77	89.60
Steam/Hot Water Distribution	0.03	0.20	1.06	1.03
Chilled Water Distribution	0.22	3.18	13.62	23.18
Totals	**43.59**	**622.08**	**3660.12**	**6312.83**

Table 12. Results by EEM Category for Federal Government

Results per Thousand Square Feet (ksf) for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, MBtu/ksf	Annual Energy Savings, $/ksf	Implementation Cost, $/ksf	Net Present Value, $/ksf
Building Envelope	3.85	35.81	246.63	285.48
Heating System	0.94	35.90	127.44	296.43
Cooling System	4.89	38.28	387.80	221.22
Ventilation and Controls	4.25	43.80	193.17	419.66
Lighting	6.55	109.58	817.32	1409.06
Service Hot Water	3.36	52.64	79.10	408.75
Plug Loads	0.00	1.08	3.69	9.10
Process Drive Systems	0.19	2.69	12.28	27.60
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.15	5.38	9.60	74.65
Central Boilers	0.29	28.74	44.69	302.46
Central Chillers	0.28	5.12	33.83	43.87
Steam/Hot Water Distribution	0.03	0.12	0.65	0.71
Chilled Water Distribution	0.10	1.47	6.26	10.56
Totals	**24.88**	**360.61**	**1962.47**	**3509.55**

Table 13. Results by EEM Category for Federal Government

Total Results for Domestic, Owned, Goal-Inventory Buildings

EEM Category	Annual Energy Savings, TBtu	Annual Energy Savings, $M	Implementation Cost, $M	Net Present Value, $M
Building Envelope	10.16	94.46	650.57	753.05
Heating System	2.49	94.69	336.16	781.93
Cooling System	12.89	100.98	1022.95	583.54
Ventilation and Controls	11.22	115.53	509.56	1107.00
Lighting	17.29	289.06	2155.96	3716.89
Service Hot Water	8.86	138.84	208.65	1078.21
Plug Loads	0.01	2.85	9.74	24.01
Process Drive Systems	0.49	7.09	32.40	72.81
Compressed Air Systems	0.00	0.00	0.00	0.00
Other Process Loads	0.40	14.20	25.33	196.91
Central Boilers	0.76	75.81	117.89	797.83
Central Chillers	0.74	13.49	89.24	115.71
Steam/Hot Water Distribution	0.07	0.33	1.72	1.87
Chilled Water Distribution	0.27	3.88	16.51	27.86
Totals	**65.63**	**951.22**	**5176.69**	**9257.63**

Table 14. Historical and Prospective Energy Intensities

	Actual 1985	Actual 1998	Executive Order 13123 Goal	With Economic Energy Savings[16]
	Energy Use, MBtu/ksf			
Federal	139.77	113.70	90.85	92.30
Civilian	154.16	121.59	100.20	100.79
Military	135.35	109.48	87.98	87.84

[16] For domestic, owned, goal-inventory buildings only.

5.0 Conclusions

Based on the analytical approach and assumptions used for this study, the total cost-effective energy savings potential in domestic, owned, goal-inventory Federal buildings is about 25 MBtu/ksf/yr or 66 trillion Btu/yr (0.066 Quads/yr). The energy savings potential per square foot is approximately the same for civilian and military sectors. The investment required to capture this potential is about $1.96/sf or $5.2 billion for the Federal government. Again, civilian and military requirements per square foot are about the same. The resulting net present value of the investment is $9.3 billion.

The energy savings potential, if captured, would result in the Federal government nearly meeting the goal of reducing energy consumption per square foot by 35% relative to 1985 figures, as required by EO 13123. The goals would be met without including the potential energy savings in foreign and leased buildings. However, these estimates of cost-effective energy savings are based on Federal financing. Recent investigations of alternative financing by the authors yielded an estimate of 0.040 to 0.048 Quads/yr of cost-effective energy savings potential, or about two-thirds of the estimate in this study via Federal financing (Dirks, Brown, and Currie, footnote 3)[17]. Fewer cost-effective energy savings projects exist with alternative financing because ESCOs and utilities have higher borrowing costs than the Federal government. Even if all of the cost-effective alternative financing projects are implemented, the savings would not be enough to achieve the 35% reduction goal. Therefore, direct Federal funding of energy efficiency projects will also be required.

For the entire Federal population, lighting was found to be the EEM category with the greatest energy savings potential, accounting for about one-fourth of the total. The most commonly recommended lighting measure was the conversion of T-12 fluorescent lights to T-8s with electronic ballasts. Other common lighting measures were CFLs, occupancy sensors or other controls, and LED exit signs. Other important categories indicated by the analysis are cooling systems, ventilation and controls, building envelope, service hot water, and heating systems.

The significant differences in the distribution of cost-effective EEMs found for civilian and military sectors are largely attributable to differences in analytical methodology rather than differences in the building stock. Most notable is the ventilation and controls category, which accounts for half of the civilian savings and none of the military savings (the FEDS model does not consider ventilation and control retrofits). The SAVEnergy audits are believed to overestimate ventilation and control opportunities because of excessive reliance on simplified rules-of-thumb, but the potential for ventilation and control retrofits is certainly greater than zero. On the other hand, the SAVEnergy audits are believed to underestimate building envelope opportunities. Audit results for the civilian agencies translated into less than half of the envelope savings per square foot found within FORSCOM with FEDS. Accurate evaluation of building envelope opportunities requires using a building energy simulation model like FEDS, which typically requires more effort than SAVEnergy audit resources allow.

One expected difference in the distribution of energy efficiency measures is the significantly greater service hot water savings opportunity found in the military. This difference can be attributed to the substantial housing floorspace it maintains for personnel and their families. Lower heating system retrofits in the military agencies would also be expected, give the higher fraction of military floorspace heated with central systems.

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[17] Energy savings and investment figures from Dirks, Brown, and Currie (footnote 3) were adjusted to correspond to the domestic, owned portion of the goal-inventory property only.

Savings opportunities associated with central energy plants and thermal distribution systems are almost certainly greater than estimated for the military. Although the military estimates for these systems were based on SAVEnergy audit results for civilian agencies with similar average site sizes, selected results from specific military sites suggests enormous potential with these systems. For example, a PNNL evaluation of energy use at Fort Stewart in Georgia estimated that 60% of the energy entering the hot water distribution system was lost to the environment. These losses represent about 15% of total energy consumption at Fort Stewart or about 17 MBtu/ksf/yr! While the conditions at Fort Stewart may or may not be representative of the military, the potential opportunity would appear to warrant further investigation. Conversion from central to distributed heating systems could result in significant energy savings, but was rarely considered in the SAVEnergy audits.

6.0 Recommendations

Resolution of the differences between SAVEnergy audit and FEDS results is needed to improve the accuracy of the estimates from this study, and to better identify significant differences in civilian and military building stock. Clearly the potential impact of ventilation and control measures should be reviewed to determine the magnitude of underestimation by FEDS and probable overestimation by the SAVEnergy audits. Prior studies comparing actual measured savings with predicted savings should be reviewed to resolve this issue. FEDS should also be used to evaluate several of the facilities where SAVEnergy audits were conducted to help segregate analytical differences from building stock differences.

The potential energy savings opportunities within central energy plants and thermal distribution systems should be more rigorously evaluated. Consideration should be given to switching to distributed energy systems as well as improving the efficiency of existing central systems.

Alternative financing alone will not likely allow the Federal government to reach its energy efficiency goals, even if all cost-effective alternative financing opportunities are implemented. Although the overall Federal budget situation has improved tremendously from a decade or even a few years ago, prospective budgets for energy retrofits have plummeted. This trend must be reversed so that plans can be made for an integration of private and public financing to achieve Federal energy savings goals.

This study focused on estimating the energy savings potential for domestic, owned, "goal-inventory" property. This subset of Federal property accounts for about 78% of the Federal property where EO 13123 applies or about 86% of the total "goal inventory" property. The other 14% of the goal inventory property is domestic, leased; foreign, owned; or foreign, leased property. Analysis of the energy savings potential for these property categories is recommended, especially for domestic, leased property, which represents the majority of the other 14%.

Family housing, which represents a substantial fraction of military floor space and energy consumption, is currently being considered for privatization (selling federally-owned housing to private companies who, in turn, lease the houses back to the government) by DoD on a site-by-site basis. Depending on how privatization is implemented, some or all of family housing may fall outside of EO 13123 or the lease arrangement may reduce the cost-effective energy savings potential. This issue should be investigated to determine the potential impact on meeting EO 13123 goals.

About 9% of Federal buildings covered by EO 13123 are currently classified as energy intensive operations and are excluded from the "goal inventory." EO 13123 requires reconsideration of the excluded status and may significantly alter the "goal inventory." When this occurs, the potential energy savings estimate should be updated to capture this change.

The clear evidence of substantial cost-effective lighting retrofit potential in both civilian and military agencies suggests that FEMP should re-emphasize its lighting support programs.

References

Currie, J.W. 1992. *Testimony before The Senate Committee on Governmental Affairs, Washington D.C., 18 February 1992.* PNNL-SA-20228, Pacific Northwest National Laboratory, Richland, Washington.

Currie, J.W., J.A. Dirks, S.A. Shankle, D.J. Stucky, and D.B. Elliott. 1994. *Lower-Bound Estimates of Energy Efficiency in the Federal Sector.* PNL-8362, Pacific Northwest National Laboratory, Richland, Washington.

FEMP. Undated. *Federal Energy Efficiency and Water Conservation Study.* U.S. Department of Energy – Federal Energy Management Program, Washington, D.C.

FEMP. 2000a. *FEMP Focus.* "Letter from the Editor." March/April 2000. Washington, D.C.

FEMP. 2000b. *Annual Report to Congress on Federal Government Energy Management and Conservation Programs, Fiscal Year 1998.* DOE/EE-0221, U.S. Department of Energy – Federal Energy Management Program, Washington, D.C.

GSA. 1999a. *Summary Report of Real Property Owned by the United States Throughout the World as of September 30, 1998.* General Services Administration, Washington, D.C.

GSA. 1999b. *Summary Report of Real Property Leased by the United States Throughout the World as of September 30, 1998.* General Services Administration, Washington, D.C.

Hopkins, M. 1991. *Energy Use in Federal Facilities: Squandering Taxpayer Dollars and Needlessly Polluting Our Environment.* The Alliance to Save Energy, Washington, D.C.

Loper, J.W., K.L. Miller, and M. Hopkins. 1998. *Leading by Example: Improving Energy Productivity in Federal Government Facilities.* The Alliance to Save Energy, Washington, D.C.

OTA. 1991. *Energy Efficiency in the Federal Government: Government by Good Example?* Office of Technology Assessment, Washington, D.C.

OTA. 1994 *Energy Efficiency in Federal Facilities: Update on Funding and Potential Savings.* Office of Technology Assessment, Washington, D.C.

Pacific Northwest National Laboratory. 1998. *Facility Energy Decision System User's Guide, Release 4.0.* PNNL-10542 Rev 2, Richland, Washington.

Appendix A

SAVEnergy Audits Reviewed and Sorted by DOE Region

Appendix A
SAVEnergy Audits Reviewed
Sorted by DOE Region

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20167	Central	Dwight D. Eisenhower Center	Abilene	Kansas	National Archives		1995
GO20347	Central	Colorado National Monument	Fruita	Colorado	Interior	National Park Service	1995
GO20434	Central	Matagorda Island National Wildlife Refuge	Austwell	Texas	Interior	Fish and Wildlife Service	1996
GO20441	Central	Rocky Mountain National Park	Estes Park	Colorado	Interior	National Park Service	1996
GO20221	Central	Rocky Mountain National Park	Estes Park	Colorado	Interior	National Park Service	1995
GO20588	Central	Rocky Flats Environmental Technology Site	Golden	Colorado	Energy		1998
GO20403	Central	Guadalupe Mountains National Park	Salt Flat	Texas	Interior	National Park Service	1996
GO20346	Central	Intermountain Fire Sciences Laboratory	Missoula	Montana	Agriculture	Forest Service	1996
GO20522	Central	North Texas Job Corps Center	McKinney	Texas	Labor		1997
GO20509	Central	Saratoga Fish Hatchery	Saratoga	Wyoming	Interior	Fish and Wildlife Service	1997
GO20420	Central	BLM District Office	Miles City	Montana	Interior	BLM	1996
GO20174	Central	Black Hills NF Supervisors Office	Custer	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Hill City Shop	Hill City	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Rangers' Quarters	Deadwood	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Pactola District HQ	Rapid City	South Dakota	Agriculture	Forest Service	1995
GO20248	Central	Mt. Rushmore National Monument	Keystone	South Dakota	Interior	National Park Service	1996
GO20597	Central	Federal Correctional Institution	Three Rivers	Texas	Justice	Bureau of Prisons	1998
GO20432	Central	Air Route Traffic Control Center	Salt Lake City	Utah	Transportation	FAA	1996
GO20568	Central	Corpus Christi Air Station	Corpus Christi	Texas	Transportation	Coast Guard	1998
GO20500	Central	Yelllowstone National Park	Mammoth	Wyoming	Interior	National Park Service	1997
GO20598	Central	Federal Detention Center	Oakdale	Louisiana	Justice	Bureau of Prisons	1999

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20545	Midwest	Bricker Federal Building	Columbus	Ohio	GSA		1998
GO20531	Midwest	Duluth Federal Bldg and U.S. Courthouse	Duluth	Minnesota	GSA		1998
GO20530	Midwest	Federal Bldg and U.S. Courthouse	South Bend	Indiana	GSA		1998
GO20436	Midwest	V.A. Medical Center	Ann Arbor	Michigan	VA		1997
GO20070	Midwest	Grand Rapids Job Corps Center	Grand Rapids	Michigan	Labor	Job Corps	1995
GO20067	Midwest	Morris Soil Research Laboratory	Morris	Minnesota	Agriculture	ARS	1995
GO20468	Midwest	Air Route Traffic Control Center	Farmington	Minnesota	Transportation	FAA	1996
GO20538	Midwest	Celebrezze Federal Building	Cleveland	Ohio	GSA		1998
GO20063	Midwest	Crab Orchard National Wildlife Refuge	Carterville	Illinois	Interior	Fish and Wildlife Service	1995
GO20068	Midwest	NASA Lewis Research Center	Cleveland	Ohio	NASA		1995
GO20430	Midwest	Northern Indiana Health Care System	Marion	Indiana	VA		1996
GO20301	Mid-Atlantic	U.S. Mint	Philadelphia	Pennsylvania	Treasury	Mint	1995
GO20305	Mid-Atlantic	Martin Luther King Federal Office Building & Courthouse	Newark	New Jersey	GSA		1995
Unknown	Mid-Atlantic	Wm. S. Moorhead Federal Building	Pittsburgh	Pennsylvania	GSA		1995
GO20543	Mid-Atlantic	Wilkes-Barre VA Medical Center	Wilkes-Barre	Pennsylvania	VA		1997
GO20266	Mid-Atlantic	Robert A. Roe Federal Office Building	Paterson	New Jersey	GSA		1995
GO20170	Mid-Atlantic	U.S. Department of Commerce - Herbert C. Hoover Building	Washington	DC	Commerce		1995
GO20169	Mid-Atlantic	U.S. Department of Treasury	Washington	DC	Treasury		1995
GO20501	Mid-Atlantic	USDA National Agricultural Library	Beltsville	Maryland	Agriculture		1997
GO20256	Mid-Atlantic	National Institute of Health, Building 31	Bethesda	Maryland	HHS	National Institute of Health	1995
GO20257	Mid-Atlantic	National Institute of Health, Building 29/29A	Bethesda	Maryland	HHS	National Institute of Health	1995
GO20525	Mid-Atlantic	National Gallery of Art	Washington	DC	National Gallery of Art		1997
GO20511	Mid-Atlantic	NASA Langley Research Center	Hampton	Virginia	NASA		1997

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20234	Northeast	White River National Fish Hatchery	Bethel	Vermont	Interior	Fish and Wildlife Service	1995
GO20423	Northeast	Alexander Pirnie Federal Courthouse and Federal Building	Utica	New York	GSA	Social Security	1997
GO20235	Northeast	Burlington Federal Building/Post Office, Court House	Burlington	Vermont	GSA		1995
GO20323	Northeast	VA Medical Center Jamaica Plain	Boston	Massachusetts	VA		1995
GO20452	Northeast	Cape Cod National Seashore	Cape Cod	Massachusetts	Interior	National Park Service	1996
GO20162	Northeast	Springfield Federal Building	Springfield	Massachusetts	GSA		1995
GO20600	Northeast	U.S. Postal Service New Hampshire District	Berlin	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Hudson	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Keene	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Littleton	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Merrimack	New Hampshire	Postal Service		1998
GO20599	Northeast	U.S. Postal Service New York District	Watertown	New York	Postal Service		1999
GO20599	Northeast	U.S. Postal Service New York District	Glens Falls	New York	Postal Service		1999
GO20066	Northeast	Plum Island Animal Disease Center	Orient Point	New York	Agriculture		1995
GO20066	Northeast	Plum Island Animal Disease Center	Plum Island	New York	Agriculture		1995
GO20602	Northeast	U.S. DOT – FAA (Logan Airport Tower)	Boston	Massachusetts	Transportation	FAA	1998
GO20602	Northeast	U.S. DOT – FAA (Nantucket Airport Surveillance Tower)	Nantucket	Massachusetts	Transportation	FAA	1998
GO20602	Northeast	U.S. DOT – FAA (Cummington Long Range Radar Tower)	Cummington	Massachusetts	Transportation	FAA	1998
GO20537	Northeast	USCG – New Castle, NH	New Castle	New Hampshire	Transportation	Coast Guard	1997
GO20574	West	Federal Highway Administration	Vancouver	Washington	Transportation	FHA	1998
GO20534	West	Veterans Administration Outpatient Clinic	Los Angeles	California	VA		1998
GO20376	West	Chemawa Indian Boarding School	Salem	Oregon	Interior	Bureau of Indian Affairs	1996
GO20150	West	Federal Building and Post Office	Carson City	Nevada	Postal Service		1995

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20475	West	Air Route Traffic Control Center	Anchorage	Alaska	Transportation	FAA	1997
GO20454	West	Golden Gate National Recreation Area	San Francisco	California	Interior	National Park Service	1996
GO20469	West	Nevada Test Site	Las Vegas	Nevada	Energy		1996
G020196	West	Bellingham Federal Building	Bellingham	Washington	GSA		1995
G020207	West	Moscow Federal Building	Moscow	Idaho	GSA		1995
G020268	West	District Office & Bunkhouse	Ketchikan	Alaska	Agriculture	Forest Service	1995
G020382	West	Sawtooth National Recreation Area Office	Twin Falls	Idaho	Agriculture	Forest Service	1996
G020307	West	Angell Job Corp Center	Yachats	Oregon	Agriculture	Forest Service	1995
G020514	West	911 Federal Building/Henri Monroe Office	Portland	Oregon	GSA		1997
G020521	West	San Francisco Nat'l Wildlife Refuge Complex	Newark	California	Interior	Fish and Wildlife Service	1995
G020521	West	Lahontan National fish Hatchery Complex	Gardnerville	Nevada	Interior	Fish and Wildlife Service	1997
G020521	West	Spring Creek National Fish Hatchery	Underwood	Washington	Interior	Fish and Wildlife Service	1997
G020521	West	Albernathy Salmon Culture Tech Center	Longview	Washington	Interior	Fish and Wildlife Service	1997
G020532	West	Shasta National Park Services	Whiskeytown	California	Interior	National Park Service	1997
GO20255	West	N Island Naval Air Station/Customs Service	San Diego	California	Treasury	Customs	1996
GO20264	Southeast	VA Medical Center	Charleston	South Carolina	VA		1995
GO20576	Southeast	USCG – Vessel Support Facility	North Charleston	South Carolina	Transportation	Coast Guard	1998
GO20445	Southeast	U. S. Courthouse	Pensacola	Florida	GSA		1997
GO20216	Southeast	NASA Dispensary	Cape Canaveral	Florida	NASA		1995
GO20451	Southeast	Fed. Bldg. Post Office-Courthouse	Clarksdale	Mississippi	GSA		1997
GO20215	Southeast	Food and Drug Administration Laboratory	Atlanta	Georgia	HHS	FDA	1995
GO20215	Southeast	Federal Building	Macon	Georgia	GSA		1995
GO20450	Southeast	Timberlake Federal Building	Tampa	Florida	GSA		1997

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20216	Southeast	Juliette Lowe Federal Building	Savannah	Georgia	GSA		1995
GO20261	Southeast	Federal Law Enforcement Training Center	Glynco	Georgia	Transportation		1995
GO20576	Southeast	US Coast Guard Group Fort Macon	Atlantic Beach	North Carolina	Transportation	Coast Guard	1998
GO20607	Southeast	Gulf Ecology Division	Gulf Breeze	Florida	EPA		1999

SAVEnergy Audits Reviewed
Sorted by Agency

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20501	Mid-Atlantic	USDA National Agricultural Library	Beltsville	Maryland	Agriculture		1997
GO20067	Midwest	Morris Soil Research Laboratory	Morris	Minnesota	Agriculture	ARS	1995
GO20346	Central	Intermountain Fire Sciences Laboratory	Missoula	Montana	Agriculture	Forest Service	1996
GO20174	Central	Black Hills NF Supervisors Office	Custer	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Hill City Shop	Hill City	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Rangers' Quarters	Deadwood	South Dakota	Agriculture	Forest Service	1995
GO20174	Central	Black Hills NF Pactola District HQ	Rapid City	South Dakota	Agriculture	Forest Service	1995
G020268	West	District Office & Bunkhouse	Ketchikan	Alaska	Agriculture	Forest Service	1995
G020382	West	Sawtooth National Recreation Area Office	Twin Falls	Idaho	Agriculture	Forest Service	1996
G020307	West	Angell Job Corp Center	Yachats	Oregon	Agriculture	Forest Service	1995
GO20066	Northeast	Plum Island Animal Disease Center	Orient Point	New York	Agriculture		1995
GO20066	Northeast	Plum Island Animal Disease Center	Plum Island	New York	Agriculture		1995
GO20170	Mid-Atlantic	U.S. Department of Commerce - Herbert C. Hoover Building	Washington	DC	Commerce		1995
GO20588	Central	Rocky Flats Environmental Technology Site	Golden	Colorado	Energy		1998
GO20469	West	Nevada Test Site	Las Vegas	Nevada	Energy		1996
GO20607	Southeast	Gulf Ecology Division	Gulf Breeze	Florida	EPA		1999
GO20423	Northeast	Alexander Pirnie Federal Courthouse and Federal Building	Utica	New York	GSA	Social Security	1997
GO20545	Midwest	Bricker Federal Building	Columbus	Ohio	GSA		1998
GO20531	Midwest	Duluth Federal Bldg and U.S. Courthouse	Duluth	Minnesota	GSA		1998
GO20530	Midwest	Federal Bldg and U.S. Courthouse	South Bend	Indiana	GSA		1998
GO20538	Midwest	Celebrezze Federal Building	Cleveland	Ohio	GSA		1998

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20305	Mid-Atlantic	Martin Luther King Federal Office Building & Courthouse	Newark	New Jersey	GSA		1995
Unknown	Mid-Atlantic	Wm. S. Moorhead Federal Building	Pittsburgh	Pennsylvania	GSA		1995
GO20266	Mid-Atlantic	Robert A. Roe Federal Office Building	Paterson	New Jersey	GSA		1995
GO20235	Northeast	Burlington Federal Building/Post Office, Court House	Burlington	Vermont	GSA		1995
GO20162	Northeast	Springfield Federal Building	Springfield	Massachusetts	GSA		1995
G020196	West	Bellingham Federal Building	Bellingham	Washington	GSA		1995
G020207	West	Moscow Federal Building	Moscow	Idaho	GSA		1995
G020514	West	911 Federal Building/Henri Monroe Office	Portland	Oregon	GSA		1997
GO20445	Southeast	U. S. Courthouse	Pensacola	Florida	GSA		1997
GO20451	Southeast	Fed. Bldg. Post Office-Courthouse	Clarksdale	Mississippi	GSA		1997
GO20215	Southeast	Federal Building	Macon	Georgia	GSA		1995
GO20450	Southeast	Timberlake Federal Building	Tampa	Florida	GSA		1997
GO20216	Southeast	Juliette Lowe Federal Building	Savannah	Georgia	GSA		1995
GO20215	Southeast	Food and Drug Administration Laboratory	Atlanta	Georgia	HHS	FDA	1995
GO20256	Mid-Atlantic	National Institute of Health, Building 31	Bethesda	Maryland	HHS	National Institute of Health	1995
GO20257	Mid-Atlantic	National Institute of Health, Building 29/29A	Bethesda	Maryland	HHS	National Institute of Health	1995
GO20376	West	Chemawa Indian Boarding School	Salem	Oregon	Interior	Bureau of Indian Affairs	1996
GO20420	Central	BLM District Office	Miles City	Montana	Interior	BLM	1996
GO20063	Midwest	Crab Orchard National Wildlife Refuge	Carterville	Illinois	Interior	Fish and Wildlife Service	1995
GO20234	Northeast	White River National Fish Hatchery	Bethel	Vermont	Interior	Fish and Wildlife Service	1995
G020521	West	San Francisco Nat'l Wildlife Refuge Complex	Newark	California	Interior	Fish and Wildlife Service	1995
G020521	West	Lahontan National fish Hatchery Complex	Gardnerville	Nevada	Interior	Fish and Wildlife Service	1997
G020521	West	Spring Creek National Fish Hatchery	Underwood	Washington	Interior	Fish and Wildlife Service	1997
G020521	West	Albernathy Salmon Culture Tech Center	Longview	Washington	Interior	Fish and Wildlife Service	1997

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20434	Central	Matagorda Island National Wildlife Refuge	Austwell	Texas	Interior	Fish and Wildlife Service	1996
GO20509	Central	Saratoga Fish Hatchery	Saratoga	Wyoming	Interior	Fish and Wildlife Service	1997
GO20347	Central	Colorado National Monument	Fruita	Colorado	Interior	National Park Service	1995
GO20441	Central	Rocky Mountain National Park	Estes Park	Colorado	Interior	National Park Service	1996
GO20221	Central	Rocky Mountain National Park	Estes Park	Colorado	Interior	National Park Service	1995
GO20403	Central	Guadalupe Mountains National Park	Salt Flat	Texas	Interior	National Park Service	1996
GO20248	Central	Mt. Rushmore National Monument	Keystone	South Dakota	Interior	National Park Service	1996
GO20500	Central	Yelllowstone National Park	Mammoth	Wyoming	Interior	National Park Service	1997
GO20454	West	Golden Gate National Recreation Area	San Francisco	California	Interior	National Park Service	1996
G020532	West	Shasta National Park Services	Whiskeytown	California	Interior	National Park Service	1997
GO20452	Northeast	Cape Cod National Seashore	Cape Cod	Massachusetts	Interior	National Park Service	1996
GO20597	Central	Federal Correctional Institution	Three Rivers	Texas	Justice	Bureau of Prisons	1998
GO20598	Central	Federal Detention Center	Oakdale	Louisiana	Justice	Bureau of Prisons	1999
GO20070	Midwest	Grand Rapids Job Corps Center	Grand Rapids	Michigan	Labor	Job Corps	1995
GO20522	Central	North Texas Job Corps Center	McKinney	Texas	Labor		1997
GO20068	Midwest	NASA Lewis Research Center	Cleveland	Ohio	NASA		1995
GO20511	Mid-Atlantic	NASA Langley Research Center	Hampton	Virginia	NASA		1997
GO20216	Southeast	NASA Dispensary	Cape Canaveral	Florida	NASA		1995
GO20167	Central	Dwight D. Eisenhower Center	Abilene	Kansas	National Archives		1995
GO20525	Mid-Atlantic	National Gallery of Art	Washington	DC	National Gallery of Art		1997
GO20600	Northeast	U.S. Postal Service New Hampshire District	Berlin	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Hudson	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Keene	New Hampshire	Postal Service		1998
GO20600	Northeast	U.S. Postal Service New Hampshire District	Littleton	New Hampshire	Postal Service		1998

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20600	Northeast	U.S. Postal Service New Hampshire District	Merrimack	New Hampshire	Postal Service		1998
GO20599	Northeast	U.S. Postal Service New York District	Watertown	New York	Postal Service		1999
GO20599	Northeast	U.S. Postal Service New York District	Glens Falls	New York	Postal Service		1999
GO20150	West	Federal Building and Post Office	Carson City	Nevada	Postal Service		1995
GO20568	Central	Corpus Christi Air Station	Corpus Christi	Texas	Transportation	Coast Guard	1998
GO20537	Northeast	USCG - New Castle, NH	New Castle	New Hampshire	Transportation	Coast Guard	1997
GO20576	Southeast	USCG - Vessel Support Facility	North Charleston	South Carolina	Transportation	Coast Guard	1998
GO20576	Southeast	US Coast Guard Group Fort Macon	Atlantic Beach	North Carolina	Transportation	Coast Guard	1998
GO20432	Central	Air Route Traffic Control Center	Salt Lake City	Utah	Transportation	FAA	1996
GO20468	Midwest	Air Route Traffic Control Center	Farmington	Minnesota	Transportation	FAA	1996
GO20602	Northeast	U.S. DOT - FAA (Logan Airport Tower)	Boston	Massachusetts	Transportation	FAA	1998
GO20602	Northeast	U.S. DOT - FAA (Nantucket Airport Surveillance Tower)	Nantucket	Massachusetts	Transportation	FAA	1998
GO20602	Northeast	U.S. DOT - FAA (Cummington Long Range Radar Tower)	Cummington	Massachusetts	Transportation	FAA	1998
GO20475	West	Air Route Traffic Control Center	Anchorage	Alaska	Transportation	FAA	1997
GO20574	West	Federal Highway Administration	Vancouver	Washington	Transportation	FHA	1998
GO20261	Southeast	Federal Law Enforcement Training Center	Glynco	Georgia	Transportation		1995
GO20255	West	N Island Naval Air Station/Customs Service	San Diego	California	Treasury	Customs	1996
GO20301	Mid-Atlantic	U.S. Mint	Philadelphia	Pennsylvania	Treasury	Mint	1995
GO20169	Mid-Atlantic	U.S. Department of Treasury	Washington	DC	Treasury		1995
GO20436	Midwest	V.A. Medical Center	Ann Arbor	Michigan	VA		1997
GO20430	Midwest	Northern Indiana Health Care System	Marion	Indiana	VA		1996
GO20543	Mid-Atlantic	Wilkes-Barre VA Medical Center	Wilkes-Barre	Pennsylvania	VA		1997
GO20323	Northeast	VA Medical Center Jamaica Plain	Boston	Massachusetts	VA		1995

DO/PO #	DOE Region	Site Name	City	State	Agency	Bureau	Audit Year
GO20534	West	Veterans Administration Outpatient Clinic	Los Angeles	California	VA		1998
GO20264	Southeast	VA Medical Center	Charleston	South Carolina	VA		1995

Appendix B

Audit Data Collected

Appendix B
Audit Data Collected

Site Identification Data
- Requisition #
- Purchase Order #
- DOE Region
- Name
- City
- State
- Agency
- Bureau
- Year Audit Conducted
- Auditing Company

Energy Price Data
- Electricity, $/MBtu
- Natural Gas, $/MBtu
- Fuel Oil, $/MBtu
- LPG, $/MBtu
- Coal, $/MBtu
- Purchased Steam or Hot Water, $/MBtu

Building Data
- Name
- Size, Square Feet
- Vintage, Year

Building Type Data
- Office
- Post Office
- Hospital
- Prison
- School
- Other Institutional
- Housing
- Storage
- Industrial
- Service
- R&D
- Other

Energy Efficiency Measure Categories[18]
- Building Envelope
- Heating System
- Cooling System
- Ventilating System
- Lighting

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[18] Used to indicate whether or not the audit considered each of the energy efficiency categories. Recommended energy efficiency measure data also recorded by energy efficiency measure category.

Service Hot Water
Plug Loads
Process Drive Systems
Compressed Air Systems
Other Process Loads
Central Boiler
Central Chiller
Steam or Hot Water Distribution
Chilled Water Distribution

Recommended Energy Efficiency Measure Data

Annual Energy Savings, MBtu
Annual Energy Savings, $
Annual Non-energy Savings, $
Implementation Cost, $
Net Present Value, $

Appendix C

SAVEnergy Audit Data Statistical Analysis

Appendix C

SAVEnergy Audit Data Statistical Analysis

One approach for evaluating the SAVEnergy audit data would be to simply assign the average EEM characteristic (e.g., investment/ft^2) for each combination of building type, vintage, building square footage (building size), and location (climate region) from the audit data to each of the Federal sites and building types in the GSA Database. Unfortunately, the sample size from the audit data was not large enough to provide robust results; in fact many building type, vintage, building size, and climate region combinations are not represented by the SAVEnergy audit data at all.

To overcome this limitation, an additive-effects model was developed via statistical regressions of the characteristics of interest as a function of vintage, building size, climate region, and building type. The linear model underlying this regression assumes that the effects of building type, vintage, building size, and climate region are independent of each other to a first approximation. Thus, for example, the change in a characteristic of interest between climate regions is assumed to be similar across vintage, building types, and building sizes.

During the statistical analysis, it was determined that building size was not a statistically significant explanatory variable; hence it was dropped from the analysis. Furthermore, only three statistically significant building type categories were identified: industrial, other[19], and "commercial" (office, post office, hospital, prison, school, other institutional, housing, storage, service, and R&D). Vintage was separated into two categories: 1962 and earlier and 1963 and later. Climate region was roughly represented by the six DOE regions. More sophisticated modeling of climate affects would be possible (e.g., based on the heating degree-days and/or cooling degree-days for every site in the sample and population) but not with the resources available to this project.

For the energy savings and dollar value of energy savings regressions the amount of investment was used as an additional explanatory variable. Thus, the investment was estimated first, and its value used for estimating energy savings and the dollar value of energy savings. Both investment and the dollar value of energy savings were used as explanatory variables for the NPV regression; hence, estimated investment and dollar value of energy savings were used when estimating NPV.

The vintage, climate region, and building type are qualitative or dummy variables, which only take on the values of zero or one. As discussed above, the value of specific characteristic of interest X (e.g., NPV) was assumed to follow an additive (linear) form with the following general format:

$$\begin{aligned} X = a &+ b_2 * \text{D-Vintage}_2 \\ &+ c_2 * \text{D-Climate}_2 + \ldots + c_6 * \text{D-Climate}_6 \\ &+ d_2 * \text{D-Type}_2 + d_3 * \text{D-Type}_3 \\ &+ e_1 * \text{P-Investment} \\ &+ f_1 * \text{P-Energy} + v \end{aligned}$$

where:

[19] A building that cannot be classified as "industrial" or one of the "commercial" building types listed here, as defined by each agency in their reporting of building stock data to GSA.

X	=	characteristic of interest
a	=	regression constant
b_i, c_i, d_i, e_i, f_i	=	regression coefficients
$D\text{-}Vintage_i$	=	vintage, dummy variables
$D\text{-}Climate_i$	=	climate region, dummy variables
$D\text{-}Type_i$	=	building type, dummy variables
P-Investment	=	investment, numerical variable
P-Energy	=	energy Savings, numerical variable
v	=	random disturbance term.

Because the model was estimated with a constant term (a), the first dummy variable in each set (i.e., $D\text{-}Vintage_1$, $D\text{-}Climate_1$, and $D\text{-}Type_1$) must be dropped from the equation to avoid a linear dependence. All of the building characteristics for the regression came from the SAVEnergy audits. The number of observations used for the investment, energy savings, and dollar value of energy savings regressions was 123; NPV data were not available for 23 of the audit data sets, so only 100 observations were used for the NPV regression.

Note that the regression analysis was conducted on individual building data, so the number of observations or buildings included in the statistical analysis is different than the number of audits evaluated. Audits reporting data for individual buildings or audits of facilities with only one building type were included in the statistical analysis. Audit data aggregated for an entire facility were not used in the statistical analysis if it represented multiple building types.

As mentioned above, the small number of observations suggests that the variance of the estimated characteristic levels may be relatively high. In fact, the regressions yielded standard errors from about one-third of the average value of the characteristic of interest to slightly less than the average value. While these values are uncomfortably high for estimating the characteristics of interest associated with a single building, the regressions yield acceptable results when applied to a large population of buildings as was done in this analysis.

Appendix D

Frequencies of Recommended Energy Efficiency Measures

Appendix D

Frequencies of Recommended Energy Efficiency Measures

The frequencies of recommended EEMs for the SAVEnergy audit sample and FEDS analyses of FORSCOM sites are presented in Tables D.1 and D.2, respectively. Table D.1 identifies the number of audits (out of 94 audits in the sample) where the specific EEMs listed were recommended. Recommendations for the same EEM within multiple buildings at the same site were counted as a single recommendation. Thus, the maximum frequency possible in Table D.1 is 94.

Similarly, Table D.2 identifies the number of FORSCOM sites (out of 11 FORSCOM sites evaluated with FEDS) where the specific EEMs listed were recommended. Again, multiple recommendations for an EEM at a single site counted as a single recommendation. Thus, the maximum frequency possible in Table D.2 is 11.

The frequencies of recommended EEMs were generally higher (relative to the maximum frequency possible) for the FEDS analyses of FORSCOM sites than for the SAVEnergy audit sample. This can be attributed to the use of a common analysis tool (FEDS) for evaluating the FORSCOM sites in contrast to using many different auditors to conduct the SAVEnergy audits. This result can also be explained by the greater commonality of building infrastructure characteristics across the FORSCOM sites than exists across the civilian agencies included in the SAVEnergy audits.

The frequencies of recommended EEMs correlate well with the estimated energy savings by EEM category for the SAVEnergy audit sample, i.e., EEMs within the Ventilation and Controls and Lighting categories are recommended most frequently and result in the greatest energy savings potential. The same degree of correlation is not found for the FEDS analyses of FORSCOM sites, but this should not be alarming because the frequency data shown do not capture the variable frequency across buildings at a single site, or the relative energy savings potential of different EEMs.

The EEM categories were developed to provide common groupings of specific EEMs. This was necessary to facilitate extrapolation of the SAVEnergy audit sample characteristics to the population of civilian agency square footage and for reporting of results. While it was usually obvious if an EEM fits into the Building Envelope or Lighting EEM categories, assignment to Heating System, Cooling System, or Ventilation and Control EEM categories was often more subjective. The general rules-of-thumb were to assign EEMs that affected only space heating to the Heating System category, those that affected only space cooling to the Cooling System category, but those that affected both space heating and cooling to the Ventilation and Controls category. Heating or cooling EEMs affecting a single building were assigned to the Heating System or Cooling System categories. Heating or cooling EEMs affecting multiple buildings were assigned to the Central Boiler, Central Chiller, or the appropriate thermal distribution category.

Table D.1 Frequencies of Recommended EEMs
SAVEnergy Audit Sample

EEM Category	Specific EEM	# Audits
Building Envelope	attic insulation	5
	roof insulation	4
	double pane windows	3
	door and window sealings	3
	wall insulation	2
	insulated garage doors	2
	other	3
Heating System	electric to fossil fuel heating conversion	7
	time-of-day thermostat controls	4
	boiler maintenance and modifications	4
	photosensitive thermostat controls	2
	district steam to building boiler conversion	2
	new boiler	2
	other	6
Cooling System	new cooling equipment of same type	7
	ultrasonic humidifiers	3
	add outside air economizer	3
	high-efficiency motors for chilled water pumps	3
	chilled water reset control	3
	new cooling equipment of different type	3
	other	5
Ventilation and Controls	high efficiency motors	31
	variable speed drives	18
	energy management control system	12
	programmable electronic thermostat	10
	ventilation rate control	8
	misc. controls	8
	exhaust heat recovery	7
	variable air volume distribution	6
	direct digital control system	6
	advanced belt drives	5
	HVAC re-commissioning	4
	other	6
Lighting	T-8 fluorescent lamps with electronic ballasts	64
	CFLs	41
	occupancy sensors	37
	LED exit signs	23
	time-of-day and photosensitive controls	18
	high pressure sodium/metal halide	11
	delamping	7
	other	15

EEM Category	Specific EEM	# Audits
Service Hot Water	electric resistance to fossil fuel conversion	3
	faucet aerators or low-flow shower heads	2
	sensor controlled faucets	2
	high-efficiency pump motor or variable speed drive (VSD)	2
	other	7
Plug Loads	new refrigerator	2
	office equipment timers	1
	convert from electric clothes dryer to liquid petroleum gas (LPG)	1
Process Drive Systems	high-efficiency motors	3
	well pump timer control	1
Compressed Air Systems	new compressor motor	1
Other Process Loads	capacitors for load factor control	4
	diesel generators	2
	other	8
Central Boiler	feedwater preheater	1
	high efficiency boiler feed pump motors	1
	new cogeneration plant	1
Central Chiller	cooling tower economizer	2
	cooling tower water pump	1
	two-speed fan for cooling tower	1
	chilled water reset	1
	control system	1
Steam/Hot Water Distribution	VSD for hot water pumps	4
	condensate line repair	3
	steam trap repair	2
	steam line repair	2
Chilled Water Distribution	VSDs for chilled water pumps	7
	primary/secondary piping system	2

Table D.2 Frequencies of Recommended EEMs
FEDS Analysis of FORSCOM Sites

EEM Category	Specific EEM	# Sites
Building Envelope	attic insulation	11
	slab-on-grade perimeter insulation	10
	suspended ceiling insulation	9
	window film	7
	roof insulation	3
	storm window	1
Heating System	automatic electric damper for boiler	10
	gas-fired furnace	10
	conventional gas-fired boiler	9
	oil-fired boiler	2
	condensing gas boiler	1
	electric furnace	1
Cooling System	open-loop ground coupled heat pump	5
	air-source heat pump	3
	closed-loop ground coupled heat pump	3
	packaged terminal air conditioner (PTAC) with gas heating	2
	window unit AC	1
	split system AC	1
	gas-engine driven chiller	1
	dual fuel heat pump (HP with gas backup)	1
Lighting	CFL	10
	T-8 fluorescent lamps with electronic ballasts	10
	low-pressure sodium pendent lamp	9
	LED exit signs	8
	mercury vapor pendent lamp	7
	mercury vapor pole lamp	5
	metal halide pole lamp	4
	T-12 fluorescent lamps with electronic ballasts	3
	flex tube exit signs	2
Service Hot Water	wrap hot water tank with insulation	11
	faucet aerators	11
	low-flow shower heads	11
	lower hot water temperature	11
	conventional gas-fired boiler	9
	condensing gas-fired boiler	7
	gas-fired water heater	6
	insulate piping	6
	central heat pump hot water system	2
	oil-fired boiler	2

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