CAN THE FEDERAL ENERGY EFFICIENCY GOALS BE ACHIEVED THROUGH RETROFITS?

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ABSTRACT

Executive Order 13123 requires Federal agencies to reduce building energy consumption per square foot by 30% in 2005 and 35% in 2010, both relative to 1985. Since 1985, energy use at federal buildings has dropped from 139.8 MBtu/ksf (million Btu per thousand square feet) to 113.7 MBtu/ksf in 1998[1] [1]. Thus, significant additional energy savings will be required to meet the future goals of 97.9 MBtu/ksf in 2005 and 90.9 MBtu/ksf in 2010.

This paper reports on the results of a study conducted by the Pacific Northwest National Laboratory[2] for the U.S. Department of Energy's (DOE's) Federal Energy Management Program (FEMP) [2]. The study estimated the life-cycle cost-effective (i.e., economic) energy savings potential in federal buildings via retrofit of energy-related infrastructure 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 systems, cooling systems, and lighting. The estimated potential was then compared with the requirements for meeting energy efficiency goals.

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 to 113.7 MBtu/ksf 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) and 2010 (90.9 MBtu/ksf). 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) retrofit 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,[3]
- replacement or retrofit technology characteristics,
- energy prices, and
- interest rates.

[1] Excluding facilities that house energy-intensive operations.

[2] Operated by Battelle for the U.S. Department of Energy under contract DE-AC06-76RL01830.

[3] Including previous retrofits, if any.

While prior estimates of the cost-effective energy savings potential have become dated, data collected from a few hundred FEMP 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.

APPROACH

With approximately three billion square feet of floor space in 500,000 federal 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 1. 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.

Civilian Agencies

As described above and shown in Table 1, 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.

- 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.

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 [3]. Thus, the objective of the statistical analysis was to develop valid correlations for predicting energy efficiency measure (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. Note that leased property was excluded from the analysis.

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.

TABLE 1. DISTRIBUTION OF CIVILIAN AGENCY FLOOR SPACE IN POPULATION AND AUDITS

Agency	% of Domestic-Owned Population Floor Space	% of Audit Floor Space[4]
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
NASA	4.78	2.30
Justice	4.68	2.17
Agriculture	4.00	3.99
Transportation	2.73	13.07
HHS	2.45	1.59
Corps of Engineers[5]	1.22	0.00
Labor	1.07	3.12
Treasury	0.66	2.54
Commerce	0.61	4.67
Education	0.55	0.00
Others	1.40	2.19
Total Domestic Owned ksf	916,100	
Total SAVEnergy Audit ksf		59,179

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 U.S. 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 [4]. 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

[4] Based on all 310 SAVEnergy Audits.

[5] 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.

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.

RESULTS

The results of the analysis are presented in Table 2 through Table 8. The first two tables show results for the SAVEnergy Audit sample. The next two tables show results for the statistical extrapolation of the SAVEnergy Audit sample to civilian federal buildings. Table 6 shows results for the Department of Defense (DoD) while integrated results for civilian and military government buildings are shown in Table 7. Finally, Table 8 compares historical and prospective energy use per square foot for the federal government and civilian and military components.

Table 2 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 121.6 MBtu/ksf. Energy savings by EEM category are shown in Table 3. 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.

Estimated annual energy savings and implementation costs for civilian agencies, shown in Table 4, are very close to the Table 2 SAVEnergy Audit sample; only the net present value (NPV) is significantly different. The NPV difference between the Audit sample and the estimate is primarily due to 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.

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 with an average of 26 MBtu/ksf for the various agencies; a narrowing of the range compared to the results of Table 2 would be expected as many of the samples are not representative of an individual agency's building stock.

TABLE 2. 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
EPA	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
NARA	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
VA	29.56	430.97	2257.28	4008.20
Average	**26.77**	**403.79**	**1948.11**	**2886.86**

TABLE 3. RESULTS BY EEM CATEGORY FOR SAVEnergy AUDIT SAMPLE DATA

Results per Thousand Square Feet (ksf) of Audit Sample Buildings

EEM Category	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**

TABLE 4. 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
FCC	24.91	571.71	2,696.63	4,413.76
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
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
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**

Energy savings estimated for civilian agencies by EEM category are shown in Table 5. 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 due to 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).

DoD results are presented in Table 6. As described in the approach, FEDS was used to estimate the energy savings potential for DoD within building envelope, heating system, cooling system, 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. The contribution of individual EEM categories for DoD 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**.**

TABLE 5. 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**

These differences are not all together unexpected. Generally, there are obvious reasons; some are due to dissimilarities in the approach and others occur due to 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. Energy management control systems

(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 Table 7. Overall, the potential annual energy savings were estimated to be about 25 MBtu/ksf or 66 trillion Btu for the 2.64 billion square feet of domestic, owned buildings in the "goal inventory." This is roughly one-fifth of the actual federal building energy consumption in FY 98. 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.

Assuming the estimated savings potential per square foot also applies to the 0.43 billion square feet of foreign and leased buildings also included in the "goal inventory," and these savings are achieved, the federal government, and its civilian and military components would meet the goal of reducing energy consumption per square foot of building floor space by 35% relative to consumption in 1985. Table 8 identifies energy consumption per square foot in 1985, 1998, and in the future if the cost-effective savings potential estimated above are achieved.

TABLE 6. 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 7. 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 8. HISTORICAL AND PROSPECTIVE ENERGY INTENSITIES

	Actual 1985	Actual 1998	Executive Order 13123 Goal	With Economic Energy Savings
	Energy Use, MBtu/ksf			
Federal	139.77	113.65	90.85	88.77
Civilian	154.16	121.59	100.20	95.57
Military	135.35	109.48	87.98	85.14

CONCLUSIONS

Based on the analytical approach and assumptions used for this study, the total cost-effective retrofit energy savings potential in domestic, owned, goal-inventory federal buildings is about 25 MBtu/ksf or 66 trillion Btu (0.066 Quads). 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 estimated energy savings potential, if applicable to the entire "goal inventory" and captured, would result in the federal government, and its military and civilian agency components, meeting the goal of reducing energy consumption per square foot by 35% relative to 1985 figures, as required by EO 13123. 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 of cost-effective energy savings potential or about two-thirds of the estimate in this study via federal financing. 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 floor space it maintains for their personnel and their families. Lower heating system retrofits in the military agencies would also be expected, give the higher fraction of military floor space heated with central systems.

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 a FORSCOM fort 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 the fort or about 17 MBtu/ksf! While the conditions at this particular fort 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.

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 75% of the federal property where EO 13123 applies or about 85% of the total “goal inventory” property. The other 15% 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 15%.

Family housing, which represents a substantial fraction of military floor space and energy consumption, is currently being privatized by DoD, i.e., federally owned housing is being sold to private companies and then leased by the government from the private companies. 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 10% 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." If 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 the government should emphasize lighting in all retrofit programs.

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