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LOWER-BOUND ESTIMATES OF ENERGY EFFICIENCY IN THE FEDERAL SECTOR

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Preface

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy-efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, facility assessment, and use of cost-sharing procurement mechanisms. Technology development focuses upon the tools, software and procedures used to identify and evaluate energy-efficiency technologies and improvements. For facility assessment, FEMP provides metering equipment and trained analysts to federal agencies exhibiting a commitment to improve energy use efficiency. To assist in procurement of energy-efficiency measures, FEMP helps federal agencies devise and implement performance contracting and utility demand-side management strategies.

Pacific Northwest Laboratory (PNL)[a] supports FEMP in its mission to achieve energy systems modernization in the federal sector. Under this charter, the Laboratory and its contractors work with federal facility energy managers to assess and implement energy-efficiency improvements at federal facilities nationwide.

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Executive Summary

The Energy Programs Directorate (EPD) at the Pacific Northwest Laboratory (PNL) was tasked by the DOE Federal Energy Management Program (FEMP) to provide lower-bound estimates of the energy and dollar savings that could be realized by implementing all life-cycle cost-effective retrofits within the federal sector. FEMP has a responsibility to recommend a course of action to DOE regarding the design, implementation, and management of a federal energy efficiency fund. The information in this report is provided to assist FEMP in developing its position.

We estimated the minimum energy-efficiency potential for the following end uses using a generic approach that combined site-specific data, state-level data, and national federal building stock data:

- lighting
- motors
- transformers
- water heating
- cooling
- space heating.

In producing these estimates we considered the savings and fuel-switching potential in electricity, natural gas, and fuel oil. We did not explicitly consider coal or other fuels but allocated those fuels to natural gas and fuel oil.

We also provide a "rule of thumb" estimate for process energy, which is shown in Table S.1 with the other end uses. Finally, we discuss energy-efficiency potential within the federal fleet but do not produce any estimates of savings. Additional background and details are provided in the text and appendix.

The lower-bound estimates shown in Table S.1 indicate that for every dollar invested the government will realize three dollars in cost savings. We identify nearly $6 billion of investment potential. This is consistent with what we have found working with federal agencies on energy systems modernization programs: an installation, or agency, can typically invest between one and two times its annual energy bill in life-cycle cost-effective retrofits.

The lower-bound estimates show that we would save a total of 106,000 BBtu, approximately 21% of the energy now used in buildings, facilities, and processes. The total annual cost of this energy is just over $4.5 billion. Our analysis indicates that at least 33% of the annual bill, $1.5 billion, could be saved.

Table S.1. Potential Annual Energy Savings, Investment Requirement, and Dollar Savings by End Use

End Use	Annual Energy Savings (BBtu)	Value of First Year Energy Savings (1991 10^6)	Present Value of Energy Savings (1991 10^6)	Required Investment (1991 10^6)	Net Present Value (1991 10^6)
Lights	32,387	$642	$3,087	$1,819	$1,278
Motors	3,531	$75	$1,080	$643	$437
Transformers	1,229	$25	$364	$159	$205
Water Heating	16,778	$333	$4,804	$915	$3,889
Cooling	485	$14	$204	$186	$18
Space Heating	39,412	$355	$6,092	$1,133	$4,950
Process	12,000	$120	$1,761	$1,000	$761
Total	105,822	$1,564	$17,392	$5,856	$11,538

The quality of our estimates for each end use varies. We believe that our estimates for lighting, motors, and transformers are reasonably accurate. Our estimates for water heating are of lower quality but credible. The estimates for cooling are a notch lower in quality than those for water heating. Our estimates for space heating are the least accurate of our rigorously produced estimates. There are several reasons for this. We did not explicitly consider all fuels. Also, thermal loop systems in the federal sector are, typically, not operated at near optimal efficiency and there is very little metered data available on these systems.

There were several end-use measures that could contribute to reducing the federal energy bill that we did not consider. Some of these measures are "low cost-no cost." These include lighting controls, setbacks for heating/cooling, and conservation voltage reduction. We did not evaluate energy management control systems. The electric and gas prices that we used were melded rates; therefore, our estimate of dollar savings is likely an underestimate when consideration of demand reductions is included. Finally, we hypothesize that explicit evaluation of individual building boilers in place of thermal loop systems could yield significant savings, but we did not evaluate this measure.

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1.0 Introduction

The Federal Energy Management Program (FEMP) is responsible for recommending a position for the U.S. Department of Energy (DOE) to present to Congress regarding the establishment of an energy efficiency fund. As input to developing a policy position, FEMP requested the Energy Programs Directorate (EPD) at Pacific Northwest Laboratory (PNL) to provide lower-bound estimates of life-cycle cost-effective savings from implementing a federally financed energy efficiency fund. The results of this analysis are presented in this report.

The federal government is the single largest user of energy in the United States, consuming nearly 1.5 quads annually at a cost of about $10 billion. Nearly half of this energy is used in buildings and facilities, and for process energy, costing us nearly $5 billion — about half of the annual federal sector bill (DOE 1991). Although no rigorous, formal analysis of the cost-effective savings potential has been done, some evidence suggests that estimates in the neighborhood of 25-40% are realistic (OTA 1991; Hopkins 1991; Currie 1992).

The purpose of this study was to take an additional step in rigor and formality compared to previous efforts. Specifically, the objective is to produce lower-bound estimates of energy and dollar savings from immediately replacing all life-cycle cost-effective technologies in federal facilities and the federal fleet. The approach used was to begin with rigorous installation and building-specific analyses and to extrapolate the results throughout all federal agencies across the country to produce final savings potential estimates.

The general approach that we use in producing the estimates is described in Section 2.0. Included is a description of the data bases we use. We described the quantity, quality, and comparability of the data. Also, we discuss the rationale for type and location of installations that would, ideally, form the bulk of the site-specific data which would be the basis used in extrapolation to the entire federal sector.

The analyses and results are presented in Section 3.0. We discuss the quality of the results and the confidence that we have in the estimates produced. We identify areas where additional work is needed to produce better estimates.

References used in the study are provided in Section 4.0.

Finally, additional analysis details are shown in the appendix. Included are state-level results for many of the end uses.

2.0 Approach

Our scope of work calls for us to produce lower-bound savings estimates (energy and dollars) for electric, fossil and "other" fuels. Furthermore, electric savings are to be broken out by lighting and "other." Finally, the fuel savings will be desegregated across the end-use sectors of buildings, transportation, and "other."

In producing these estimates, we decided to begin work at the lowest level of end-use disaggregation. We conceptually approached the problem as shown in Table 2.1. This would be a useful breakout, especially if information could be developed on energy and dollar savings and required investment for each federal agency by state. This latter information is more than we could hope for in this preliminary effort. However, we have proceeded by generating estimates for each "X" in Table 2.1. Due to the inherent uncertainty that is in these estimates, we have chosen to aggregate the nonelectric estimates as agreed upon in our statement of work.

We decided to allocate all nonelectric fuel use to natural gas and fuel oil due to time and funding constraints. We show the uses of coal in Table 2.1 using an asterisk (*) but do not provide savings estimates. We apportioned coal consumption to oil and natural gas based on the relative ratio of natural gas to oil use, a ratio of roughly 2 to 1 (DOE 1991).

Table 2.1. Federal Sector End Use by Fuel Type

	Electricity	Oil	Coal	Natural Gas	Petroleum
Lights	X				
Motors	X				
Transformers	X				
Space Cooling	X				
Space Heating					
Forced Air	X	X	*	X	
Steam		X	*	X	
High Temp H_2O		X	*	X	
Water Heating	X	X	*	X	
Vehicles					X

In other words, we assume the same amount of primary energy is used; however, it is assumed to be all fuel oil and natural gas. We see no obvious reason why this assumption has significant impact on our lower-bound estimates.

One potentially significant area for savings--process energy--was not rigorously addressed. Even if we had additional time, it would be difficult to adequately evaluate this area because almost no information exists other than what is available in DOE (1991). We do provide a "rule of thumb" estimate of savings potential based on our experience in supporting federal agencies in energy systems modernization efforts.

We were also asked to estimate the near-term potential for renewable energy technologies within the federal sector. While there are niche markets for renewable, they will not make a significant contribution in the near term. Given that our objective is to estimate lower-bound savings estimates, we have not attempted to estimate a lower-bound for renewable.

The approach we use to estimate the lower-bound of cost-effective energy savings potential is to begin with facility-specific analyses and to extrapolate the findings throughout the federal sector using data on building square footage per state, state level energy prices, and near-term projections of utility demand-side management (DSM) rebate levels. Our focus is on energy savings potential in buildings and facilities, transportation, and operations.

Note that the scope of this effort called for estimating the savings potential in the federal sector. While the current federal sector energy consumption by end use is sometimes developed in the course of this effort, it was not always necessary to estimate end-use energy consumption in order to obtain estimates of energy savings potential. While current consumption was estimated for some end uses (lighting, space cooling, processes and vehicles), water heating provides an example of how savings potential can be estimated without estimating total consumption. Water flow restrictors reduce water use at faucets. We can estimate the number of faucets and current use at the faucets, and thus estimate savings potential due to installation of flow restrictors, without estimating non-faucet hot water use.

We are assuming the building and technology stock of the federal sector to be static. That is, we assume that there is no new construction and that there is no retirement of existing structures, etc. It can be argued that this assumption will lead to overestimates of energy savings. With a business-as-usual environment, the total stock of energy-using infrastructure in the federal sector would rise; i.e., there would be net additions over time. However, the Department of Defense (DoD) is the major energy user in the federal sector and DoD is in the process of "downsizing." Given that the majority of the value of retrofits accrue within a 5-year time frame, the inherent inertia in the federal system to not

close or retire any building, and the political sentiment that is building for not creating more unemployment, we believe that our assumption of a static building stock will not significantly impact the lower-bound estimates we have produced.

DoD is the largest energy consumer within the federal government. In the operation of buildings and facilities, DoD uses about 64% of all electricity and nearly 84% of all non-electric energy. The Department of Energy (DOE) is the next largest consumer within the federal government and within the buildings and facilities category. Together DoD and DOE consume about 80% of all energy used in federal buildings and facilities as well as over 70% of the total federal buildings and facilities energy bill. DoD and DOE also account for the bulk of the more than half billion dollars of process energy used in the federal sector.

Given the relative magnitude of DoD and DOE energy consumption, it is most important that we begin our analysis with representative detailed energy characterization data for DoD and DOE installations. Furthermore, because building envelopes and energy systems are dependent on ambient climate conditions, it is also important that the installation-specific data we use represent the boundaries of climatic conditions within the country.

There are also many buildings scattered around the country that are neither DoD nor DOE controlled, but belong to other federal agencies. It is important for us to determine if the envelopes, existing end-use technologies, and operating conditions of these buildings are significantly different from buildings assigned to the same use but owned by DoD and DOE. If differences are minimal, or if the number of buildings with significant differences is small, then we can assume that the installation-specific data from DoD and DOE are reasonably representative of the remainder of the federal sector, for the purpose of estimating lower-bound energy savings potential.

Consistent with the methodology used in Shankle et al. (1993), we have derived estimates of federally owned building space by state, by federal agency group (GSA, DoD, and other), and by building type. This comprises our basic buildings data set (Table A.1). The overwhelming majority of federal building space is located in border states. Also, the overwhelming majority of PNL engineering field activities in support of energy systems modernization efforts with federal agencies have been in New England and the northeast corridor, the southeast, and the west coast. Therefore, it is most likely that our field experience has been at representative federal buildings and facilities. Based on our experience, we have working estimates and rules of thumb that relate end-use technology type and vintage with building type and geographic location.

Estimating the energy savings potential within the federal sector requires estimating the avoided energy costs from using new technologies and implementing new management strategies. Energy costs, especially electricity costs, vary significantly around the

nation. We have used the same state average electricity prices used in Shankle et al. (1993) and shown in Table A.2 for all the analyses in this report. We also needed to anchor on prices for other fuels (natural gas, fuel oil, etc.). These are listed in Table A.3.

Additional complexity arises when consideration is given to electricity demand-side management rebates. Ideally, DSM rebate types and levels need to be identified and projected into the future. For this exercise, we have chosen to use our current estimates of DSM rebates for each state. We first categorized states to "high," "medium," or "low" based on the average rebate level (Table A.4) and assigned a rebate level to each rebate category (Table A.5). The one exception to this approach was for lighting, where we used the estimates produced by Shankle et al. (1993).

All analyses were conducted using the life-cycle cost methodology. However, only lighting and thermal loop systems have significant operations and maintenance (O&M) components. We have not reported the O&M portion of lighting because that is reported in Shankle et al. (1993). Also, we have not estimated the O&M portion for thermal loops, so we do not report that.

The analysis period we use is 25 years, the same analysis period we use for all life-cycle cost analyses that we conduct for FEMP. Finally, we use the standard federal discount rate of 4.6%, the standard federal rate at the time this analysis was performed.

The above description characterizes the generic approach that we used in this study. However, the specific approach used to extrapolate end-use, site-specific estimates to the federal sector depended on the quantity and quality of data at hand. We discuss the approach used for each end use in Section 3.0, "Analysis and Results."

3.0 Analysis and Results

In this section we present the analysis and results by end use. We address, in order, lighting, motors, transformers, water heating, space cooling, space heating, processes, and vehicles. Finally, we summarize the results in the form called for in our statement of work.

3.1 Lighting

Estimates of the savings potential and investment requirements in lighting were developed by Shankle et al. (1993) and are summarized in this section. Lighting retrofits have the potential of saving the most money and the most energy of any electrical end use in the federal sector. Of all the estimates that we have produced for this study, we have the highest level of confidence in our estimates on the potential savings from lighting because of the research that led to the Shankle report.

The potential for energy savings from relighting federally owned buildings with energy efficient lighting products projects is tremendous. We estimate that total potential cost-effective energy savings could amount to over 52% of the current annual lighting electricity consumption. Fluorescent lighting fixtures could be cost-effectively retrofit so as to reduce their annual electricity use by 47%; incandescent fixture electricity use could be reduced by 55%; and the electricity used by exit signs could be reduced by over 90% through the installation of light-emitting diode (LED) and self-luminescent (tritium gas) signs. All of these retrofits would be cost-effective, in that their life-cycle cost would be less than that of the existing fixtures.

We estimated the existing stock of lighting fixtures in federally owned buildings, and then using the Lighting Technology Screening Matrix (LTSM) (Dirks et al. 1992), we determined the minimum life-cycle cost retrofit for each type of existing lighting fixture. Estimates of the existing stock were developed for four types of fluorescent lighting fixtures (2, 3, and 4 lamp F40 four-foot fixtures and 2 lamp F96 eight-foot fixtures, all with standard magnetic ballasts); one type of incandescent fixture (75-watt single bulb fixture); and one type of exit sign (containing two 20-watt incandescent bulbs).

We assumed that federal monies would be combined with utility rebates to fund the lighting retrofits. The schedule for investing in lighting retrofits is described in Shankle et al. (1993).

The summary for lighting is shown in Table 3.1. Included are the annual energy savings, the net present value of the investment, the value of the annual energy savings, the net present value of the energy savings, and the net present value of the life-cycle cost savings.

Table 3.1. Lighting Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (MWh)	9,490,272
Annual Energy Savings (BBtu)	32,387
Value of First Year Energy Savings (1991 $)	$641,486,000
Present Value of Energy Savings (1991 $)	$3,087,042,000
Required Investment (1991 $)	$1,819,264,000
Net Present Value (1991 $)	$1,277,778,000

3.2 Motors

Based on our energy modernization activities for FEMP and other federal agencies (Brodrick et al. 1993; Secrest et al. 1991; Dixon et al. 1992a, 1992b), we decided to group all motors into one of three categories: 1-10hp, 10-20hp, and 20+hp. Each of these categories was broken down into two motor types: ventilation and other (non-ventilation).

Nonventilation motors are typically used for process operations, water pumping, and sewage pumping at large multibuilding installations such as those found within DoD and DOE. These installations typically function as small cities and provide most of their own utility services. The number of non-ventilation motors was based on the building area for all building types within DoD and DOE. The combined DoD and DOE building areas were multiplied by estimates of motor densities (motors/sq. ft.) which we have estimated at DoD and DOE installations in our energy systems modernization activities to produce an estimate of the total number of nonventilation motors in the federal sector. This total was then shared to the state level based on DoD and DOE building space square footage in each state.

Ventilation motors are typically used in commercial, industrial, and residential buildings. Very little air-handling is required in storage facilities; therefore, ventilation motors are

typically not found in these types of buildings. As such, storage and warehousing facilities were excluded from this analysis. Residential buildings were also excluded because we have found that the small motor sizes found in residences typically make them uneconomical to replace except on failure. The stock of ventilation motors was estimated and shared out to the state level using the same procedure as was used for nonventilation motors. The one exception is that we included all federal agencies.

For each motor type, two energy resource options were investigated. A motor may be replaced with either a high-efficiency motor or an adjustable-speed drive (ASD) unit. According to the American Council for an Energy-Efficient Economy's (ACEEE's) Energy Efficient Motor Systems (Nadel et al. 1991), the ASD option is applicable to approximately 30% of the existing motors. Thus, two scenarios were developed for each type of motor: replace 100% with high-efficiency, or replace 70% with high-efficiency and 30% with ASD motors.

These options were examined for each motor type at the state level. Total kilowatt-hour savings potential for each scenario was calculated using kilowatt-hour savings per motor (Nadel et al. 1991 and PNL field data) and the motor quantity estimates. Electricity prices for each state were then used to calculate the value of the annual energy savings. Installed costs per motor were established through ACEEE and vendor contacts. The installed cost of each scenario incorporated the utility DSM rebates shown in Tables A.4 and A.5 in the appendix.

The results are shown in Table 3.2. The nation could save nearly half a billion dollars by immediately implementing all life-cycle cost-effective motor retrofits. More detail is shown in Table A.6.

Table 3.2. Motor Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (MWh)	1,034,914
Annual Energy Savings (BBtu)	3,531
Value of First Year Energy Savings (1991 $)	$74,546,000
Present Value of Energy Savings (1991 $)	$1,080,096,000
Required Investment (1991 $)	$643,324,000
Net Present Value (1991 $)	$436,772,000

3.3 Transformers

Potential energy savings for transformers were estimated for DoD and DOE installations. We assumed that these agencies composed the bulk of transformer use; therefore, no other agencies were considered. Estimates on the number and size of transformers for DoD sites were derived from data collected by PNL at Fort Lewis, Washington (Secrest et al. 1991), and at Fort Drum, New York (Dixon et al. 1992a, 1992b). Current PNL energy systems modernization activities at other DoD installations support our findings at these two installations. We used Hanford, Washington, transformer survey data as representative of DOE installations.

We first classified transformers by size, according to kilovolt-amperes (kVA). We then equated each size classification with estimates of annual energy savings (AES) and investment cost (IC) which we have derived for Fort Lewis and have used at Fort Drum. The Hanford transformer survey does not contain data on AES or IC. For those transformer sizes existing at Fort Drum and Hanford but not existing at Fort Lewis, the AES and IC were interpolated from the Fort Lewis data. We did not include transformer sizes greater than 2,500 kVA, as we have found that retrofits are seldom cost-effective for transformers this large.

We then calculated a transformer density, in terms of thousand square feet of building space (Kft^2) per transformer, for each transformer size category. For DoD installations, the estimate was based on the number of each transformer size and the combined total floor space at Fort Lewis and Fort Drum. For DOE installations, we used a transformer density based on Hanford data.

Knowing the DoD and DOE floor space by state, transformer density by size category, average state electricity prices, average state DSM rebate levels, and the IC and AES for each transformer size, we could then estimate the total number of life-cycle cost-effective transformer retrofits in the federal sector.

By retrofitting existing transformers with high-efficiency transformers, a minimum potential annual energy savings of 360,000 megawatt-hours (MWh) could be realized. The savings would amount to over $25 million per year. The summary is presented in Table 3.3, with more detail in Table A.7 in the appendix.

The retrofit program would involve replacing approximately 138,000 transformers on DoD and DOE sites, and would require $159 million in investment. These retrofits represent a net present value of over $204 million.

Table 3.3. Transformer Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (MWh)	360,321
Annual Energy Savings (BBtu)	1,229
Value of First Year Energy Savings (1991 $)	$25,078,000
Present Value of Energy Savings (1991 $)	$364,021,000
Required Investment (1991 $)	$159,439,000
Net Present Value (1991 $)	$204,582,000

3.4 Water Heating

We estimated potential water heating savings for all federal facilities. We grouped all federal agencies into two classifications: those that we assumed have the capability of complete conversion to natural gas for all life-cycle cost-effective fuel-switch opportunities, and those agencies that we assumed have the ability to convert only a portion of their facilities to natural gas.

Within these two classifications, we defined three sectors: residential, low water use intensity commercial, and high water use intensity commercial. We assigned prisons and hospitals to the high water use intensity commercial sector. The other two sectors comprise buildings representing the traditional commercial/residential definitions.

We considered four water heater energy resource options (EROs): wrapping existing water heaters with R-11 fiberglass insulation, reducing water heater usage with low-flow showerheads and faucet aerators, replacing existing heaters with high-efficiency heaters, and replacing existing heaters with high-efficiency natural gas heaters. Logical combinations of these measures were also considered. (Wraps are not used in combination with any replacement options as the high-efficiency units have insulation levels similar to a conventional design with a wrap.) Table 3.4 gives all of the combinations considered for each sector.

We assumed that DoD and DOE have the capability of complete conversion to natural gas. We reasoned that DoD and DOE installations tend to be relatively large, essentially mini-cities. As such, these installations present a very attractive market for gas distributors. Also, the size of the installations presents the operators with economies of scale,

Table 3.4. Energy Resource Options By Water Heating Sector

ERO	Residential	Low-Intensity Commercial	High-Intensity Commercial
Wrap	X	X	X
Reduce Use			
- Low Flow	X	[a]	X
- Aerator	X	X	X
Wrap & Reduce	X	X	X
Replace w/ Hi-Eff.	X	X	X
Replace & Reduce	X	X	X
Replace w/ Gas	X	X	X
Gas & Reduce	X	X	X

(a) Measure not considered for this sector.

making it worth their while to incur the conversion costs to gas. Indeed, in our experience with DoD and DOE facilities, we have found that these installations either have natural gas onsite, or are in a position to access gas and convert if it is life-cycle cost-effective to do so.

On the other hand, other federal agencies (OFAs) are more likely to have the majority of their floor space dispersed about the country in single buildings or small clusters of buildings similar to the private sector. As such, we assumed that only a portion of OFA facilities would have potential access to natural gas. We assumed that 28% of the OFA commercial and residential buildings not currently using gas for water heating could switch to gas. This percentage was calculated from NBECS[a] (28% of the NBECS metropolitan buildings not using gas for water heating had gas available).

We calculated existing water heating fuel shares for the commercial buildings from energy-use intensities (EUIs) which we have developed for Fort Drum and Fort Lewis. Water heating fuel shares for residential buildings were taken from RBECS.[b]

(a) NBECS = Nonresidential Buildings Energy Consumption Survey.
(b) RBECS = Residential Buildings Energy Consumption Survey.

The average federal residential housing unit has 1,500 square feet of floor space, and we assumed that there is one 50-gallon water heater for each unit. In addition, we assumed that high water use intensity commercial buildings had a single central water heater with a loop system and that low water use intensity commercial buildings use distributed water heaters. Table 3.5 gives average commercial building sizes, predicted heater capacities, predicted heater dimensions, and predicted heaters per thousand square feet and other data necessary for this analysis. Our estimates of occupants were based on CBECS[a] regressions, storage required capacities were determined from American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHREA) data, and tank dimensions were based on typical sizes.

We assumed that the average building vintage was 1961-1973 and that buildings are evenly distributed over climate zones. The representative high-intensity commercial building was a hospital, the representative low-intensity commercial building was a small office building.

There are many other assumptions that were necessary for us to make prior to calculating the potential energy savings in water heating, and they are too numerous to list for this report. An example is the assumption of standby loss for water heaters (we arrived at 20% for electric and 45% for oil and gas). Most of the assumptions that were necessary to make are embodied in the Facility Energy Decision Screening (FEDS) system being developed at PNL and many of these are documented in Secrest et al. (1991).

Table 3.5. Predicted Number of Employees, Heaters, and Dimensions

Building Type:	DoD/DOE/High	Other/High	DoD/DOE/Low	Other/Low
Average Building Size	36,891	54,466	6,990	7,536
Pred. Emp./ft^2	0.315369	0.303129	0.281691	0.281691
Pred. Employees/Building	116	165	20	21
Required Capacity (gal/emp)	5	5	1	1
Useable Capacity (gal/bldg)	831	1,179	28	30
# of Central Systems	1	1	0	0
# of Distributed Htrs (50 gal)	0	0	1	1
Heater Diameter (in.)	45.5	51.1	18.5	18.5
Heater Height (in.)	118.2	132.9	45.0	45.0
Heater Density (htrs/kft^2)	0.0271	0.0184	0.1431	0.1327

(a) CBECS = Commercial Buildings Energy Consumption Survey.

The calculation of savings was done much the same way as for the other end uses. Nearly 90% of the savings potential is in the commercial sector with the DoD/DOE classification having the greatest potential. Within the residential sector, which comprises only about 10% of the savings potential, fuel-switching from electric water heaters to natural gas causes an increase in energy use (a negative savings) because natural gas heaters use more energy. However, cost savings are realized because of the relative capital and fuel costs. Electric hot water heater retrofits comprise over 70% of the dollar savings potential. The summary is given in Table 3.6 and additional details can be found in Table A.8 in the appendix.

Table 3.6. Water Heating Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (BBtu)	16,778
Value of First Year Energy Savings (1991 $)	$333,490,000
Present Value of Energy Savings (1991 $)	$4,803,868,000
Required Investment (1991 $)	$914,837,000
Net Present Value (1991 $)	$3,889,001,000

3.5 Space Cooling

Energy savings potential for cooling was estimated for all federal buildings. More than any other end use, the energy savings from cooling that could be achieved through immediate investment in new technology appear to be limited. This is because a relatively large expense is associated with replacing existing equipment that is still in operating condition. The energy cost portion of the life-cycle cost of cooling is relatively low. Furthermore, the amount of energy used in cooling is relatively low compared with space heating and hot water heating. Finally, the overall efficiency improvements in cooling systems have been modest over the past decade or so, in the neighborhood of 10%.

There can be significant savings when replacing failed equipment by participating in utility DSM programs to upgrade the new equipment beyond the efficiencies warranted from a standard life-cycle cost analysis. However, we have not attempted to estimate those savings. Also, there can be significant cost savings from reducing on-peak costs with more efficient, and creative, operation of cooling equipment. We did not evaluate demand reduction strategies in this analysis. As such, our estimates represent a lower bound.

We classified buildings as either housing or commercial and estimated the average size for each building class. We also estimated a national average cooling system size for both building types. We then estimated regression equations of cooling energy consumption as a function of cooling degree days (CDDs) using data from Burt Hill Kosar Rittlelman (1985). We used these regression equations and state average CDDs to estimate the cooling energy consumption for both building classifications. We assumed that existing cooling equipment in housing and commercial buildings has coefficients of performance (COPs) of 2.18 and 2.33, respectively. These are the 1970 average COPs (personal communications, James Broderick, DOE Office of Buildings Technologies). We assumed that the COP for new cooling equipment is 2.45 for housing and 2.63 for commercial buildings (Broderick). We then divided the ratio of the existing COP by the retrofit COP and multiplied this by the existing cooling energy consumption to determine the retrofit energy consumption. The difference between the existing and retrofit energy consumption represents the savings.

We calculated the aggregate energy and dollar savings using the generic approach developed for this study. Estimates were produced at the state level using average state electricity prices and DSM rebate levels. We estimated the retrofit costs to be $2,340 for housing and $8,700 for commercial buildings.

Life-cycle cost-effective replacement of existing equipment with new more efficient units represents a potential annual energy savings of about 142,000 megawatt-hours (MWh), or $13.8 million in the first year. This would involve the replacement of cooling equipment in approximately 14% of the commercial buildings in the federal sector and would require an investment of about $186 million. (Cooling units for housing were not found to be life-cycle cost effective to replace before failure.) These retrofits represent a present value of energy savings of $204 million and a net present value of $18 million. The summary is shown in Table 3.7.

Table 3.7. Cooling Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (MWh)	142,000
Annual Energy Savings (BBtu)	485
Value of First Year Energy Savings (1991 $)	$13,800,000
Present Value of Energy Savings (1991 $)	$204,000,000
Required Investment (1991 $)	$186,000,000
Net Present Value (1991 $)	$18,000,000

3.6 Space Heating

Estimating space heating energy conservation potential proved to be problematic. We know that the federal sector is more energy-intensive than the private sector, especially in space heating. We know that there are significant amounts of nonelectric energy used in the federal sector but we have very little information on the amounts used in different end uses. Given the lack of metered and verifiable aggregate data, we began by designing a simple, aggregate model of commercial building space heating consumption, using data from Burt Hill Kosar Rittelmann Associates (1985) and other sources. We confirmed that the model does a reasonable job of predicting private sector energy-use intensity. We then applied the model to the national federal building stock to estimate total space heating energy consumption. We then subtracted the energy use that we have estimated for all other electric and nonelectric end uses from the total energy used in buildings and facilities as reported in DOE (1991). This represented the residual energy used, and we would expect the number to be somewhat larger than what our model predicted. The residual number was several times larger than our model predicted.

We have reached several conclusions regarding this problem. First, DOE (1991) indicates that a significant amount of process energy may be reported within the buildings and facilities category. Second, even if we were able to separate out the process energy, we know from our energy system modernization activities at large federal installations that the thermal loop systems are inefficient. Third, even if the thermal loop systems were operating at optimal efficiency, the federal sector would have a higher energy use intensity than the private sector in its commercial building stock because the average federal building is older and smaller than its private sector counterpart.

Because of the intractable problems in our preferred approach, we decided to use actual data on federal building space heating energy use in place of the commercial building model. Fort Lewis energy consumption data was used to calculate a relationship between space heating energy use intensity and climate (heating degree days). The relationship appears to approximate the information that we have from other federal installations. This was applied to all federal buildings, by state, to calculate existing space heating energy consumption. Consumption was estimated for residential buildings, commercial buildings not on thermal loop systems, and commercial buildings on thermal loop systems. We assumed that 25% of the commercial buildings were on thermal loops. This is based on our field experience to date with the federal sector; we have not been able to determine if this estimate is representative of DoD and DOE.

In each sector, a percentage cost-effective savings potential was calculated from Fort Lewis data, and used to estimate energy savings potential. Costs were calculated in a similar fashion. Results are presented in Table 3.8.

Table 3.8. Space Heating Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Energy Efficiency Potential	
Annual Energy Savings (BBtu)	39,412
Value of First Year Energy Savings (1991 $)	$197,058,214
PV of Energy Savings (1991 $)	$3,511,066,451
Fuel-Switching Potential	
First Year Energy Cost Reduction (1991 $)	$158,145,234
PV of Annual Energy Cost Reduction (1991 $)	$2,580,910,389
Total Potential	
Annual Energy Savings (BBtu)	39,412
Value of First Year Energy Cost Reduction (1991 $)	$355,203,448
PV of Annual Energy Cost Reduction	$6,091,976,840
Required Investment (1991 $)	$1,132,796,135
NPV (1991 $)	$4,950,209,469

Additional investigation should be done regarding nonelectric fuel consumption within the federal sector. We really need to confirm or reject the hypothesis that significant savings potential is possible.

3.7 Processes

DOE (1991) reports that process energy use in the federal sector totals at least 0.06 quads, costing about $600 million annually. Some process energy is also bundled into the figures report for buildings and facilities.

There is no easy way to extrapolate site-specific estimates of savings to the rest of the federal sector by analyzing a few selected federal installations. The reason is that the majority of process energy appears to be used in relatively unique processes. Examples include the nuclear weapons production complex within DOE, the munitions production sites within DoD, missile fabrication at Vandenburg AFB, and the production of artillery pieces at Watervliet Arsenal.

We are engaged in modernization activities at some installations that use process energy and believe that a "rule of thumb" that we have used can be applied to the use of process energy. In general, we have found that from 1 to 2 times the annual energy bill can be cost-justified as an investment in energy efficiency at most federal installations. The investment will typically result in an annual energy savings of 20%. Using this rule of thumb, we have developed the estimates shown in Table 3.9 for process energy.

Table 3.9. Process Energy: Potential Annual Energy Savings, Investment Requirement, and Dollar Savings

Annual Energy Savings (BBtu)	12,000
Value of First Year Energy Savings (1991 $)	$120,000,000
Present Value of Energy Savings (1991 $)	$1,761,212,000
Required Investment (1991 $)	$1,000,000,000
Net Present Value (1991 $)	$761,000,000

3.8 Vehicles

In fiscal year 1989, the federal fleet owned 106,108 sedans, 15,973 station wagons, 323,479 light trucks, 12,641 buses and ambulances, and 55,481 medium and heavy trucks, which consumed over 329 million gallons of petroleum. A reduction in petroleum consumption by 10% would save approximately $31 million annually, given that the average cost for auto gasoline for the federal fleet is $0.96 per gallon.

Vehicles in the federal fleet exhibit characteristics that are significantly different from characteristics that make energy efficiency investments in other end uses attractive. For example, vehicles have a very short economic life compared with end-use technologies such as lights, motors, and transformers. Transformers, for example, can last upwards of 50 years. Vehicles, especially high use vehicles, have a useful life in the 3- to 5-year time frame. This relatively short economic life makes the systematic upgrade of the fleet one of the most attractive energy efficiency strategies. This is a path that the government is following by increasing the fuel efficiency standards over time and requiring the purchase of long-lived vehicles. Although we have not done an exhaustive search, we have found enough evidence to suggest that simply increasing the rate of retirement and purchase of new vehicles is likely not to be cost-effective.

Another key characteristic exhibited by vehicles is that the government can exercise considerable control over the management and use of the existing stock. This characteristic is unlike that for motors and transformers - these devices are typically either on line or in a standby mode for emergency service. However, the ability to control and manage the technology is akin, in some ways, to lighting. The federal manager can save energy and dollars by simply doing a better job at managing the existing stock of lighting. Thus, other than systematic upgrading of the fleet, management of the existing and evolving fleet appears to offer the most opportunities.

We do not have a straightforward solution, or recommendation, as we do in lights, motors, transformers, cooling equipment, etc. The issues are extremely complex. For example, given the job requirements of those who use the fleet, there is obviously an optimal fleet size. However, we will never really know what that is. Therefore, if we arbitrarily reduce the size of the fleet, we may either increase or decrease costs depending on maintenance activities and fuel use. This is because there is also an optimal level of maintenance required for a given fleet size and usage. A decrease in fleet size could cause an increase in maintenance requirements which might not be met, thus resulting in decreased gas mileage.

Although straightforward solutions do not exist, a reasonable target for savings would be more efficient management of the stock. Carpooling, telephone use, electronic mail, and teleconferencing are options; even programming ourselves to ask "is it necessary to physically meet with other parties on this issue?" every time we plan to use a government vehicle can reduce the number of trips and, also, possibly, have a positive impact on job productivity.

Using a target of 10% savings from improved management of the federal fleet would mean that roughly $30 million could be saved annually, accounting for 329 million gallons of petroleum while requiring very little investment.

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Appendix

Appendix

Table A.1. Building Stock By State and Agency and Building Type (in 1000s of ft^2)

Agency Group	State	Office	Hospital	Prison	School	OtherInst	Housing
GSA	Alabama	2,985	10	0	2	6	3
	Alaska	1,702	4	0	1	2	6
	Arizona	1,895	9	0	3	5	7
	Arkansas	1,243	11	0	0	2	2
	California	17,436	50	0	8	15	28
	Colorado	3,642	10	0	2	4	4
	Connecticut	1,258	4	0	1	0	2
	Delaware	302	2	0	0	0	1
	DC	16,360	13	0	0	2	1
	Florida	5,281	21	0	3	2	8
	Georgia	5,345	18	0	4	12	9
	Hawaii	2,476	3	0	1	4	10
	Idaho	814	4	0	0	0	1
	Illinois	7,130	19	0	4	4	5
	Indiana	2,350	5	0	1	3	1
	Iowa	1,014	3	0	0	1	0
	Kansas	1,492	7	0	1	6	4
	Kentucky	2,003	11	0	2	6	5
	Louisiana	2,277	9	0	1	3	4
	Maine	587	2	0	0	0	2
	Maryland	7,447	22	0	4	6	7
	Massachusetts	3,283	13	0	1	3	3
	Michigan	3,239	10	0	1	1	2
	Minnesota	1,895	11	0	0	0	0
	Mississippi	1,453	7	0	2	1	3
	Missouri	4,591	10	0	1	3	3

Table A.1. (contd)

Agency Group	State	Office	Hospital	Prison	School	OtherInst	Housing
	Montana	895	2	0	0	1	1
	Nebraska	1,656	5	0	0	0	2
	Nevada	903	2	0	0	1	1
	New Hampshire	661	1	0	0	0	1
	New Jersey	3,745	8	0	1	5	4
	New Mexico	2,832	6	0	2	4	4
	New York	10,700	37	0	3	11	6
	North Carolina	3,023	12	0	2	5	9
	North Dakota	728	3	0	1	0	3
	Ohio	4,986	16	0	1	4	1
	Oklahoma	1,982	8	0	2	3	3
	Oregon	1,769	5	0	0	1	1
	Pennsylvania	7,718	23	0	2	5	1
	Rhode Island	547	2	0	0	0	1
	South Carolina	2,018	9	0	2	4	6
	South Dakota	632	4	0	1	1	1
	Tennessee	3,105	13	0	1	4	2
	Texas	9,820	38	0	7	13	14
	Utah	1,477	3	0	1	2	1
	Vermont	268	1	0	0	0	0
	Virginia	12,659	18	0	5	12	12
	Washington	3,705	9	0	2	6	7
	West Virginia	914	4	0	0	1	0
	Wisconsin	1,063	12	0	1	2	1
	Wyoming	566	2	0	0	11	1
DoD	Alabama	2,480	773	0	3,261	2,750	10,439
	Alaska	1,414	327	0	1,250	1,155	20,627
	Arizona	1,574	716	0	3,472	2,113	21,078
	Arkansas	1,033	885	0	679	1,018	5,498
	California	14,485	3,858	0	10,653	7,021	88,523
	Colorado	3,026	766	0	3,246	1,999	12,811
	Connecticut	1,045	302	0	711	64	5,109
	Delaware	251	134	0	351	56	2,435

Table A.1. (contd)

Agency Group	State	Office	Hospital	Prison	School	OtherInst	Housing
	DC	13,592	999	0	497	1,045	3,769
	Florida	4,387	1,655	0	4,401	997	25,116
	Georgia	4,440	1,364	0	5,906	5,390	27,584
	Hawaii	2,057	266	0	921	1,980	32,679
	Idaho	676	286	0	415	175	3,368
	Illinois	5,924	1,470	0	4,807	1,944	15,326
	Indiana	1,952	413	0	1,061	1,266	4,362
	Iowa	842	201	0	583	277	303
	Kansas	1,240	531	0	1,345	2,703	13,286
	Kentucky	1,664	820	0	2,216	2,685	16,900
	Louisiana	1,892	700	0	1,505	1,573	11,994
	Maine	488	153	0	552	182	5,149
	Maryland	6,187	1,663	0	5,633	2,882	21,162
	Massachusetts	2,727	985	0	1,488	1,611	9,282
	Michigan	2,691	735	0	1,006	446	6,836
	Minnesota	1,574	834	0	563	180	757
	Mississippi	1,208	561	0	2,344	482	8,515
	Missouri	3,814	790	0	1,576	1,366	8,721
	Montana	744	117	0	355	243	3,797
	Nebraska	1,376	352	0	177	231	4,776
	Nevada	750	160	0	287	340	4,653
	New Hampshire	549	112	0	278	90	2,581
	New Jersey	3,111	620	0	1,949	2,172	12,289
	New Mexico	2,353	499	0	2,483	1,769	13,647
	New York	8,890	2,837	0	4,529	5,049	19,036
	North Carolina	2,511	927	0	2,863	2,259	30,224
	North Dakota	605	248	0	792	112	9,542
	Ohio	4,142	1,217	0	1,244	1,719	4,153
	Oklahoma	1,647	599	0	2,390	1,508	9,961
	Oregon	1,470	357	0	632	406	2,771
	Pennsylvania	6,412	1,763	0	2,071	2,256	4,695
	Rhode Island	454	149	0	672	80	3,677
	South Carolina	1,676	689	0	2,131	1,860	19,260
	South Dakota	525	293	0	1,175	541	4,599

Table A.1. (contd)

Agency Group	State	Office	Hospital	Prison	School	OtherInst	Housing
	Tennessee	2,579	1,041	0	843	1,771	6,055
	Texas	8,158	2,963	0	9,422	5,856	45,576
	Utah	1,227	260	0	709	719	4,641
	Vermont	223	86	0	138	19	85
	Virginia	10,517	1,377	0	6,287	5,693	36,923
	Washington	3,078	718	0	2,609	2,832	23,342
	West Virginia	760	314	0	384	426	241
	Wisconsin	883	893	0	706	1,117	3,581
	Wyoming	470	135	0	168	4,942	3,238
OFA	Alabama	2,972	1,744	483	689	724	921
	Alaska	1,695	739	27	264	304	1,819
	Arizona	1,887	1,617	89	734	556	1,859
	Arkansas	1,237	1,998	17	144	268	485
	California	17,359	8,713	1,410	2,252	1,849	7,806
	Colorado	3,626	1,729	194	686	526	1,130
	Connecticut	1,252	682	203	150	17	450
	Delaware	300	302	0	74	15	215
	DC	16,288	2,256	0	105	275	332
	Florida	5,258	3,738	561	930	262	2,215
	Georgia	5,321	3,081	606	1,248	1,419	2,432
	Hawaii	2,465	600	13	195	521	2,882
	Idaho	811	647	0	88	46	297
	Illinois	7,099	3,321	585	1,016	512	1,351
	Indiana	2,340	933	673	224	333	385
	Iowa	1,010	454	0	123	73	27
	Kansas	1,485	1,199	855	284	712	1,172
	Kentucky	1,994	1,852	990	468	707	1,490
	Louisiana	2,267	1,582	7	318	414	1,058
	Maine	584	344	0	117	48	454
	Maryland	7,414	3,755	23	1,191	759	1,866
	Massachusetts	3,269	2,225	0	315	424	818
	Michigan	3,224	1,660	386	213	117	603
	Minnesota	1,886	1,883	142	119	47	67

Table A.1. (contd)

Agency Group	State	Office	Hospital	Prison	School	OtherInst	Housing
	Mississippi	1,447	1,267	0	495	127	751
	Missouri	4,570	1,783	423	333	360	769
	Montana	891	264	0	75	64	335
	Nebraska	1,649	795	0	37	61	421
	Nevada	899	361	62	61	89	410
	New Hampshire	658	253	0	59	24	228
	New Jersey	3,729	1,400	110	412	572	1,084
	New Mexico	2,820	1,126	0	525	466	1,203
	New York	10,653	6,407	501	957	1,329	1,678
	North Carolina	3,010	2,092	271	605	595	2,665
	North Dakota	725	560	0	167	30	841
	Ohio	4,964	2,748	0	263	453	366
	Oklahoma	1,973	1,352	597	505	397	878
	Oregon	1,762	807	0	134	107	244
	Pennsylvania	7,684	3,980	1,011	438	594	414
	Rhode Island	544	338	0	142	21	324
	South Carolina	2,009	1,556	2	450	490	1,698
	South Dakota	629	662	0	248	143	406
	Tennessee	3,091	2,351	272	178	466	534
	Texas	9,777	6,692	1,837	1,991	1,542	4,019
	Utah	1,470	586	0	150	189	409
	Vermont	267	194	0	29	5	8
	Virginia	12,603	3,109	353	1,329	1,499	3,256
	Washington	3,689	1,622	47	551	746	2,058
	West Virginia	910	709	716	81	112	21
	Wisconsin	1,058	2,016	475	149	294	316
	Wyoming	564	304	0	36	1,301	285

Table A.2. State Average Electricity Prices

State	Average Industrial Price ($/kWh)	Average Commercial Price ($/kWh)	Average Price ($/kWh)
Alaska	$0.094	$0.088	$0.091
Alabama	$0.045	$0.069	$0.057
Arkansas	$0.063	$0.074	$0.068
Arizona	$0.061	$0.088	$0.075
California	$0.090	$0.112	$0.101
Colorado	$0.046	$0.044	$0.045
Connecticut	$0.080	$0.093	$0.087
DC	$0.066	$0.081	$0.073
Delaware	$0.047	$0.071	$0.059
Florida	$0.049	$0.064	$0.057
Georgia	$0.048	$0.069	$0.058
Hawaii	$0.071	$0.108	$0.089
Iowa	$0.039	$0.073	$0.056
Idaho	$0.027	$0.041	$0.034
Illinois	$0.061	$0.088	$0.075
Indiana	$0.042	$0.059	$0.050
Kansas	$0.047	$0.065	$0.056
Kentucky	$0.038	$0.054	$0.046
Louisiana	$0.039	$0.069	$0.054
Massachusetts	$0.088	$0.100	$0.094
Maryland	$0.078	$0.087	$0.083
Maine	$0.064	$0.082	$0.073
Michigan	$0.060	$0.083	$0.071
Minnesota	$0.045	$0.066	$0.056
Missouri	$0.052	$0.067	$0.059
Mississippi	$0.042	$0.070	$0.056
Montana	$0.024	$0.043	$0.033
North Carolina	$0.052	$0.063	$0.058
North Dakota	$0.047	$0.059	$0.053
Nebraska	$0.039	$0.060	$0.049
New Hampshire	$0.087	$0.104	$0.095
New Jersey	$0.077	$0.095	$0.086
New Mexico	$0.052	$0.085	$0.069

Table A.2. (contd)

State	Average Industrial Price ($/kWh)	Average Commercial Price ($/kWh)	Average Price ($/kWh)
Nevada	$0.067	$0.062	$0.064
New York	$0.066	$0.118	$0.092
Ohio	$0.044	$0.078	$0.061
Oklahoma	$0.033	$0.068	$0.050
Oregon	$0.037	$0.047	$0.042
Pennsylvania	$0.065	$0.077	$0.071
Rhode Island	$0.094	$0.113	$0.103
South Carolina	$0.043	$0.060	$0.052
South Dakota	$0.048	$0.080	$0.064
Tennessee	$0.042	$0.057	$0.050
Texas	$0.042	$0.066	$0.054
Utah	$0.037	$0.059	$0.048
Virginia	$0.042	$0.057	$0.050
Vermont	$0.049	$0.086	$0.068
Washington	$0.023	$0.048	$0.035
Wisconsin	$0.040	$0.060	$0.050
West Virginia	$0.035	$0.053	$0.044
Wyoming	$0.034	$0.052	$0.043

Data are August (Com) and September (Ind), 1991 prices reported in December, 1991 (Com) and January, 1992 (Ind) EUN.

Table A.3. Fuel Oil Prices

(Average cost per unit from Annual Report to Congress on Federal Government Energy Management and Conservation Programs, FY 1990, p. 21)

$0.75/gallon = $5.40/MBtu

State Gas Prices (Nov. 91 Prices from Energy User News, April 1992)

State	Commercial Gas Price ($/1000cf)	Gas Price ($/MBtu)
Alabama	$5.39	$5.21
Alaska	$2.58	$2.50
Arizona	$5.05	$4.88
Arkansas	$4.32	$4.18
California	$7.63	$7.38
Colorado	$3.99	$3.86
Connecticut	$7.13	$6.90
DC	$5.18	$5.01
Delaware	$4.94	$4.78
Florida	$5.23	$5.06
Georgia	$5.18	$5.01
Hawaii	$13.02	$12.59
Idaho	$4.59	$4.44
Illinois	$4.22	$4.08
Indiana	$3.99	$3.86
Iowa	$4.41	$4.26
Kansas	$3.06	$2.96
Kentucky	$4.32	$4.18
Louisiana	$4.89	$4.73
Maine	$6.12	$5.92
Maryland	$4.88	$4.72
Massachusetts	$6.67	$6.45
Michigan	$4.58	$4.43
Minnesota	$3.94	$3.81
Mississippi	$3.92	$3.79
Missouri	$4.30	$4.16

Table A.3. (contd)

State	Commercial Gas Price ($/1000cf)	Gas Price ($/MBtu)
Montana	$4.39	$4.25
Nebraska	$4.05	$3.92
Nevada	$4.30	$4.16
New Hampshire	$6.59	$6.37
New Jersey	$4.81	$4.65
New Mexico	$4.06	$3.93
New York	$5.46	$5.28
North Carolina	$4.63	$4.48
North Dakota	$4.52	$4.37
Ohio	$4.61	$4.46
Oklahoma	$4.08	$3.95
Oregon	$4.69	$4.54
Pennsylvania	$5.81	$5.62
Rhode Island	$7.30	$7.06
South Carolina	$5.33	$5.15
South Dakota	$4.11	$3.97
Tennessee	$4.73	$4.57
Texas	$4.53	$4.38
Utah	$4.37	$4.23
Vermont	$5.10	$4.93
Virginia	$4.88	$4.72
Washington	$4.11	$3.97
West Virginia	$5.51	$5.33
Wisconsin	$4.42	$4.27
Wyoming	$4.40	$4.26

Table A.4. State Rebate Classifications

State	Classification
Alaska	Low
Alabama	Med
Arkansas	Low
Arizona	Low
California	High
Colorado	Low
Connecticut	High
DC	Low
Delaware	Low
Florida	Med
Georgia	Med
Hawaii	Low
Iowa	Low
Idaho	High
Illinois	Med
Indiana	Med
Kansas	Low
Kentucky	Med
Louisiana	Low
Massachusetts	High
Maryland	Low
Maine	High
Michigan	Low
Minnesota	High
Missouri	Low
Mississippi	Low
Montana	High
North Carolina	Low
North Dakota	Low
Nebraska	Low
New Hampshire	Low
New Jersey	High
New Mexico	Low
Nevada	Low
New York	High

Table A.4. (contd)

State	Classification
Ohio	Low
Oklahoma	Med
Oregon	High
Pennsylvania	High
Rhode Island	Low
South Carolina	Low
South Dakota	Low
Tennessee	Low
Texas	Low
Utah	Low
Virginia	Low
Vermont	High
Washington	High
Wisconsin	High
West Virginia	Low
Wyoming	Low

Table A.5. Average Rebate Levels by Classification

Base Case		
Low	Med	High
5%	25%	50%

Table A.6. Motor Retrofit Potential by Size and Type

Existing Motors			Replacement Motors							
Motor Type	Motor Size (HP)	Number of Motors	Motor Type	Motor Size (HP)	Number of Motors to Retrofit	Energy Savings (MWh)	Value of First Year Energy Savings	Present Value of Energy Savings	Investment Requirement	Net Present Value
Other	1-10	294,916	Other	1-10	179,859	79,498	$4,958,888	71,864,044	$52,981,422	$18,882,622
			Other ASD	1-10	70,185	65,805	$6,060,458	87,873,028	$51,951,100	$35,921,928
Vent.	1-10	875,165	Vent.	1-10	534,309	236,165	$14,694,446	212,587,557	$157,104,559	$55,482,998
			Vent. ASD	1-10	206,367	194,000	$17,720,481	261,544,911	$152,753,211	$103,791,700
Other	10-20	47,160	Other	10-20	1,721	1,594	$73,246	1,067,165	$894,246	$172,919
			Other ASD	10-20	45,439	116,248	$7,931,856	115,100,791	$66,401,538	$48,699,253
Vent.	10-20	72,644	Vent.	10-20	2,894	2,680	$123,208	1,794,602	$1,504,024	$290,578
			Vent. ASD	10-20	69,750	178,441	$12,130,991	175,767,212	$101,841,533	$73,925,679
Other	>20	18,235	Other ASD	>20	18,235	156,828	$10,573,324	153,447,024	$56,394,864	$97,052,160
Vent.	>20	485	Vent. ASD	>20	485	4,165	$279,501	4,050,307	$1,497,674	$2,552,633
Totals	All	1,308,605	Totals	All	1,129,246	1,034,914	$74,546,399	1,080,096,640	$643,324,171	$436,772,469

Table A.7. Transformer Retrofit Estimate Totals

	Number of Transformers to Retrofit	Total Annual Energy Savings (MWh)	Value of First Year Annual Energy Savings (1991 $)	Present Value of Energy Savings	Investment Requirement (1991 $)	Net Present Value (1991 $)
Total DoD	124,939	325,366	$22,571,688	327,611,871	$140,980,824	$186,631,047
Total DOE	13,335	34,955	$2,506,518	36,409,974	$18,458,556	$17,951,418
Total	138,275	360,321	$25,078,206	364,021,845	$159,439,380	$204,582,465

Table A.8 Water Heating Retrofit Potential By Fuel Type and Sector

Building Type	Number of Heaters to Retrofit	Energy Savings (MBtu)	Annual of First Year Energy Savings ($)	Value Present Value of Energy Savings ($)	Investment Requirement	Net Present Value
Residential						
Elect.	177,407	-264,914	24,110,546	334,115,716	74,664,355	259,451,361
Gas	230,470	2,112,201	11,444,815	204,671,049	21,894,646	182,776,403
Oil	6,919	63,414	342,657	5,602,439	657,340	4,945,099
Total	414,796	1,910,701	35,898,018	544,389,204	97,216,341	447,172,863
Comm. DoD/DOE						
Elect.	1,056,681	118,689	140,752,603	1,852,188,531	387,485,144	1,464,703,387
Gas	430,006	2,335,159	11,812,345	217,137,590	75,065,694	142,071,896
Oil	527,021	3,076,270	18,251,957	303,330,375	119,479,758	183,850,617
Total	2,013,708	5,530,118	170,816,905	2,372,656,496	582,030,596	1,790,625,900
Comm. OFA						
Elect.	446,563	2,268,908	89,262,457	1,230,061,119	110,577,565	1,119,483,554
Gas	181,725	3,162,794	15,815,061	290,645,113	54,864,289	235,780,824
Oil	222,724	3,905,096	21,697,666	366,115,793	70,178,090	295,937,703
Total	851,012	9,336,798	126,775,184	1,886,822,025	235,619,944	1,651,202,081
Comm. All						
Elect.	1,503,244	2,387,597	230,015,060	3,082,249,650	498,062,709	2,584,186,941
Gas	611,731	5,497,953	27,627,406	507,782,703	129,929,983	377,852,720
Oil	749,745	6,981,366	39,949,623	669,446,168	189,657,848	479,788,320
Total	2,864,720	14,866,917	297,592,088	4,259,478,521	817,620,540	3,441,827,982
All Build.						
Elect.	1,680,651	2,122,683	254,125,606	3,416,365,366	572,727,064	2,843,638,302
Gas	842,201	7,610,154	39,072,221	712,453,752	151,824,629	560,629,123
Oil	756,664	7,044,780	40,292,280	675,048,607	190,315,188	484,733,419
Total	3,279,516	16,777,617	333,490,107	4,803,867,725	914,866,881	3,889,000,844
Grand Total	3,279,516	16,777,618	333,490,106	4,803,867,725	914,866,881	3,889,000,845

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