Title
Estimated Savings from Energy-Efficient Federal Purchasing

Authors
Johnson, Francis X
Harris, Jeffrey

Publication Date
2000-03-01

LBNL-42719

Ernest Orlando Lawrence Berkeley National Laboratory

Estimated Savings from Energy-Efficient Federal Purchasing

Francis X. Johnson and Jeffrey Harris

Environmental Energy Technologies Division

March 2000

LBNL-42719

Estimated Savings from Energy-Efficient Federal Purchasing

Francis X. Johnson*
Jeffrey Harris

March 2000

Energy Analysis Program
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory—
Washington DC Projects Office
University of California
Washington DC 20024

*Frank Johnson, formerly of LBNL, is affiliated with the Stockholm Environment Institute.

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Federal Energy Management Program, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Acknowledgments

We would like to thank the reviewers of this report for their comments and corrections. Thanks to Barbara Atkinson and Jon Koomey (LBNL) who provided valuable comments, data, and advice on methodology throughout the project. Graham Parker and Andrew Nichols (Pacific Northwest National Laboratory) have provided useful data and insights. Eric Noble provided valuable supporting data for the product savings levels and categories. Phil Coleman (LBNL) and Katie McGervey (DOE-FEMP) have provided guidance throughout the project regarding the development and implementation of the PEERs. Special thanks to Nancy Casey-McCabe (University of Maryland, previously LBNL) who developed the initial data sources to support this study.

A number of other individuals and organizations contributed data and/or insights that were valuable in the preparation of this report. We would like to thank Bob Harrison, Kim Holland, Monty Ingram, Brenda Longest, and Bob Matza (Defense Logistics Agency); Craig Collins, Dennis Dickerson, and Don Morey (Department of Defense); Tom Bee (DOD, retired); Jim Murray (D&R International); Chris Tremper (McNeil Technologies); Rhonda Althaus and Evelyn Auberry (General Services Administration); Lanny Huber (Department of the Interior); Tom Morehouse (Institute for Defense Analysis); and Lee Debaillie (US Army Corps of Engineers, CERL). Our further appreciation and apologies to anyone whom we have inadvertently left out.

Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

The Federal Energy Management Program (FEMP) of the Department of Energy (DOE) assists federal agencies in complying with energy-efficient procurement requirements of the Energy Policy Act of 1992 (EPACT) and Executive Order 13123 (Clinton 1999). The Executive Order directs all federal agencies to buy ENERGYSTAR® labeled products or products in the upper quartile of the market with respect to energy efficiency. FEMP issues Product Energy Efficiency Recommendations (PEERs) which establish energy performance levels consistent with the Executive Order for each type of product. The FEMP program on energy-efficient procurement also contributes to the federal goal of reducing energy intensity in buildings in 2010 by 35% compared to 1985 levels.

This report projects estimated annual energy and cost savings in 2010 from federal purchases of twenty-one energy-using products for which FEMP has issued efficiency recommendations to date. These products fall into five groups: residential equipment, residential appliances, office equipment, lighting, and water-saving products. The five product groups together account for approximately one-fourth to one-third of total federal energy use in buildings, although only selected products within each group—those most widely purchased by federal agencies—are covered by FEMP recommendations. Not included in this analysis are several important equipment categories: non-residential heating and cooling equipment, electric motors, transformers, additional lighting products, and windows and roofing. For several of these, PEERs were still in preparation as of early 1999 when this analysis was done; for others FEMP may develop energy-efficient criteria in the future.

The methodology for estimating savings is based on a detailed characterization of residential, office, and other buildings in the federal stock. Residential buildings are further divided into single-family housing (civilian and military) and military troop housing. The overall building stock is assumed to remain largely unchanged over the analysis period, from now to 2010. Data for the years 1995-97 are used to characterize the installed equipment base. Equipment turnover estimates are based on end-of-life replacement plus an allowance for new construction and product replacement during building renovation and refurbishment. Estimated energy savings per unit are based on assumptions used in the cost-effectiveness section of the PEERs (Table 7).

The data on actual purchasing patterns of federal agencies are limited to reporting of aggregate dollar amounts by broad category of purchases, and only for transactions over $25,000. There is virtually no reported information on equipment purchases by contractors for use in federal facilities. Absent reported data, to assess the impact of the FEMP program on energy-efficient purchasing we developed several scenarios based on the likely range of federal compliance with the FEMP-recommended energy efficiency levels. These scenarios range from a relatively conservative case (Scenario 3) which assumes that energy-efficient federal purchasing increases gradually, from a 20% (pre-program) base case today to 80% penetration by 2010, to a "Maximum Technical Potential" case, in which all federal purchases beginning immediately, are assumed to reflect the "best-available" level of efficiency identified in the FEMP purchasing recommendations. For all the scenarios we assume that, while most federal purchasers will buy a "base case" product (i.e., low first-cost and relatively inefficient), an average of 20% of all federal purchases already represent the more efficient models that meet FEMP recommendations. This is the baseline from which future savings are calculated.

Estimated annual savings in 2010 for the twenty-one products together range from 8.2 to 30.8 TBtu (site energy)[1] for the four scenarios, with corresponding energy cost savings of $119-426 million/year and reduced CO_2 emissions of about 0.3-1.2 million tons of carbon per year (Tables 8-10 and Figures 10-12). These savings amount to 2-9 % of annual energy use in federal buildings, and 3-12% of annual energy costs. They also represent between 6% and 21% of the additional savings that federal agencies need to achieve, to meet the goals for 2010 set forth in Executive Order 13123. Purchases of energy-efficient fluorescent lighting products alone account for about one-third of the site energy savings in 2010.

There are several important considerations in interpreting these results:

- The actual number of products purchased for use in federal facilities is itself uncertain, based on estimated equipment stock turnover rather than actual reported data on federal purchases.
- The savings reflect all new equipment purchases and replacement, as well as equipment installed during construction, renovation, and other capital projects in federal facilities,

[1]Unless otherwise noted, for consistency with current practice by FEMP and other US government agencies, energy consumption is reported in this paper in English rather than SI units (1 Btu = 1055 j.) and electricity is reported as end-use (site) energy at 3413 Btu/kWh.

including projects financed by utilities and energy services companies (ESCOs).[2]

- These savings represent only direct impacts within the federal sector. We believe that the FEMP program also produces important indirect (positive) impacts due to the "market-pull" effect of federal purchasing, since the federal government is the world's single largest purchaser of energy-using equipment.
- Interactions among some products and end-uses can affect the savings. For example, energy-efficient lighting lowers space cooling energy use and thus reduces savings from efficient air conditioners. Efficient lighting can also increase heating energy use and thus increase the savings from efficient boilers.
- We have not considered early replacement of products, which in some cases would be warranted by the significant savings to be achieved, and often occur as part of lighting retrofits and other federal projects.
- Finally, the estimated savings do not account for a significant number of energy-using products purchased for use in federal facilities that are not yet covered by FEMP efficiency recommendations and not included in this analysis.

In spite of these limitations, it is clear that the FEMP program for energy-efficient federal purchasing offers significant opportunities for energy and cost savings, and that the PEERs can make an important contribution to the federal goals for energy savings and reduced carbon emissions, as well as encourage cost-effective purchasing practices by others who may follow the government's lead.

[2]Despite the growth in utility and ESCO funded capital projects, these sources combined with construction and renovation still represent a small fraction of overall federal purchasing for most types of energy-using equipment.

BACKGROUND AND PURPOSE

The DOE Federal Energy Management Program (FEMP) issues Product Energy Efficiency Recommendations (PEERs) to assist federal agencies in complying with the requirements of the Energy Policy Act of 1992 (EPACT) and Executive Order 13123 (Clinton 1999). The Executive Order directs all federal agencies to buy ENERGY STAR® labeled products, or products in the upper quartile of the market with respect to energy efficiency, based on FEMP-designated performance criteria. A further goal of EPACT and the Executive Order is to use the buying power of the federal government to help "pull" the overall commercial market towards greater efficiency. The FEMP efficiency recommendations, distributed by DOE in both hard-copy form and on-line (DOE 1999a, www.eren.doe.gov/femp/procurement) help implement these goals by providing federal purchasers (and others) with technical guidance on efficiency levels for selected energy-using products, consistent with requirements of the Executive Order.

With a growing number of FEMP efficiency recommendations for the purchase of energy-efficient products, there is a need for a quantitative assessment of the energy, economic, and environmental savings expected to result from federal buyers adopting the FEMP efficiency recommendations in their day-to-day purchasing, as well as in construction and other contract specifications. This analysis can provide valuable guidance for targeting future procurement activities as well as planning related FEMP projects. This report represents a first step toward an improved understanding of how energy-efficient purchasing, in combination with other policies and programs, can promote cost-effective investments in energy efficiency in both the federal and non-federal sectors.

This report includes estimated savings for twenty-one specific products for which FEMP efficiency recommendations had been issued as of June 1999. These include:

- five types of residential equipment: central air conditioners, air source heat pumps, residential furnaces, electric water heaters, gas water heaters;
- four residential appliances: room air conditioners, refrigerators, dishwashers, and clotheswashers;
- five lighting products: fluorescent lamps, ballasts, and luminaires; exit signs; and compact fluorescent lamps;
- office equipment: computers, monitors, printers, copiers, and fax machines; and
- two water-saving products: showerheads and faucets.

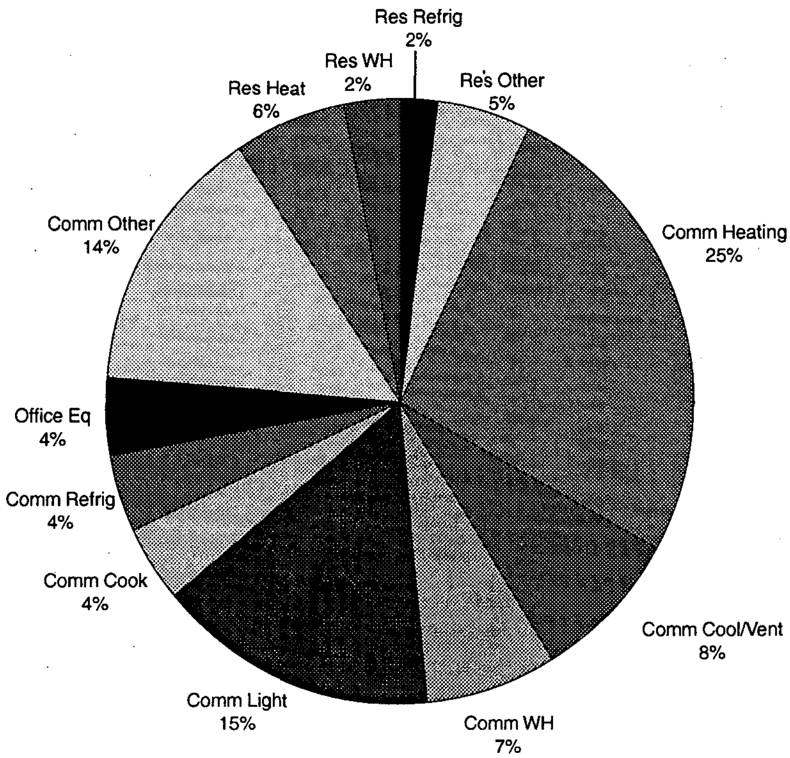
The five product groups covered in this analysis address end-uses accounting for about one-third of federal energy use in buildings. As **Figure 1** shows, commercial lighting accounts for 15% of federal building energy consumption, office equipment for 4%, and the residential products (except "other") for 14%. Note that, absent a detailed analysis of energy by end-use in federal buildings, these estimated end-use shares were themselves derived from an end-use breakdown for the total US building stock that is statistically inferred rather than measured. Also, there are a number of other energy-using products in each group that were not covered by the PEERs and are not analyzed here.

The following sections provide details on the data, assumptions, and methodology used to model, on a product-by-product basis, the expected impacts of the energy-efficient federal purchasing program. We then summarize the results in terms of estimated energy and cost savings as of 2010, and offer some general conclusions about the contribution of the FEMP program to energy-efficient federal purchasing.

FEDERAL SECTOR CHARACTERISTICS

In this section, we characterize the federal sector building and equipment stock, including the data and assumptions used to estimate savings. We adopted a product-by-product approach, as opposed to calculating savings by end-use categories. We therefore needed to quantify the savings accruing to annual purchases of each product, based on the purchase volume and main energy-related characteristics (average capacity, usage patterns, etc.). In order to quantify the expected savings, we had to determine a baseline level of energy consumption for each product and then consider various levels of expected compliance with the FEMP efficiency recommendations. Data on compliance are difficult and expensive to gather; there are few detailed reports of who buys which products and in what volume. The shortage of data has been exacerbated by recent policy changes favoring decentralized decision-making, purchases from commercial sources in addition to the federal supply agencies, and the increased use of government-issued credit cards. Consequently, we had to rely on relatively aggregate data and assumptions concerning the federal building stock, appliance and equipment saturations, and average lifetime and turnover rates for each product.

Figure 1: End-Use Shares in Federal Buildings (Site Energy)
Source: LBNL estimates based on CBECS 1995, RECS, 1993



Data Types and Sources

Four main types of data were required for the analysis: building and equipment stocks, purchasing volume, and per-unit energy consumption. The building and equipment stock data were used to model equipment stock turnover, which is in turn the basis for estimating annual replacement purchases for normal product turnover each year. Detailed data on purchase volume for federal agencies were generally not available, although in some cases aggregate dollar amounts were available, from which we could estimate the number of products purchased. For the most part, however, annual product purchases were inferred from equipment stock turnover plus net changes in building floorspace. In terms of federal buyers, there is an important distinction between defense and civilian sectors; calculations were made separately where the data permitted. Energy consumption data included the estimated energy use for each product, or Unit Energy Consumption (UEC), based on the cost-effectiveness examples in each FEMP product energy efficiency recommendation (PEER).

The Current Federal Building Stock

Table 1 provides a summary of the federal building stock by building type, agency, and location for FY1996. Total federal floorspace as of FY1996 was approximately 3.6 billion square feet, with over 90% of this space government-owned and the remainder leased. About 22% of the total floorspace is residential; 21% is office space (see **Figure 2**). Of the office space alone, about 18% is leased – although this analysis did not distinguish between energy savings potential in owned and leased space.

For purposes of this analysis, we grouped the remaining federal building types into a single category labeled "other." This grouping is based on the fact that the most important distinction for this analysis is between offices and all other facilities, since lighting and office equipment are far more prevalent in office space. We use different equipment saturations and UEC assumptions for office and "other" as appropriate, and as the data allowed.

About 90% of the federal building stock is located in the U.S., with overseas facilities consisting mainly of military installations and Department of State facilities in both U.S. territories and foreign countries. Overall, the Department of Defense (DOD) accounts for about 2/3 of total federal floor area. Civilian agencies predominate in a few categories, notably office space, where they represent about 72% of the total. Although

Table 1: 1996 Federal Building Stock by Type, Agency, and Location (Million sq. ft.)

	United States			Overseas			Worldwide		
	DOD	Civilian	Total	DOD	Civilian	Total	DOD	Civilian	Total
All Buildings	**2043**	**1164**	**3207**	**290**	**63**	**353**	**2333**	**1227**	**3560**
Residential	642	54	696	91	3	94	733	57	790
Office	188	513	701	27	28	55	215	541	756
Other	1213	597	1810	172	32	205	1385	630	2015

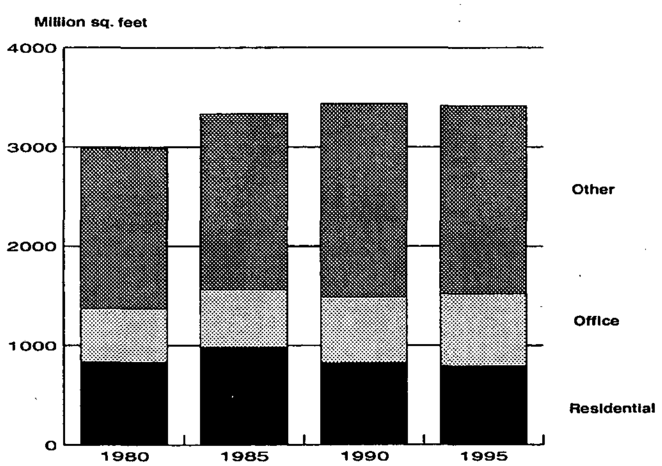
Sources: GSA 1998a and US DOD 1997.

Note: These floorspace totals for 1996 differ slightly from those shown in the FEMP Annual Report (DOE 1998b) but we used them for analysis purposes because of the more detailed breakdown by building type.

records of the General Services Administration (GSA 1998a) do not include all data for the overseas portion of DOD building stock, we have estimated it from DOD data (US DOD 1997).

Federal residential buildings can be further broken out into three main types: civilian housing, military family housing, and military housing for unaccompanied personnel (troop housing). As of FY1996, there were approximately 35,000 civilian housing units (US DOD1997, GSA 1998a), 325,000 family housing units (Morey 1997), and 357,000 troop housing units worldwide (DMDC 1997). The number of unaccompanied personnel living in troop housing was approximately 590,000 (US DOD 1997) for an average occupancy of 1.65 persons/unit. Troop housing units can be further categorized based on the type of unit and geographical location. Many troop housing units are 2, 3, or 4 bedroom suites in multi-family buildings; many also include a small kitchenette. About 80% of troop housing units are located in the U.S.

Figure 2: Federal Building Stock by Type, Selected Years



Historical Changes in the Federal Building Stock

Historical changes in the federal building stock are important determinants of future equipment stock and energy consumption, due to the replacement demand and the effect of retirements on average efficiency of the equipment stock. For long-lifetime products, the difference between the efficiency of new products and those in the stock can be significant. Most of the products purchased between now and 2010 will in fact be used as replacements for the stock currently in place. We compiled and/or estimated historical data on the building stock, with particular attention to residential buildings since many residential appliances and equipment are relatively long-lived (compared with office equipment, for example). Figure 2 shows trends in federal building floor area for selected years for the three main building types: residential, office, and other. By 1995, residential space had shrunk by a third from its 1985 peak, mainly as a result of military downsizing and overseas troop withdrawals. Office space increased by about 25% from 1985 to 1995, while other building floorspace has increased modestly. The total stock of federal non-residential buildings is likely to be fairly constant in the future after accounting for DOD downsizing, although there will continue to be conversions and renovations that change the average efficiency of equipment in place as a result of pre-failure replacement (before the end of the product's useful life).

For the residential stock, the more significant figure is the number of housing units, rather than floor area, since residential equipment and appliances are generally determined on a per household basis. **Figures 3** and **4** show the historical trends in military family and troop housing stocks, with troop housing given in number of persons housed. As shown in the graphs, troop housing has fluctuated considerably with wartime needs, reaching peaks during the Korea and Vietnam conflicts. Family housing is somewhat more stable, but has declined since 1990 in response to changing military needs associated with political changes in Eastern Europe and the former Soviet Union. It is also important to note that most active-duty military families do not live in DOD family housing, but often choose to rent or buy in the private sector. The share of active-duty military families in DOD family housing has tended towards 30-35% in recent years (US CBO 1993). As the aging building stock is renovated or replaced, this figure could increase as DOD family housing becomes more attractive, or decrease with an accelerated effort by DOD to privatize housing ownership and operation. Changes in the proportion of military personnel who are married and in the number of military couples will also affect the demand for family housing.

Figure 3: U.S. Military Family Housing Stock, 1950-1996

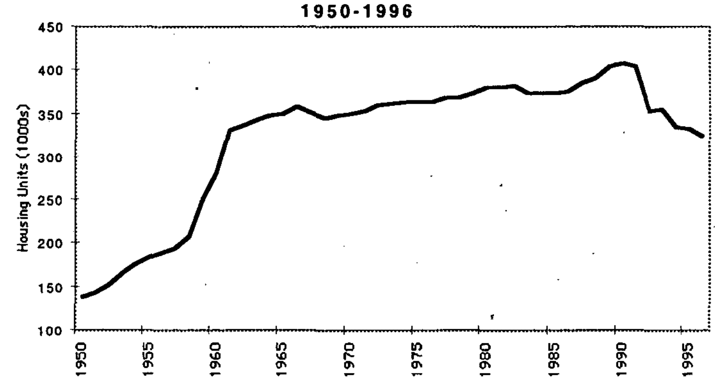
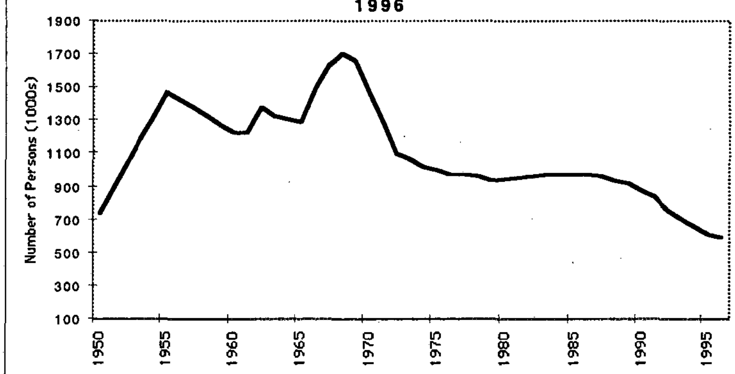


Figure 4: U.S. Military Troop Housing Stock, 1950-1996



Federal Market

The federal market for energy-related products is estimated at roughly $12 billion annually, of which about $4 billion, or 25%, are building-related equipment purchases (Casey-McCabe 1995). Of this $4 billion, approximately 10% is for lighting equipment, 30% for office equipment, 15% for residential and commercial appliances, 25% for heating and cooling equipment, and the remaining 20% for building materials and miscellaneous products. Such estimates are highly uncertain, however, because there is no comprehensive tracking system for federal purchases. We could not use data from the Federal Acquisition Data Center to directly estimate the annual demand for each product of interest, because purchases under $25,000 are not reported at all, and transactions over this amount are recorded only as aggregate dollar amounts. However, in some cases we did use these data as a rough check on estimates derived from new construction and and equipment stock turnover. Energy-using equipment is purchased both by government agencies themselves and also indirectly, by federal construction and maintenance contractors and energy service providers. Finally, there is energy use associated with services and leased equipment (e.g., photocopy services paid on a per-copy basis). Although more difficult to track, it is possible that federal contract services and leased equipment could also be influenced by the FEMP recommended energy efficiency guidelines, but we generally did not attempt to estimate these effects.

The federal market can also be characterized in terms of its share of the overall U.S. commercial market; this relationship differs for each product. Where federal purchasing is a larger share of the overall market, government purchasing policies can create a stronger "market-pull" on manufacturers and distributors as well as influencing non-federal buyers. Rough estimates of the federal market share for some products can be found by comparing government and commercial purchasing data (DOC 1997, GSA-CD 1997, DLA 1997). In general, although the federal government is often the largest single customer for any product, the federal market share is only about 1% of national sales for most residential products. However, one product type, compact refrigerators, has a much higher share, about 5%. The federal market share is also higher for lighting and office equipment, around 3-5%. These ratios reflect the federal shares of total floor area for corresponding building types: federal buildings account for about 6-7% of all office buildings, 4-5% of "other" buildings, and less than 1% of residential housing units (GSA 1998a, DOE 1997).

The federal market can also be characterized in terms of the supply source, i.e., products obtained through the federal supply agencies (GSA and the Defense Logistics Agency, DLA) vs. federal purchasing directly from commercial sources (including contractor purchases). The two federal supply agencies provide a significant fraction of residential appliances, including over 50% of refrigerators and 10-20% of dishwashers and room air conditioners. By comparison, supply agencies provide less than 1% of residential equipment such as central air conditioners (Harrison 1996). Builders and contractors tend to choose heating, cooling, and water heating equipment for federal projects based on standard specifications and their own established relations with distributors. This is logical, since this equipment is fairly bulky, costly to transport, and must be professionally installed.

The supply agencies' share of lighting and office equipment sales is generally higher than for residential appliances and equipment, although with some qualifications. With respect to lighting, approximately 15% of all federal lighting products are supplied through DLA (Ingram 1996). For office technologies, we do not have sufficient data for the government as a whole. Purchasing of computers and communication-related products is highly decentralized for the most part, although GSA maintains a database of products and vendors (Clark 1998). For some office products, such as copiers, GSA has a significant share of the federal market. But copiers are provided through several different channels, including direct purchase, lease-to-buy, rental, and cost-per-copy. GSA also sells Navy shipboard copiers that have distinct characteristics and occupy a special market niche. The general conclusion is that the multiple purchasing paths for a given product are often complex and difficult to quantify with the limited data available.

Products available through the federal supply agencies can differ in both energy and non-energy specifications from those available on the commercial market. In some cases, typical products available through the supply services (especially DLA) are more energy-efficient than those offered on the commercial market as a whole. This is due to an emphasis on life-cycle cost-effectiveness by some of the supply agency acquisition groups and the possibility for volume discounts that reduce the difference in first-cost between inefficient and efficient models. However, we have not tried to model any differences in efficiency between GSA- or DLA-supplied products and those purchased from commercial sources because of limited data and the generally small share of the supply services in the overall federal market.

Product Shares and Densities

We analyzed energy and cost savings for four product groups: Residential Equipment, Residential Appliances, Lighting Technologies, and Office Equipment. In general, unless there were specific data to the contrary, we assumed that federal building characteristics are similar to their residential and non-residential counterparts in the overall U.S. building stock. Market shares for the two commercial sector categories (lighting and office equipment) are expressed as equipment densities per unit of floor area, while the residential product shares are specified as equipment saturations (% of households). The saturations for water-saving technologies were not estimated separately, but were instead based on the water heater saturations in the existing stock. We distinguished between saturations of residential products in new and existing buildings due to the long lifetime of these products and the significant efficiency changes in recent years as a result of federal appliance standards.

Approximately 15% of federal non-residential floor area is in buildings smaller than 10,000 square feet (DOE 1997); we assume that these buildings are likely to have some residential-type heating, cooling, or water heating equipment. For example, government field offices in rural areas will often consist of one- or two-story buildings whose energy equipment and usage profiles are more like residential than non-residential buildings. For these smaller non-residential buildings, we assumed that 50% of the office buildings (i.e., 7.5% of total federal office building space) and 25% of the other buildings (i.e., 3.75% of other federal building space) had equipment saturations similar to residences, based on an assumed 1500 square feet per "equivalent residential unit." The remaining small office and "other" buildings were treated like the other commercial buildings, with some further qualifications as discussed below. The above assumptions generally resulted in only minor additions to the total stock of residential products, except for refrigerators, which are quite common in office buildings and other non-residential buildings of all sizes.

Residential Equipment

Gas furnaces, central air conditioners, (air-source) heat pumps, and electric or gas storage water heaters are commonly used in federal residential buildings. **Table 2** shows the saturations for existing and new single-family housing and DOD troop housing. Single-family housing includes housing for active-duty military families as well as all civilian housing (park rangers, etc.). Saturations of residential equipment are low in troop housing because many of these are in large multi-family buildings with central space conditioning and water heating. We based the saturations (market shares) from the 1993 Residential Energy Consumption Survey, RECS (DOE 1995a, 1995b), the 1995 Commercial Building Energy Consumption Survey, CBECS (DOE 1997), and the Department of Interior residential database for the civilian sector (DOI 1997). We also assumed five water heaters per 100,000 square feet for office buildings and two per 100,000 square feet for other buildings. These values are then multiplied by the technology and fuel shares, based on estimated saturations of residential style water heaters in commercial buildings (Sezgen and Koomey 1995).

Residential Appliances

Table 3 shows residential appliance saturations for existing and new housing units, again for both single-family and DOD troop housing, along with assumptions for the density of residential appliances in commercial buildings. New-building saturations are based on the RECS data for homes built after 1980. Estimates for troop housing are based on common kitchens and laundry areas, which generally support 10-20 persons. The ongoing program of renovation and upgrading in troop housing results in new-unit saturations that up to twice as high as appliance saturations in the overall federal stock (Dickerson 1996). We also made assumptions about appliance densities in non-residential buildings based on federal property inventory data (Dixon et al. 1992).

Lighting Technologies

The installed stock and usage estimates were based on the lighting equipment densities and usage from the XENERGY commercial buildings database (XENERGY 1995 and Fisher 1999). These had to be mapped from the commercial building categories to the federal building categories; for this purpose we adopted the assumptions given in **Table 4.**

The importance of lighting energy use and savings, and the need to account for both replacement of light fixtures (luminaires) and of individual components (lamps, ballasts) called for some additional analysis beyond that applied to other product groups. We compared the estimated lighting usage assumptions in the PEERs with other sources. For linear (tube-type) fluorescent lighting, annual usage assumed in calculating cost-effectiveness for the PEERs was 3600 hours, which was very close to other estimates of 3664 hours for offices and 3881 for "other" (Fisher 1999). We ignored the modest use of linear fluorescents in federal single-family residences, but did consider fluorescent lighting in troop housing.

Usage assumptions are especially important with respect to the potential for replacing incandescent light bulbs with compact fluorescent lamps (CFLs), since energy and cost savings (and CFL lifetime) depend critically on the annual hours of use. We created five usage

Table 2: Residential Equipment Product Saturations and Densities in 1996

	Stock Residential Saturations (% of housing units)		New Residential Saturations (% of housing units)		Non-residential Product Densities (per 100,000 sq.ft.)*	
Product	Single Family Housing	Troop Housing	Single Family Housing	Troop Housing	Office Buildings	Other Buildings
Central Air Conditioners	43%	2%	67%	3%	-	-
Gas Furnaces	63%	2%	79%	3%	-	-
Electric Water Heaters	36%	2%	33%	1%	5	2
Gas Water Heaters	64%	2%	67%	3%	5	2
Heat Pumps	10%	1%	19%	1%	-	-

Sources: calculations based on DOE 1995a,b and DOE 1997

* Excludes small non-residential buildings, where residential-type equipment saturations are assumed based on 1 residence-equivalent per 1500 sq.ft.

Table 3: Residential Appliance Product Saturations and Densities in 1996

	Stock Residential Saturations (% of housing units)		New Residential Saturations (% of housing units)		Non-residential Product Densities (per 100,000 sq.ft.)	
Product	Single Family Housing	Troop Housing	Single Family Housing	Troop Housing	Office Buildings	Other Buildings
Compact Refrigerators	0%	60%	0%	50%	2	2
Standard Refrigerators	120%	36%	115%	42%	10	2
Room Air Conditioners	17%	2%	1%	0%	-	-
Dishwashers	58%	10%	85%	11%	2	1
Clothes Washer	94%	13%	97%	14%	-	2

Sources: LBNL calculations based on DOE 1995a,b and DOE 1997

categories, based on the corresponding assumptions in the PEER and the significant difference in usage patterns between commercial and residential lighting. Low usage (500 hours) and moderate usage (1200 hours) are common in residential settings, although they are also found in some commercial settings, such as task lighting. High (2000 hours) and "very high" usage (3333 hours) tend to be found in commercial buildings. Constant usage (8760 hours) is common in buildings that need to operate 24 hours per day, such as hospitals and prisons. We converted single-family residential usage data (Wenzel et al 1997) to these usage categories. We did not have applicable data on usage categories for commercial buildings, so we developed separate estimates, for offices and "other" buildings, of lighting densities for each usage category. We first assumed a fraction of light bulb sockets that were in constant use (ranging from 20% for schools to 50% for hospitals and prisons), then assigned equal shares to the remaining (low, moderate, high, and very-high use) categories.

Lighting density and usage assumptions are summarized in **Table 5.** Note that we have not considered exterior applications, such as parking garages or outdoor facilities. It is also important to note that there are other types of lighting technologies not considered here (e.g., commercial down-lights and industrial high-intensity discharge lamps). The same is true for lighting controls, which add could add to energy savings but would also affect the baseline energy consumption and estimated

Table 4: Mapping of XENERGY/LBNL Building Types to Federal Building Types to Estimate Lighting Densities and Usage

Federal Building type	XENERGY/LBNL constituent building types
Office	Average of Small Office and Large Office
Hospital	Health
Prison	Average of Health and Lodging
School	Average of College and School
Other Institutional	Average of Small Office and Large Office
Single Family Housing	not applicable (1)
Troop Housing	Lodging
Storage	Warehouse
Industrial	Industry
Service	Average of Grocery, Restaurant, and Retail
Research & Development	Average of Industry, Small Office and Large Office
Miscellaneous	Average of all building types

(1) Sources: XENERGY 1995 and Wenzel et al. 1997

Table 5: Lighting Equipment Usage and Densities

Product	Usage (hours/year)	Density (products/1000sq ft.) by Building Type: Offices	Other	Single-Family Housing*	Troop Housing
Fluorescent Systems					
Lamps	3600	29.8	17.8	0.0	7.9
Ballasts	3600	23.6	14.2	0.0	6.2
Fixtures	3600	10.8	7.1	0.0	3.6
Exit Signs	8760	0.6	0.5	0.0	0.3
Incandescents to CFLs					
Low Use	500	0.6	0.5	11.7	11.1
Medium Use	1200	0.6	0.5	1.9	1.8
High Use	2000	0.6	0.5	0.9	0.9
Extra High Use	3333	0.6	0.5	0.3	0.3
Constant Use	8760	0.8	0.8	0.1	0.1

Sources: XENERGY 1995 and Wenzel et al. 1997

* Assuming 1500 sq.ft. per single-family housing unit (DOD and civilian).

savings from lamps, ballasts, and fixtures. Finally, this study does not address the interactions between lighting and other end-uses (e.g. heating and cooling) that can affect overall energy use and savings (Sezgen and Koomey 1998).

Office Technologies

We used estimated office equipment density estimates from a recent study (Koomey et al. 1995a) to determine the number of units installed in federal office and "other" buildings; the results are shown in **Table 6.** We have not considered office equipment in federally owned residential settings, since such equipment is generally purchased by individuals rather than the government. It should be noted, however, that there may be an indirect effect of the FEMP (and ENERGY STAR®) criteria, since individuals buying computers or other equipment for home use might seek a model similar to what they use at the office.

Table 6: Office Technology Densities (products per 1000 square feet)

Product	Building Type: Offices	Other
Monitors	2.53	0.34
CPUs	2.36	0.21
Laser Printers	1.09	0.17
Copiers	0.19	0.06
Fax Machines	0.44	0.09

Source: Koomey et al. 1995a

Water-Saving Technologies

Water-Saving Technologies

Rather than accounting for the stock of showerheads and faucets directly, we assume that, on average, faucets and showerheads are replaced at the same frequency as electric and gas water heaters. This ignores small differences in the turnover rates of plumbing fixtures vs. water heaters, as well as hot water savings from products used with other water heating fuels (e.g., oil fired boilers or central steam systems). For buildings with centrally-supplied hot water, which serves about one-third of all federal residential facilities, the savings from faucets and showerheads are difficult to estimate due to distribution system losses. Also, we did not have adequate data on the fuel source of central hot water systems in troop housing. As a result, hot water energy savings due to lower-flow plumbing fixtures are probably conservative.

METHODOLOGY FOR ESTIMATING SAVINGS

Since the FEMP purchasing recommendations are targeted to specific products, we developed a consistent methodology to assess impacts on a product-by-product basis. A spreadsheet model of the federal building and equipment stock was used to estimate purchases related to stock turnover and new additions for each product, from 1996-2010. Several assumptions were adopted for baseline trends in the energy efficiency of new purchases, for each product covered by a FEMP efficiency recommendation. We then developed four scenarios to describe the range of possible impacts that could result from federal agency use of the FEMP energy-efficient purchasing recommendations, as described below.

Modeling Framework

The modeling framework for savings estimates was implemented using two Excel workbooks, as depicted in **Figure 5.** The first workbook, FEDSTOCK, includes nine spreadsheets with calculations that estimate the number of units purchased annually for each product. The GSABldgStock worksheet takes federal building stock data as input and gives the historical and projected building stock, along with net additions, for the three building types modeled – residential, office, and other. ResBldgStock adds floor area and other details needed to further characterize the residential stock, including military family housing, troop housing, and civilian sector housing. ResEquip includes details on historical and projected equipment saturations, which ResPurch uses to determine the annual purchases for residential equipment and appliances. LightSys takes as input lighting equipment densities and usage, and maps them from the commercial building types to the federal building types. Light1996 maps the equipment densities and usage to installed product densities and usage, and calculates the base year turnover and replacement. LightPurch determines the annual number of purchases for the five lighting products. OfficeDensity includes historical and projected product densities, which OfficePurch uses to calculate the annual number of purchases for the five office technologies.

The outputs from the FEDStock workbook are the annual number of purchases and the annual number of products in the stock. This information is transferred to the AnnPurch spreadsheet in the PEERSAVE workbook. The other external inputs to PEERSAVE are the unit energy and cost savings for each product based on the assumptions in the FEMP product energy efficiency recommendations (PEERs). Three spreadsheets show the savings parameters for all the products: (1) BaseShare, with savings estimates in future years relative to the base year, (2) Eligibility, which shows the share of products eligible for replacement through the PEERs;, and (3) ProgPen with assumed program penetration rates over time. There are five spreadsheets for calculating savings by product group; the Residential Equipment group is split into two spreadsheets for gas and electricity savings. Finally, there is a summary spreadsheet for all products, with summary graphics for savings in the target year of 2010.

Time Frame

The analysis covers the period from 1996 to 2010. Projected energy savings start in 1998 for all products except CFLs. Because the CFL recommendation came out in 1999, we have started the savings estimates in 1999. The analysis goes out to 2010, which corresponds to a target year for federal energy savings of 35% in building energy intensities, compared with 1985 levels (Clinton 1999). For many of the products we analyze, a substantial fraction of today's stock will have been replaced by 2010, although annual savings would continue to increase beyond 2010, along with the assumed growth in program penetration rates. Extension of the analysis beyond 2010 would be straightforward, but the assumptions regarding changes in efficiency and technologies would be more speculative over a longer time frame.

Building and Equipment Stock Forecast

We used historical data on the federal building stock to develop an equipment stock turnover model for each product. Based on the product's average equipment life we calculated moving averages to estimate replacement demand in each forecast year. Net additions were interpreted as the sum of New Construction, Renovations, Refurbishments, and New Leases, minus Demolition and Expired Leases. For family housing, new construction projections (1997-2005) were used to add the demand in new buildings to the replacement demand to arrive at the total annual sales figures. For troop housing, information on new construction was used to adjust equipment saturations in future years, rather than attempting to separately account for new construction. For the non-residential forecast, we assumed that federal sector new construction would be 1.25%/year, or one-half the rate of growth in the commercial sector as a whole as forecasted by the DOE Energy Information Administration (EIA 1998). Renovation and refurbishment were assumed at the rate of 3.2% of the stock, and demolition at 1.22% per year based on the same EIA forecast (DOE 1998).

Military housing has been undergoing a significant amount of replacement and renovation in recent years, as DOD emphasizes housing upgrades and modernization to encourage volunteer enlistment and retention. Approximately one-third of all military construction funds during 1995-97 were spent on troop housing (DOD 1997). For unaccompanied personnel there has been a trend towards converting single units into multi-room suites. This trend is expected to continue in the foreseeable future, with resulting impacts on appliance types, saturations, and energy consumption (Dickerson

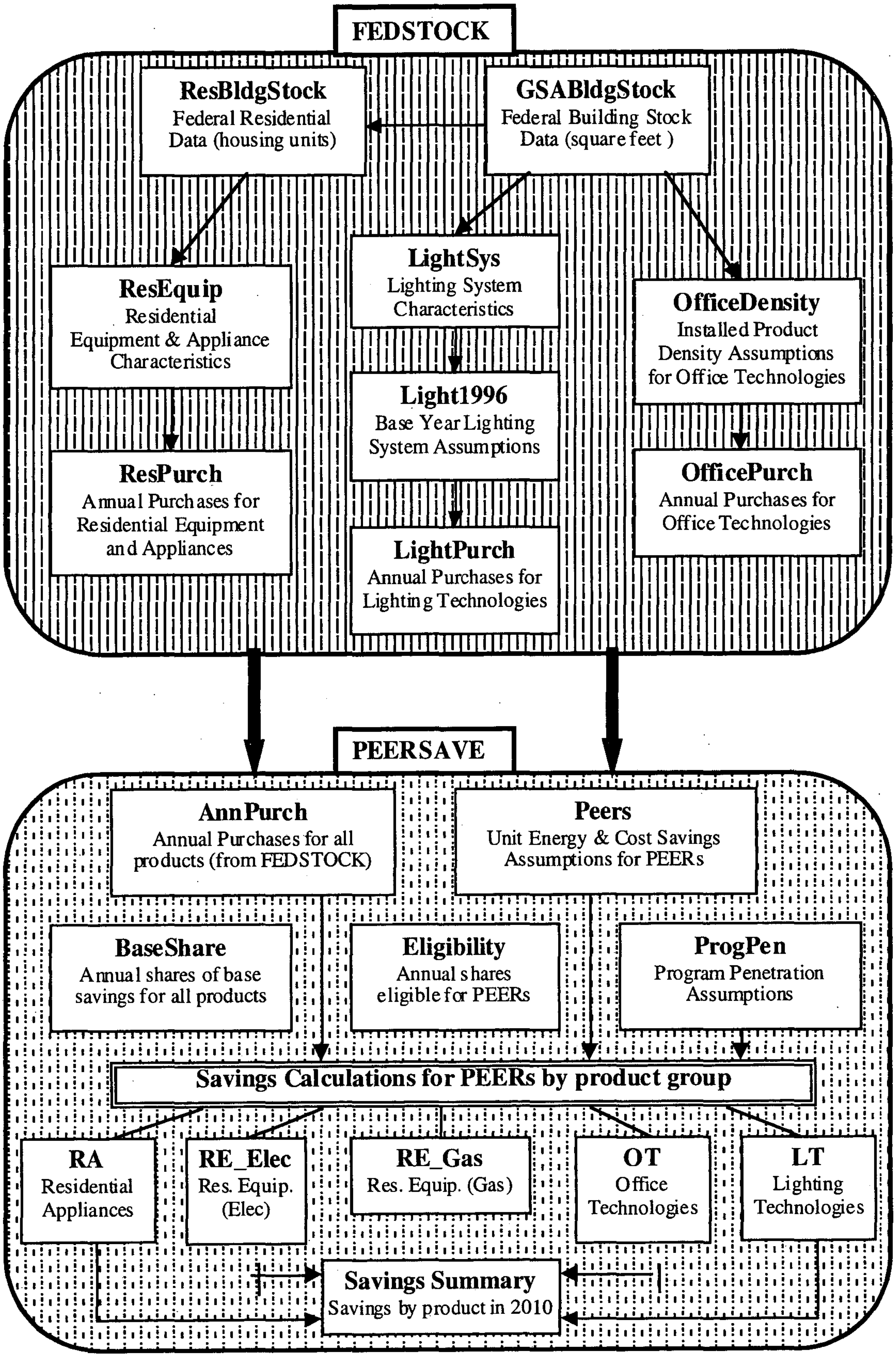


Figure 5: Modeling Framework for PEER Savings Estimates

1996). We have tried to reflect these trends in the stock turnover models used for this analysis.

Figures 6-9 show the estimates of annual units purchased by federal agencies for each of the four product groups over the period 1996 - 2010. In the case of residential equipment, purchasing volume is fairly stable, due to the longer product lifetimes and the expectation of continuing upgrades in military housing. Annual sales of gas furnaces and central air conditioners vary together because this is by far the most common configuration in military family housing. Sales of some residential appliances, such as compact refrigerators, are expected to decline significantly because of the changes in the troop housing stock mentioned above. Lighting equipment sales are relatively constant because we have assumed no changes in product density. Office equipment sales are generally increasing because the office product densities are expected to increase (Koomey et al 1995).

Economic Assumptions

Assumptions regarding costs and financial parameters are generally consistent with those presented in the PEERs themselves. We used average federal energy prices for FY 1996: $0.06/kWh for electricity and $0.40/therm for natural gas. We did not apply any energy price escalation factors, nor discount future savings to present value. For those products that use both gas and electricity (e.g. clothes washers and dishwashers), we calculated the energy costs separately for each fuel and then added the two costs to determine the annual cost savings.

Scenarios for Estimating Savings

Assumptions concerning three characteristics were used in defining the scenarios: eligibility, efficiency level, and program penetration rate. Eligibility refers to the share of products that are technically feasible (or compatible) for replacement. Efficiency level is either Recommended or Best Available (or an average of the two), as defined in the FEMP product energy efficiency recommendations (PEERs). Program penetration, ranging from 0% to 100%, refers to the proportion of federal purchases in a

Figure 6: Residential Appliance Purchases

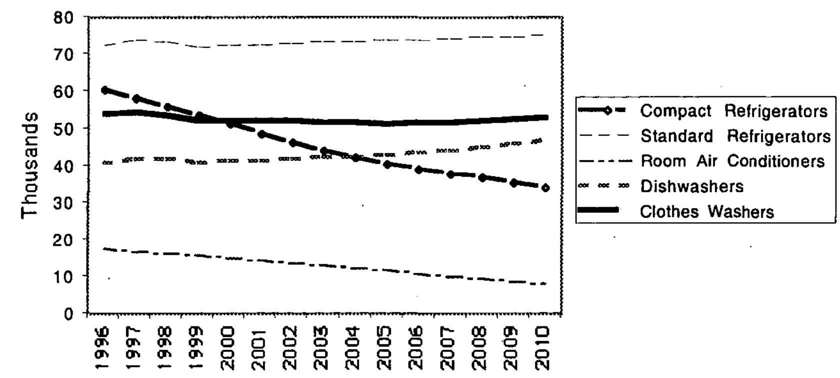


Figure 7: Residential Equipment Purchases

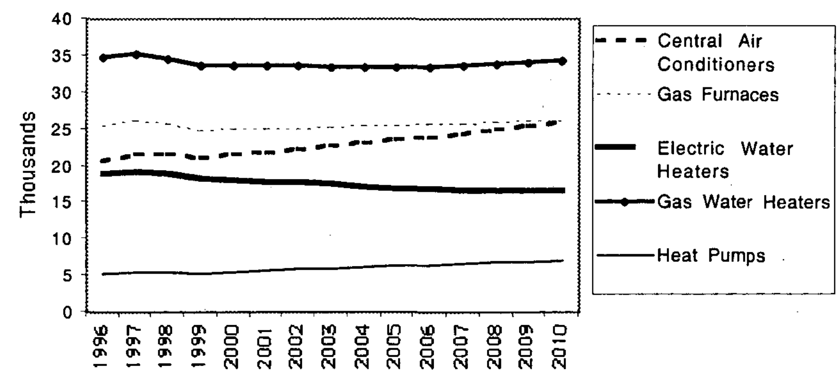


Figure 8: Office Technology Purchases

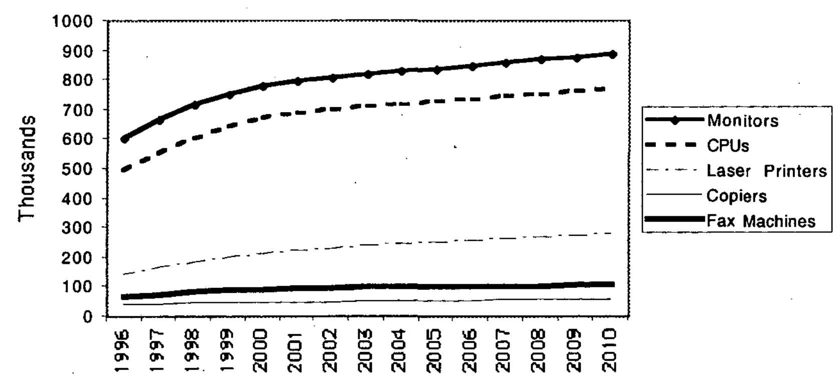
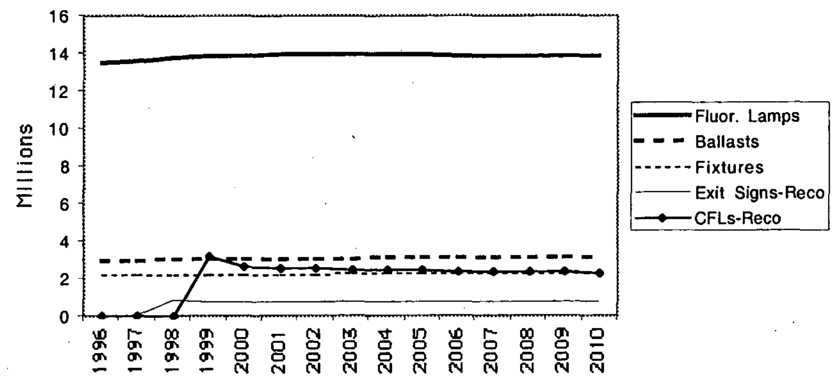


Figure 9: Lighting Technology Purchases



given year expected to adhere to the FEMP recommendations for energy-efficient purchasing. Non-participants (i.e., 100% minus the program penetration) are assumed to purchase baseline models. However, even in the absence of the program, we assume that under a business-as-usual case 20% of federal purchasers would continue to buy more efficient products, with average efficiencies equal to the FEMP "Recommended" levels. For each scenario, savings are estimated in comparison with this business-as-usual base case. The purpose of using these different scenarios is to better illustrate the range of possible futures in terms of what federal agencies actually do to implement the the FEMP purchasing recommendations and the provisions of Executive Order 13123.

We did not explicitly increase future efficiencies of either the base case or the FEMP Recommended (or Best Available) products between now and 2010. The implicit assumption is that if the baseline model does increase in efficiency, due to market forces and/or new DOE efficiency standards, then the FEMP purchasing levels will also be revised so that the net effect on energy savings remains largely unchanged, at least for the next ten years.

We defined four scenarios to express the range of possible impacts:

Scenario #1: Max Tech (Best Available @100% Penetration)

This scenario assumes that today's Best Available efficiency level is chosen for all purchases, beginning immediately. This scenario thus represents an upper bound for potential savings estimates for each product (at least with respect to today's commercially available technologies). In reality, the best available technology is also likely to improve over time, so even the Max- Tech scenario may be a conservative estimate of the theoretical maximum savings.

Scenario #2: Recommended at 100% Penetration

Under this scenario, all federal purchases, beginning immediately, just meet the minimum levels of FEMP Recommended efficiency for each product.

Scenario #3: Recommended at 20-80% Penetration

This scenario recognizes that it may be unrealistic to assume that all federal purchasers will follow the FEMP guidelines and fully comply with the Executive Order, even after allowing sufficient time for FEMP's outreach efforts to reach more agencies and buyers. However, it also makes sense to assume that the program's penetration rate will increase over time. Consequently we assume that the percentage of purchases at the Recommended efficiency levels increase in a linear fashion, from the initial pre-program baseline of 20% to 80% in 2010. In cases where annual purchasing volume remains roughly constant, the average annual compliance rate due to the program, over the 12-year period, is 30% (in addition to the 20% who of federal buyers who were already purchasing, on average, products that meet FEMP's Recommended efficiency levels). This scenario is envisioned as a **realistic lower bound** for the estimated savings, because it couples the lowest FEMP-recommended efficiency level with an average incremental penetration rate of 30% over the next ten years.

Scenario #4: Average (of Recommended, Best Available) at 20-80% Penetration

This fourth scenario recognizes that many buyers may exceed the FEMP recommended efficiency levels, for two reasons. First, it is likely that higher efficiency levels will be cost-effective in some cases. Second, in practice buyers face a limited choice of FEMP-complying models, whether they buy from commercial sources or the federal supply agencies. We assume that the typical purchase in each year has an efficiency level equal to the average of the Recommended and Best Available levels. We use the same assumptions as in the previous scenario regarding penetration rates that ramp up from 20% (baseline) to 80% in 2010. We consider this scenario to represent a **most likely** estimate of program savings.

Energy Savings Assumptions

The annual savings for a given product are based on five parameters: number of units purchased, energy savings per unit, eligibility, and program penetration. These are all linear multipliers:

Annual Savings = Purchases x Unit_Savings
x Eligibility x Penetration

The number of annual purchases is calculated in the FEDSTOCK model as described above. Energy Savings per unit are taken from the cost-effectiveness example in each PEER.[6] The other variables can be easily changed to examine the effects of different scenario assumptions, as discussed briefly below.

Unit Energy Savings and Lifetimes

The FEMP product energy efficiency recommendation (PEER) specifies annual energy use or efficiency for a baseline model, a FEMP-recommended model, and a "Best Available" model for each product category. For each PEER, a separate table on cost-effectiveness shows annual energy use and costs (using average federal prices for fuel or electricity) for a typical usage pattern, as well as the annual and lifetime savings from purchasing either the Recommended or Best Available models instead of a baseline model. These values are summarized in **Table 7,** along with assumed product lifetimes (used in the FEDSTOCK model).

Note that the product groupings are treated somewhat differently here than in the preceding discussions. We have separated the residential gas and electric products, and list water-saving products, dishwashers and clothes washers under both groups. In this way, we account separately for gas and electricity savings, based on the fuel type used to supply hot water. Separating gas and electric products is convenient for allowing price comparisons, carbon savings estimates, and other impacts that differ by fuel. One minor difference in Table 8 from the PEER assumptions is that we have set the water-saving product lifetimes to 13 rather than 10 years, for consistency with water heater lifetimes. The annual savings per unit in Table 7 are used to estimate overall savings, as discussed in the next section.

[6]In other words, we re-interpreted the "typical" value from each PEER as an average savings per unit for all purchases. The choice of this single value to represent savings per unit for all purchases, while useful as a simplifying assumption, may not reflect the actual average across all the products purchased, especially for larger equipment such as boilers or chillers. However, we used our best judgment in re-interpreting typical values as average values for each product, and consider this a reasonable solution in practice – absent detailed data on the characteristics of actual federal purchases, or sufficiently detailed end-use energy data to calibrate these numbers to energy use per unit in the existing stock.

Eligibility

The share of purchases and/or the share of savings that are eligible for application of the PEERs is defined as the eligibility for that product. Technological or market constraints can affect eligibility. For most products, we have assumed 100% eligibility, but there were several exceptions. In the case of water-saving products, we assumed 50% eligibility in order to avoid double-counting energy savings associated with more efficient water heaters. For clothes washers, we adjusted the eligibility factor to 70% to account for the fact that DOD family housing occupants purchase their clothes washers themselves. For ballasts and luminaires, we have set the eligibility at 50% to account for the fact that 50% of the shipments in 1996 were already electronic ballasts (NEMA 1999), most of which probably meet the FEMP Recommended levels. For the "low-use" category of CFLs, we applied an eligibility factor of 50% to account for problems associated with fixture compatibility, light quality, and other market constraints posed by CFL substitution, especially when the usage levels are low. For the other CFL categories, we have assumed 100% eligibility because we assume that, for federal buyers, the economic savings are high enough (along with policy directives) to outweigh the other difficulties.

Penetration

Penetration refers to the share of federal purchases that actually follow the FEMP efficiency recommendations. Starting with a baseline assumption of 20% penetration even in the absence of the program, th assumed penetration rates are 100% in Scenarios #1 (Max Tech) and #2 (Recommended) as defined above. The other two scenarios assume steadily growing penetration rates, from the 20% baseline to 80% over the period 1998-2010. There were three exceptions to this definition in the case of lighting: fluorescent lamp/ballasts/luminaires, exit signs, and CFLs, as discussed below.

Special Assumptions for Non-Residential Lighting

For fluorescent lamps, ballasts, and luminaires in non-residential buildings, we used a special approach to quantify the four scenarios, due to several unique circumstances:

- Double-counting—Lamps and ballasts are purchased individually and also installed as part of a complete luminaire; we wanted to avoid double-counting the savings from improved (T8) lamps and

Table 7: Product Energy and Cost Savings Assumptions

Products by Group	Product Lifetime (years)	Energy Units	Baseline Model: Annual Energy Cost	Baseline Model: Annual Energy Cost[1]	Recommended: Annual Energy Savings	Recommended: Annual Energy Cost Savings	Best Available: Annual Energy Cost	Best Available: Annual Energy Cost Savings
Residential Appliances								
Compact Refrigerator	11	kWh	375	$23	46	$3	105	$6
Standard Refrigerator	19	kWh	732	$44	77	$5	199	$12
Room Air Conditioner	15	kWh	830	$50	80	$5	190	$11
Dishwasher (Elec. WH)	13	kWh	700	$42	81	$5	246	$15
Clothes Washer	13	kWh	880	$53	464	$28	631	$38
Residential Equipment (Elec.)								
Central Air Conditioner	15	kWh	3600	$216	600	$36	1600	$90
Heat Pump (Air Source)	15	kWh	12500	$750	1700	$102	4300	$260
Electric Water Heater	13	kWh	5106	$306	333	$20	484	$29
Water Products (Elec. WH)	13	kWh	3340	$200	308	$18	996	$60
Residential Equipment (Gas)								
Gas Furnace	20	therms	790	$316	105	$42	155	$62
Gas Water Heater	13	therms	283	$113	37	$15	75	$30
Dishwasher (Gas WH)[2]	13	kWh/ therms	233/16	$20	27/2	$2	82/6	$7
Clothes Washer (Gas WH)[2]	13	kWh therms	220/23	$22	116/12	$12	1158/16	$16
Water Products (Gas WH)	13	therms	185	$74	13	$5	39	$14
Office Technologies								
Computer monitor	4	kWh	250	$15	163	$7	201	$12
Personal Computer	4	kWh	185	$11	85	$5	134	$8
Computer Printer	6	kWh	641	$38	362	$21	521	$31
Copier	6	kWh	1532	$92	394	$24	558	$34
Fax Machine	6	kWh	356	$21	42	$2	278	$16
Lighting Technologies								
Fluorescent Tube Lamp (per lamp)	5	kWh	45	$3	11	$1	15	$1
Fluorescent Ballast	15	kWh	206	$12	50	$3	60	$4
Fluorescent Luminaire	15	kWh	407	$24	191	$11	202	$12
Exit Sign (Recomm./Best)	2/10	kWh	350	$21	262	$16	334	$20
CFL-low use, standard life (12yr)	12	kWh	30	$2	22	$1	n/a	n/a
CFL-moderate use, std. life (5yr)	5	kWh	72	$4	52	$3	n/a	n/a
CFLs-high use, extended life (5yr)	5	kWh	120	$7	86	$5	n/a	n/a
CFLs-very high use, ext. use (3yr)	3	kWh	200	$12	143	$10	n/a	n/a

Source: DOE/FEMP 1999, "Buying Energy Efficient Products," with usage differentiation for CFLs (see text)

[1]Costs in 1996 $ based on average federal electricity price of $0.06/kWh and gas price of $0.40 /therm

[2]For clothes washers and dishwashers, direct electricity use and indirect gas use (for hot water) are shown separately.

(electronic) ballasts, and from an entirely new luminaire which includes the same upgraded components. Thus, we separately calculated savings for retrofitted lamps/ballasts and for new or replacement luminaires. (Note that although some of the efficiency gains in a new luminaire come from better lamps and ballasts, as well as improved optics, we allocated all these savings to the luminaire itself rather than its components.)

- Simultaneous change to T8 lamps and electronic ballasts—When an existing luminaire is retrofitted (rewired) to use efficient T8 lamps and electronic ballasts, it is common for both the lamp and ballast to be replaced at the same time to avoid a lamp-ballast mismatch. We assumed that efficiency improvements, from T12 to T8 lamps and from magnetic to electronic ballasts, would occur only as part of a lighting retrofit project—not when failed units were replaced on a one-for-one basis.
- We divided the existing luminaire stock into two segments. The first segment was the portion with T12s and magnetic ballasts, estimated at 2/3 of the stock, or 67%. The second segment consisted of those with T8s and electronic ballasts—about 1/3 of the stock. The first segment underwent luminaire replacement at the normal rate based on their average lifetime of 15 years.
- We then estimated the stock of luminaires that were "eligible" for lamp/ballast retrofit based on the luminaire replacement rate, i.e. by subtracting the newly installed luminaires from the stock. Of this eligible stock, we assumed that 1/15 would be replaced each year in the "Recommended" scenarios (Scenarios 2 and 4). For the Best Available scenarios (Scenarios 1 and 3), we assumed a higher retrofit rate of 1/10 to be replaced each year. These were assumed to be retrofitted each year as a result of lighting upgrades – either budgeted by the agency or financed through ESCO or utility shared-savings contracts. For energy savings from the combined lamp/ballast replacement we drew upon the FEMP Recommendation for efficient ballasts, and used this same source to allocate savings between the two products.

Special Assumptions for CFLs and Exit Signs

We had to make special calculations for both compact fluorescent light bulbs (CFLs) and LED (light-emitting diode) exit signs, due to the significant difference in lifetime for new, efficient products compared to those being replaced. (In the case of LED exit signs, these are assumed to replace older units equipped with incandescent or CFL lamps.) Rather than assuming 100% replacement at the end-of-life, which would result in replacing most of the stock in the first year, we instead assumed that actual conversions would take place gradually. For example, since a moderate-use CFL has the same lifetime as about six incandescent bulbs, we phased in the CFL replacements over a six-year period. We also set the annual penetration rate at 80% of sales for both exit signs and CFLs, beginning in the first year, since the phased replacement already reflects gradual adoption. This approach avoids the unrealistic assumption of overnight replacement and smoothes out energy savings across the time frame under study.

The fact that CFLs were further subdivided according to annual hours of use required some adjustments in the calculation of unit energy savings. First, we assumed that most lighting "sockets" in the constant usage category were already fitted with CFLs, so that no further savings were assumed. This means that our savings estimates are probably conservative. A separate interpretation was required for the Max Tech case, since the FEMP efficiency recommendation for CFLs does not list a Best Available model.[7] For the "100 % Recommended" scenario, federal buyers are assumed to choose CFLs in all but the low usage applications, while the Max Tech case also includes replacement for this low usage category. This interpretation is consistent with the strong relationship between usage and savings for lighting products, depending on the application.

Energy Cost Savings

We translated annual energy savings as of 2010 into energy cost savings using the current (1998) level of average (domestic) electricity and natural gas prices paid by federal agencies: \$0.06/kWh and \$0.40/therm of gas. Both values are expressed in 1996 dollars, with no price escalation for future prices nor any discounting of future costs to present-value. Also, note that the annual cost savings in 2010 (see text below, and Table 9) refer to reductions in energy costs only; they do **not** reflect net savings, after accounting for the added purchase price of more efficient equipment.

Greenhouse Gas (CO_2) Emissions Savings

Reducing emissions of carbon dioxide (CO_2), a greenhouse gas that contributes to climate change, is an important goal for the federal sector (Clinton 1999). There are significant carbon savings attributable to

[7]Today's CFL products have very similar levels of energy efficiency; the main differences are in lifetime, reliability, power quality, and important consumer features such as color temperature and dimmability.

energy-efficient purchasing, corresponding to the reduction in electricity generation and fuel use. To estimate the avoided emissions of greenhouse gases—essentially, CO_2 from combustion of fossil fuel in electric power plants or end-use combustion of natural gas—we used the standard assumptions adopted for analyzing savings from all DOE buildings sector energy efficiency programs (DOE 1999b). This method estimates a single, nationwide average value for CO_2 emissions saved per unit of saved electricity or gas (50.34 x10^3 MTC/TBtu [site] for electricity and 14.40 x10^3 MTC/TBtu for gas). While beyond the scope of this study, a further analysis might refine these estimates by accounting for any differences between federal sources of electricity (by primary fuel used for power generation, perhaps by region) and the national average power generation mix.

RESULTS: ESTIMATES OF EXPECTED SAVINGS

The savings estimates for the four scenarios and each product group are presented in **Tables 8-10** and **Figures 10-12.** Energy savings are in trillions of British Thermal Units (TBtu = 10^{12} Btu) of delivered (site) energy, while cost savings are in millions of 1996 dollars (based on current 1998 average federal energy prices, not discounted). Estimated annual savings are shown for the year 2010. This time frame represents full implementation of the FEMP procurement program, with an opportunity for most or all of the existing equipment stock to be replaced through normal stock turnover. Because some products have a longer average lifetime than 12-13 years, savings will continue accrue beyond 2010. This is also the target year for federal building energy reductions of 35% (compared to 1985 energy intensities), and thus provides a useful point of reference.

Residential Appliances

Estimated annual energy savings in 2010 from federal purchases of efficient residential electric appliances range from 0.2-1.3 TBtu, with cost savings from $4-23 million. Savings for these products are relatively low compared to other product groups, due to a variety of factors: declining federal purchases, lower unit consumption due to federal appliance efficiency standards, and (as a result) FEMP efficiency recommendations that are close to baseline efficiency levels.

Residential Equipment (Electric)

Estimated electricity savings for residential space conditioning and water heating equipment range from 0.5-3.3 TBtu, with annual cost savings ranging from $8-$58 million. Not surprisingly, most of these savings are for efficient central air conditioners (CACs) and heat pumps. In the case of CACs, this is due to the high volume of purchases, while for heat pumps, it is due mainly to large savings per unit.

Residential Equipment (Gas)

Estimated natural gas savings for residential equipment range from 1.9-8.4 TBtu, with annual cost savings from $7-34 million. More than half of these savings are from efficient gas furnaces. The energy savings of this product group are relatively high compared with other residential products, although the cost savings are lower due to the relative prices of natural gas and electricity.

Office Technologies

Savings for office equipment range from 2.7–6.8 TBtu and $47–119 million. Continually rising demand for office products, particularly computers and monitors, results in significant savings.

Lighting Technologies

Lighting offers the largest savings of all product groups, from 3.0-11.0 TBtu/year and $53-193 million/year. This represents over one-third of the energy and cost savings in each scenario, for the selected products we analyzed. As with the other categories, these savings include some impacts of the Federal Relighting Initiative and other programs, as well as from the Energy-Efficient Purchasing Program itself.

Summary

Annual savings estimates for the twenty-one products taken together range from 8.2-30.8 TBtu and $119–426 million/year. To put this in perspective, energy consumption in federal buildings was 360 TBtu (site) in FY1996 and energy costs were about $3.6 billion. Thus the savings amount to 2-9% of the energy used in federal buildings, and 3-12% of federal spending for energy in buildings. Reductions in annual greenhouse gas emissions range from 345 to 1245 x103 MTC, depending on the scenario.

Equally significant, the projected savings from federal purchases of these selected energy-efficient products alone represent 6-21% of the total energy savings that agencies need to achieve between now and 2010, in order to meet the overall savings goal of 35% in federal facilities that was mandated in the 1999 Executive Order.

[8]Note, however, that the cost-effectiveness example in each PEER does show a discounted stream of energy costs and savings, for the lifetime of each new product.

Table 8: Annual Energy Savings in 2010 by Product for 4 Scenarios (Trillion Btu, site)	Scenario 1 Max Tech (Best Available) @100%	Scenario 2 - Recommended @100%	Scenario 3 - Recommended @20-80%	Scenario 4 - Average (Best Avail, Recom) @20-80%
Residential Appliances (Elec.)	**1.3**	**0.5**	**0.2**	**0.4**
Compact Refrigerators	0.1	0.1	0.0	0.0
Standard Refrigerator	0.6	0.2	0.1	0.2
Room Air Conditioners	0.1	0.0	0.0	0.0
Dishwasher	0.2	0.0	0.0	0.0
Clothes Washer	0.3	0.2	0.1	0.1
Residential Equipment (Elec.)	**3.3**	**1.2**	**0.5**	**1.0**
Central Air Conditioners	1.5	0.5	0.2	0.5
Heat Pumps (air-source)	1.1	0.4	0.1	0.3
Electric Water Heaters	0.3	0.2	0.1	0.1
Water Products (Elec. WH)	0.4	0.1	0.0	0.1
Residential Equipment (Gas)	**8.4**	**4.9**	**1.9**	**2.7**
Gas Furnaces	4.4	2.8	1.0	1.5
Gas Water Heaters	2.1	1.3	0.5	0.7
Dishwasher (Gas WH)*	0.3	0.1	0.0	0.1
Clothes Washer (Gas WH)*	0.8	0.6	0.2	0.3
Water Products (Gas WH)	0.8	0.2	0.1	0.2
Office Technologies	**6.8**	**4.2**	**2.7**	**3.5**
Computer monitors	2.0	1.6	1.0	1.2
Personal Computers	1.2	0.7	0.5	0.6
Computer Printers	2.4	1.6	0.9	1.2
Copiers	0.5	0.4	0.2	0.3
Fax Machines	0.6	0.1	0.0	0.2
Lighting Technologies**	**11.0**	**8.3**	**3.0**	**3.9**
Fluorescent Tube Lamps	0.6	0.3	0.1	0.1
Fluorescent Ballasts	1.2	0.7	0.2	0.3
Luminaires	5.8	5.5	1.7	1.7
Exit Signs	1.7	1.1	0.5	0.9
CFLs	1.7	0.8	0.6	1.0
Grand Totals	**30.8**	**19.2**	**8.2**	**11.6**

* Includes only gas savings for reduced hot water use in clothes washers and dishwashers.

** Scenario definitions are different for lighting products – see text.

OTHER ISSUES AND IMPACTS

In developing these savings estimates we had to make a number of assumptions, and some program impacts were not considered due to data limitations or because they were inherently difficult to quantify. While we defined the four savings scenarios using our own judgment, they have some empirical basis in FEMP's feedback to date from federal buyers in other agencies. These and other programmatic issues, as discussed below, would benefit from further study.

Table 9: Annual Energy Cost Savings in 2010 by Product for 4 Scenarios (Million $1996)*

	Scenario 1 Max Tech (Best Available @100%	Scenario 2 - Recommended @100%	Scenario 3 – Recommended @20-80%	Scenario 4 - Average (Best Avail,Recom) @20-80%
Residential Appliances (Elec.)	**22.7**	**9.5**	**3.6**	**6.9**
Compact Refrigerators	2.6	1.0	0.4	0.8
Standard Refrigerator	10.5	3.5	1.3	3.1
Room Air Conditioners	1.7	0.6	0.2	0.4
Dishwasher	2.6	0.7	0.3	0.8
Clothes Washer	5.3	3.6	1.3	1.8
Residential Equipment (Elec.)	**57.9**	**20.5**	**7.9**	**17.4**
Central Air Conditioners	26.7	8.7	3.4	8.0
Heat Pumps (air-source)	19.1	6.5	2.6	5.8
Electric Water Heaters	5.7	3.6	1.3	1.8
Water Products (Elec. WH)	6.4	1.7	0.6	1.8
Residential Equipment (Gas)	**33.7**	**19.7**	**7.4**	**11.0**
Gas Furnaces	17.7	11.1	4.2	5.9
Gas Water Heaters	8.5	5.1	1.9	2.8
Dishwasher (Gas WH)**	1.1	0.3	0.1	0.3
Clothes Washer (Gas WH)**	3.3	2.3	0.9	1.1
Water Products (Gas WH)	3.2	0.9	0.3	0.9
Office Technologies	**118.8**	**74.7**	**47.0**	**62.3**
Computer monitors	35.3	27.3	17.9	20.8
Personal Computers	21.2	12.3	8.1	11.3
Computer Printers	42.6	27.5	16.4	21.6
Copiers	9.6	6.3	3.8	4.9
Fax Machines	10.1	1.3	0.8	3.7
Lighting Technologies* **	**193.1**	**146.5**	**52.6**	**69.1**
Fluorescent Tube Lamps	11.1	5.3	1.2	2.3
Fluorescent Ballasts	21.6	12.1	2.8	4.4
Luminaires	101.8	96.2	29.2	30.1
Exit Signs	29.1	18.6	8.7	15.6
CFLs	29.4	14.2	10.6	16.7
Grand Totals	**426.2**	**271.0**	**118.5**	**166.7**

* Based on average current federal energy prices: $0.06/kWh electricity and $0.40/therm gas.

** Includes only gas savings for reduced hot water use in clothes washers and dishwashers.

*** Scenario definitions are different for lighting products – see text.

Empirical Evidence for Projected Savings

The choice of four scenarios to describe a range of possible energy saving outcomes was a response to the limited data available on actual federal purchasing practices. FEMP continues to explore opportunities to obtain better data at reasonable effort and cost, especial-

Table 10: Annual Reductions in CO_2 Emissions in 2010 by Product for 4 Scenarios ($x10^3$ MT_C)

	Scenario 1 Max Tech (Best Available @100%	Scenario 2 - Recommended @100%	Scenario 3 – Recommended @20-80%	Scenario 4 - Average (Best Avail,Recom) @20-80%
Residential Appliances (Elec.)	**65.1**	**27.3**	**10.2**	**19.7**
Compact Refrigerators	7.5	2.9	1.2	2.4
Standard Refrigerator	30.1	10.1	3.8	8.8
Room Air Conditioners	4.8	1.8	0.6	1.3
Dishwasher	7.6	2.1	0.8	2.2
Clothes Washer	15.1	10.4	3.9	5.0
Residential Equipment (Elec.)	**165.7**	**58.8**	**22.7**	**50.0**
Central Air Conditioners	76.5	24.8	9.7	22.9
Heat Pumps (air-source)	54.6	18.7	7.4	16.7
Electric Water Heaters	16.2	10.4	3.8	5.2
Water Products (Elec. WH)	18.3	4.8	1.8	5.1
Residential Equipment (Gas)	**121.4**	**71.1**	**26.8**	**39.4**
Gas Furnaces	63.7	39.9	15.1	21.1
Gas Water Heaters	30.5	18.5	6.9	9.9
Dishwasher (Gas WH)	3.8	1.2	0.5	1.1
Clothes Washer (Gas WH)*	11.8	8.2	3.1	4.0
Water Products (Gas WH)*	11.5	3.3	1.2	3.3
Office Technologies	**340.1**	**213.9**	**134.6**	**178.5**
Computer monitors	101.0	78.2	51.4	59.7
Personal Computers	60.8	35.3	23.2	32.4
Computer Printers	122.0	78.7	47.1	61.7
Copiers	27.4	18.0	10.8	14.0
Fax Machines	29.0	3.6	2.1	10.7
Lighting Technologies**	**553.0**	**419.5**	**150.6**	**197.9**
Fluorescent Tube Lamps	31.9	15.3	3.5	6.6
Fluorescent Ballasts	61.9	34.7	7.9	12.7
Luminaires	291.5	275.6	83.7	86.1
Exit Signs	83.4	53.3	25.0	44.5
CFLs	84.3	40.6	30.4	47.9
Grand Totals	**1245.2**	**790.5**	**344.9**	**485.5**

* Includes only gas savings for reduced hot water use in clothes washers and dishwashers.

** Scenario definitions are different for lighting products – see text.

ly from the new on-line purchasing systems being established by GSA and DLA. However, for the majority of purchases which are made from commercial sources, not through the federal supply agencies, the lack of detailed, comprehensive data will continue to pose a challenge. Given the huge volume, diversity, and decentralized nature of federal purchasing, the most direct solution would be a sample survey of buying practices in each agency. This is unlikely to happen with the resources currently available to FEMP.

On the other hand, there are some partial (anecdotal) sources of information that can help us judge the reasonableness of assumptions. First, some quantitative indicators related to dissemination and use of the FEMP energy efficiency recommendations (PEERs), which are available to federal buyers both in printed form and online at the FEMP web site (www.eren.doe.gov\femp\procurement). Over the past three years, more than 3000 copies of the FEMP looseleaf binder "Buying Energy-Efficient Products" have been distributed on request to federal employees. A much smaller number of requests have come from non-federal buyers, manufacturers and distributors, and other interested government or private sector organizations outside the U.S. Between summer 1998 and summer 1999, activity on the FEMP Web site quadrupled, to a level of about 20,000 "page views" and roughly 6,000 visitors per month. While most of these are from government agency personnel, individuals from more than 50 foreign countries have also visited the site within the past year.

FEMP continues to receive positive feedback from other federal agencies on its energy-efficient procurement program and the PEERs in particular. In late 1997, FEMP organized a series of focus groups with purchasers, specifiers, and facility energy managers from 11 federal agencies. This group endorsed the overall approach and called for FEMP to establish efficiency recommendations for additional product categories, mainly for non-residential equipment which has been the emphasis since that time. An interagency survey conducted for FEMP in Fall 1998 found that energy-efficient procurement accounted for well over half of all energy-saving projects or activities undertaken by agencies in response to FEMP programs and services.

Figure 10. Annual Energy Savings in 2010

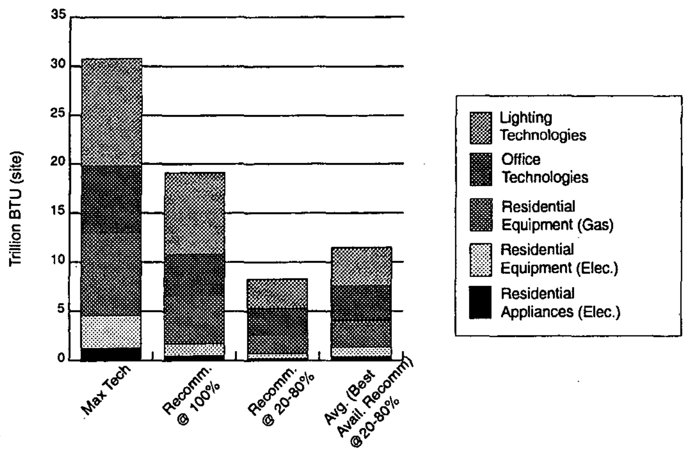


Figure 11. Annual Energy Cost Savings in 2010

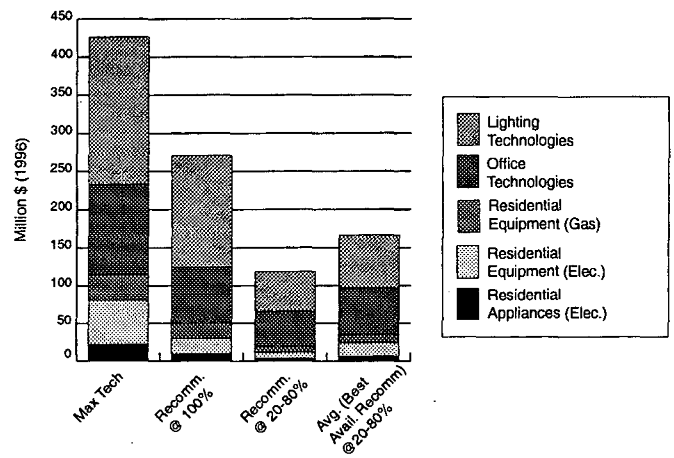
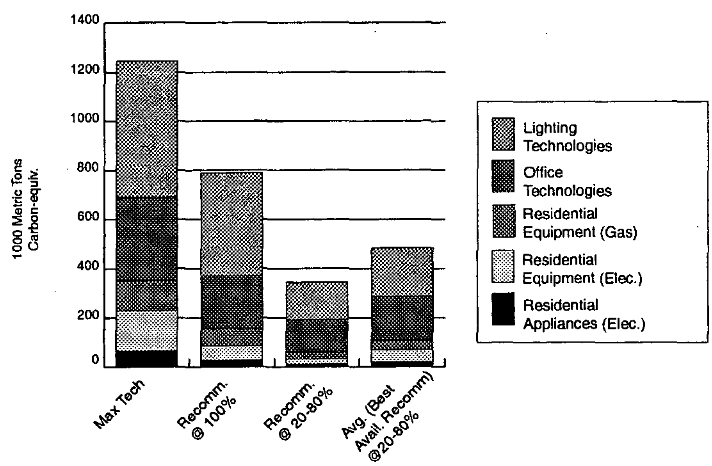


Figure 12. Annual CO_2 Emissions Reductions in 2010 (1000 MTc)



Perhaps most significantly, the FEMP energy efficiency criteria have been adopted by other agencies as part of their guide specifications for new construction and renovation projects. For example, the US Navy recently changed their guide specifications for non-residential lighting, exit signs, and distribution transformers to match the DOE efficiency criteria. Based on the volume of military construction in one year alone (1998), these Navy guide specs saved an estimated $1.2 million/year in reduced electricity use by 500,000 efficient (T-8) fluorescent lamps, 200,000 electronic ballasts, and 20,000 LED exit signs. Similarly, the Army Corps of Engineers, which designs and specifies up to $1.5 billion of construction work annually, has updated its guide spec to incorporate the FEMP criteria for energy-efficient chillers. The same chiller efficiency criteria are being included, along with other energy and environmental criteria, in a new guide spec developed jointly by Arcom MasterSpec and Green Seal, a non-profit environmental group. MasterSpec is used extensively in GSA construction, and is also the guide spec most widely used by private architecture and engineering firms. The FEMP chiller recommendations were also incorporated by GSA and DOE as part of a streamlined procurement process called a Basic Ordering Agreement, for use by all government agencies. Finally, as part of a joint project with the National Institute of Building Sciences, the FEMP efficiency criteria are being incorporated as part of an interagency project to consolidate and update many federal guide specs.

For all of these reasons, as well as the renewed emphasis on energy-efficient purchasing in the recent Executive Order 13123 (June 1999), we believe that the assumptions used in the four scenarios covers a range of plausible implementation rates for the FEMP purchasing recommendations, and that Scenario #4 captures the most likely path. Again, this scenario represents an increase from 20% (pre-program base case) to 80% penetration of energy efficiency purchases, with the average federal purchase at an efficiency level midway between the FEMP-recommended and "Best Available" levels.

Early Replacement

An implicit assumption in the above discussion is that there is no early replacement of equipment or appliances. With the exception of lighting equipment (see text, above) we assume that all products are replaced at the end of their useful lives. In practice, though, some equipment will be replaced early for various reasons; consequently, our analysis may under-estimate these savings. Substantial early replacement, especially for lighting systems, occurs as a result of cost-effective energy efficiency retrofit projects, as well as during overall facility renovation that may be unrelated to energy savings. Other product change-outs occur in response to advancing technology and/or changes in user requirements; office equipment is one obvious example, with typical replacement/upgrade cycles for computers and monitors that much shorter than the equipment's physical lifetime. The FEMP efficiency recommendations can provide a mechanism to help federal buyers take advantage of energy and cost savings when product replacements occur for these other reasons.

International Facilities

This report includes federal facilities outside the U.S. in the estimates of product purchases and calculations of energy saved in the four scenarios. These overseas buildings account for only about 10% of total federal government floorspace, but nearly 25% of military housing units. In general, we made the simplifying assumption that the energy, economic, and market conditions are similar for these international facilities as for those located in the U.S. For a number of reasons, such assumptions may be inaccurate and could be refined in future analyses. First, both the efficiency of the installed equipment stock and appliance saturation rates overseas may differ from that in federal buildings domestically, due to local climates, construction practices, and the availability and relative cost of fuels. Next, the efficiency levels and availability of the energy-using appliances and equipment themselves may differ from those in the domestic U.S. market. Third, the costs of product purchase and installation may differ, thus affecting the cost-effectiveness of choosing different levels of product efficiency. Finally, the carbon intensity of electricity generation will differ in other countries, so the associated CO_2 savings will also be different. A more detailed analysis would need to consider some of these differences by modeling program impacts separately for federal facilities in each country or region.

Indirect Program Impacts

The FEMP program for energy-efficient procurement represents an opportunity not only to save energy and money within the federal sector, but to significantly influence the broader U.S. market. As noted above, FEMP is making tangible progress in transforming decisions that affect federal purchasing, through the inclusion of the recommended efficiency criteria in federal supply agencies' on-line and printed catalogs, the incorporation of these same efficiency levels in government agency guide specifications, and the development of basic ordering agreements to streamline purchasing. By helping buyers to more easily recognize and value energy-efficient products, reducing transaction costs for these federal buyers, setting a concrete example for other (non-federal) purchasers, and attracting the attention of manufacturers and suppliers to a customer-base that supports increased energy efficiency, the program may also contribute to broader market-transforming effects not accounted for in our estimates of direct savings.

For example, the FEMP efficiency recommendations, along with criteria for ENERGY STAR® labeled products, have been incorporated in an Energy Star Purchasing Toolkit prepared by the EPA with support from DOE. This publication and the accompanying Web site (www.energystar.gov) are targeted mainly to state and local government agencies, as well as larger corporate customers. To date, over 1100 copies of the Toolkit have been distributed through state/local government associations; the Web site also offers hot-links to and from the FEMP procurement web site.

Indirect program impacts extend to the commercial sector as a whole because the federal government is the largest buyer of energy-using products in the country (and often in the world) and also because of the high profile of the federal government as a purchaser. Manufacturers, distributors, retailers, vendors, and other commercial actors are likely to keep an eye on expected trends in the energy characteristics of products demanded by their largest customer. These indirect impacts, although difficult to quantify, suggest an important topic for further study.

Interaction with Other Programs

It is important to note the other energy efficiency policies and programs that may interact with some aspects of the PEERs. We found that there was no credible way to separate the impact of other programs from those of the procurement program itself. One notable example is the EPA/DOE ENERGY STAR® labeling program. For every product with an existing or planned ENERGY STAR label, an important step in the process of analyzing product efficiency data and developing the FEMP purchase recommendations was to coordinate with the ENERGY STAR program staff in order to assure that the same efficiency levels were used. The intent was to send the strongest possible signal to the market on a common efficiency level endorsed for both federal agencies and (on a voluntary basis) for non-federal buyers. In practice, there is no way to separate out the effects on federal purchasing decisions of the FEMP-issued efficiency recommendations vs. the ENERGY STAR product labels, where applicable. The two efforts reinforce each other: ENERGY STAR labels make it easier for federal (and other) buyers to identify and select efficient products, while government policies favoring energy-efficient purchasing make it more attractive for manufacturers and retail partners to upgrade the efficiency of their products and join the ENERGY STAR program, in order to maintain access to the federal market.

Energy savings performance contracts (ESPCs) are another important contributor to the increased efficiency of federal equipment purchases. Both FEMP and the Army Corps of Engineers have established indefinite-quantity contracts that permit any federal facility to hire a pre-qualified energy service company (ESCO) to implement energy-savings projects and then pay for them based on the utility bill savings over a period of up to 25 years. The Postal Service and Air Force have also established ESPC contracts, for their facilities only. Moreover, many federal facilities can obtain energy efficiency financing and other services from the utilities who provide their gas and electric services, under "area-wide agreements" negotiated on behalf of the federal government. Federal use of both ESCO and utility-based project financing is on the increase, especially for non-residential lighting. FEMP expects that both programs will have a significant impact on federal energy savings by 2010 (DOE 1998b). Some of the savings we attribute to overall federal purchases of energy-efficient equipment will occur through these ESPC and utility area-wide programs, although at present the typical ESPC project involves an investment of well over $1 million, and the great majority of equipment purchases are made at a much smaller scale.

DOD Issues: Mobility, Specialized Products, Security

In this analysis we attempted to account separately for Defense Department purchases in terms of total product volume but we did not address qualitative differences in the types of products demanded. Some portion of DOD purchases, including several of the products analyzed above, may have special requirements in terms of security, mobility, climate-hardened equipment, and other criteria. DOD requirements for such specialized products means that our standard assumptions regarding energy efficiency, availability, cost, product lifetimes, and other characteristics may not be fully representative for the armed services, which represent about three-fourths of all facility floorspace in the federal government and about the same share of product purchasing. This does not mean that energy efficiency is irrelevant for such DOD products; on the contrary, efficiency could be viewed as a strategic asset for the military, in terms of mobility and mission enhancement, by reducing fuel supply requirements. Energy efficiency may also be correlated with other desirable characteristics for military use, such as longer lifetimes, reliability, weather-resistance, etc. Finally, there are potential efficiency improvements in military vehicles and weapons support equipment, which to date the FEMP program has not addressed. In the future, a cooperative effort with DOD analysts could prove fruitful in terms of both energy efficiency and national security.

CONCLUSIONS

We have developed a consistent and comprehensive framework with which to estimate the impacts of the Product Energy Efficiency Recommendations (PEERs) issued by the Federal Energy Management Program (FEMP). This analysis included twenty-one selected products, distributed among energy end-use categories that account for about one-third of (site) energy consumption in federal buildings. The estimated annual savings in 2010 for these products, based on our four scenarios, represent about 2-9% of current annual federal energy consumption in buildings, and about 3-12% of current annual expenditures. Savings associated with energy-efficient purchase also provide between 6% and 21% of the total additional savings needed for federal facilities to meet the targeted goals for 2010. Of the four scenarios analyzed, the most likely case would produce annual energy cost savings worth about $167 million/year in 2010. The PEERs can therefore make a significant contribution to the energy reduction goals of the federal government while at the same time saving taxpayer dollars.

REFERENCES

Atkinson, Barbara et al. 1992. *Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings.* Lawrence Berkeley National Laboratory. LBL-31469. December.

Casey-McCabe, Nancy. 1995. *Federal Purchasing Volume.* Internal Memorandum,. Lawrence Berkeley National Laboratory, Washington, DC.

Clark, A. 1998. General Services Administration, *Personal Communication,* April 20.

Clinton, William J. 1999. Executive Order 13123—Greening the Government Through Efficient Energy Management. Federal Register, Vol. 64, No. 109. Tuesday, June 8, 1999.

Dickerson, M. 1996. Department of Defense, *Personal Communication,* October 25.

Dixon, D.R. et al. 1992. *Fort Drum Integrated Resource Assessment.* Pacific Northwest National Laboratories. Richland, Washington. PNL-8424.

Energy Policy Act of 1992 (EPACT). 1992. P.L. 102-486.

Fisher, D. 1999. Lighting System Counts, *Internal Communication.* Lawrence Berkeley Laboratory. June.

General Services Administration (GSA). 1998a. *Summary Report of Real Property Owned by the United States throughout the World as of September 30, 1996.* Office of Real Property. February.

GSA. 1998b. *Impact of Downsizing on Real Property.* Office of Real Property, FY1998.

GSA. 1997. Purchasing Data for FY1996, Federal Procurement Data System. CD-ROM format.

Harrison, Bob. 1996. *Database for Purchases of Heating, Cooling, and Water Heating Equipment.* Defense Logistics Agency (DLA). Philadelphia, PA.

Ingram, Monty. 1996. *Personal Communication.* Defense Logistics Agency. Richmond, VA.

Koomey, J.G., et al. 1991a. *The Potential for Electricity Efficiency Improvements in the U.S. Residential Sector.* Lawrence Berkeley Laboratory. LBL-30477.

Koomey, J.G., et al. 1994a. *Buildings Sector Demand-Side Efficiency Technology Summaries.* Lawrence Berkeley National Laboratory. LBL-33887. Download from http://enduse.lbl.gov/Info/LBNL-33887.pdf

Koomey, J.G., C. Dunham, and J.D. Lutz. 1994b. *The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-use Treatment.* Lawrence Berkeley National Laboratory. LBL-35475. Download from http://enduse.lbl.gov/Info/LBNL-35475.pdf

Koomey, J.G., Cramer, M., Piette, M.A. and Eto, J.H.. 1995a. *Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties.* Lawrence Berkeley National Laboratory. LBL-37383. Download from http://enduse.lbl.gov/Info/LBNL-37383.pdf

Koomey, J. G., et al. 1995b. *Residential Sector End-Use Forecasting with EPRI-REEPS 2.1: Summary Input Assumptions and Results.* Lawrence Berkeley National Laboratory. LBL-34044. Download from http://enduse.lbl.gov/Info/LBNL-34044.pdf

Morey, Don. 1997. Family Housing Data, U.S. Department of Defense.

Sezgen, A.O. and J. G. Koomey. *1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting.* Lawrence Berkeley National Laboratory. Berkeley, CA. LBL-37398. Download from http://enduse.lbl.gov/Info/LBNL-37398.pdf

Sezgen, A. O. and J. G. Koomey. 1998. *Interactions between Lighting and Space Conditioning Energy Use in U.S. Commercial Buildings.* Lawrence Berkeley National Laboratory. LBNL-39795. April. Also forth-coming in *Energy—The International Journal.* Berkeley, CA. Download from http://enduse.lbl.gov/Projects/CommData.html.

Shankle, S.A., Dirks, J.A., Elliott, D.B., Richman, E.E., and Grover, S.E. 1993. *Estimate of Federal Relighting Potential and Demand for Efficient Products.* Pacific Northwest National Laboratories. PNL-8930.

US Congressional Budget Office (US CBO). 1993. *Family Housing, Department of Defense.*

U.S. Department of Commerce (US DOC). 1996. "Manufacturers' Shipments to Federal Government Agencies." *1992 Census of Manufactures,* MC92-S-3. June.

US DOC. 1999. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis.* National Institute of Standards and Technology. April.

US Department of Defense (US DOD). 1997. *POM Data for Buildings and Construction.*

US Department of Defense, Defense Manpower Data Center (DMDC). 1997. *Troop Housing Database.*

US Department of Energy (US DOE). 1995a. *Household Energy Consumption and Expenditures 1993, Part 1: National Data,* Washington, DC: Energy Information Administration. DOE/EIA-0321/1(95).

US DOE. 1995b. *Residential Energy Consumption Survey: Housing Characteristics 1993.* Energy Information Administration. DOE/EIA-0314(93). Washington, DC.

US Department of Energy. Energy Information Administration. (US DOE/EIA). 1998. *Assumptions to the Annual Energy Outlook 1999 With Projections to 2020* (AEO99). Washington, DC. December. Download: http://www.eia.doe.gov/oiaf/assum99/055499.pdf

US DOE/EIA. 1997. *1995 Commercial Buildings Energy Consumption Survey (CBECS).* Energy Information Administration. Washington, DC.

US DOE/EIA. 1998a. *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures.* DOE/EIA-0625(95), Energy Information Administration. Washington DC. October.

US DOE. 1998b. *Annual Report to Congress on Federal Government Energy Management and Conservation Programs – Fiscal Year 1996.* Office of Federal Energy Management Programs. Washington DC. July 17. DOE/EE-0192.

US DOE. 1999a. *Buying Energy Efficient Products. Federal Energy Management Program.* (looseleaf, updated 9/99) Available on request from (800) 363-3732. Viewable or downloadable at http://www.eren.doe.gov/femp/procurement.

US DOE. 1999b. *1999 BTS Core Data Book.* Prepared for the DOE Office of Building Technology, State and Community Programs by D&R International. Washington DC. June 18.

US Department of the Interior (DOI). 1997. *Civilian Housing Database.* Boulder, CO.

Vorsatz, D. et al. 1997. *Lighting Market Sourcebook for the U.S.* Lawrence Berkeley National Laboratory. LBNL-39102.

Wenzel, T.P., et al. 1997. *Energy Data Sourcebook for the U.S. Residential Sector.* LBL-40297. Berkeley, CA. September. Download from http://enduse.lbl.gov/Info/LBNL-40297.pdf.

Xenergy, Inc. 1995. Extract of XENCAP lighting audit database showing lighting equipment and lighting hours of operation for over 24,000 buildings nationwide for the years 1990 to early 1995.

Ernest Orlando Lawrence Berkeley National Laboratory
One Cyclotron Road | Berkeley, California 94720

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098