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Achieved and Potential Energy Savings through Energy Efficient Procurement

K. Sydny Fujita and Margaret Taylor

**Environmental Energy
Technologies Division**

November 7, 2012

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Executive Summary

Energy Efficient Procurement The federal government spends a significant amount on the energy consumed by its buildings; in 2011, for example, federal building energy use was estimated to cost $7.2 billion. Consuming less energy in the federal sector could help the nation address several important policy goals, including: (1) increasing energy security; (2) reducing greenhouse gas emissions and other negative externalities of electric power generation; (3) increasing the return on taxpayer dollars; and (4) increasing private sector innovative activity in efficient technologies through increased demand for these technologies.

Of the policy tools available to the federal government to encourage the efficient use of energy, federal energy-efficient procurement requirements are among the least visible and least studied, although they have had a substantial impact on federal energy use and have the potential to induce greater energy savings in the future. This report provides technical background and detailed results for the most comprehensive analysis to date of the impact of the Federal Energy Management Program's (FEMP) energy efficient product purchasing (EEPP) requirements on national energy use. It is intended as an in-depth technical companion to *Program Potential – Estimates of Federal Energy Cost Savings from Energy Efficient Procurement* (Taylor and Fujita 2012a), which provides aggregate results and focuses on the motivations for adhering to EEPP requirements.

This analysis is modeled after two reports completed in 2000 by Jeffrey Harris and Francis Johnson on the potential energy impact of FEMP EEPP requirements for the twenty-one products that were covered by the program at that time. Where possible, this report follows the methodologies established in these reports, updating the savings estimates for the original twenty-one products, as well as providing estimates for 40 products that have since been covered by the EEPP requirements. Estimated annual energy savings for 2015 are presented in the table below. Encouraging the purchase of products with the best available efficiency could lead to even greater savings; given the current size of the federal stock of energy-using equipment, a great deal more could be saved if full compliance of the stock or a stock at maximum available efficiency could be achieved, as demonstrated with the Best Available scenario.

Annual Energy Savings Summary, TBtu (2015)

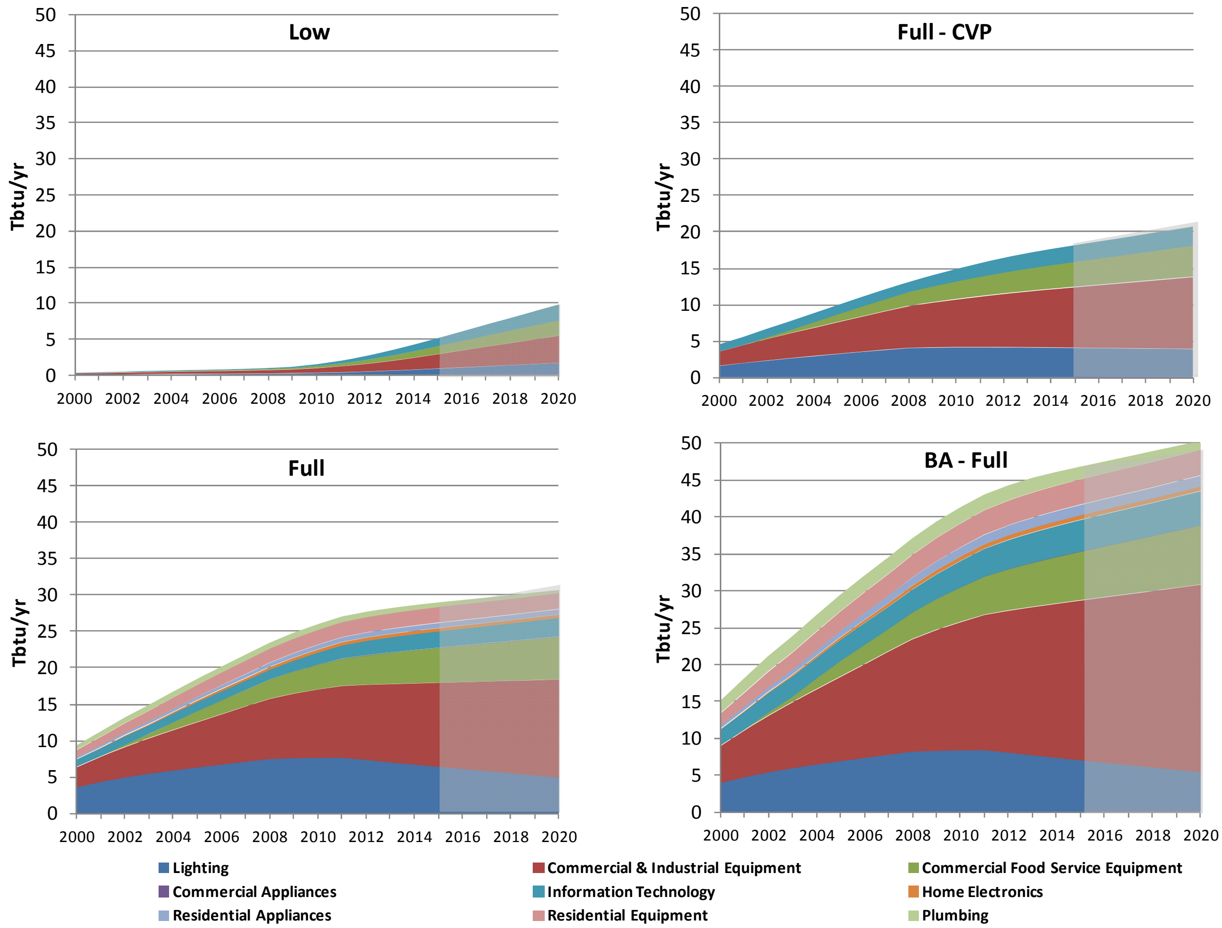
Product Category	Low	Low-Batch	Medium	Transition	Full	Full-CVP	BA-Full
Commercial and Industrial Equipment	32.3	33.8	54.6	99.5	198.6	137.5	421.0
Lighting	25.6	25.6	59.9	103.1	164.7	107.7	182.7
Information Technology	30.3	30.3	52.6	59.6	61.1	61.1	112.3
Commercial Food Service Equipment	13.9	13.9	25.8	44.5	59.2	44.0	84.5
Residential Equipment	-	7.1	11.7	20.7	36.8	-	53.8
Home Electronics	-	3.1	7.9	10.2	12.6	-	16.5
Commercial Appliances	-	0.1	0.2	0.4	0.5	-	0.7
Residential Appliances	-	3.6	7.6	10.6	16.0	-	34.0
Plumbing	-	-	5.2	8.6	9.5	-	31.7
Total	102	118	226	357	559	350	937

Note: Low is the most conservative scenario. Low-Batch and Medium, represent increasingly optimistic estimates of the current rates of compliance with EEPP requirements. The transition scenario models an instantaneous change from low to full compliance. The Full scenarios are hypothetical scenarios in which all federal purchases (including all previous years) comply with efficiency requirements. Best Available (BA) scenario is a hypothetical variation on Full scenario, in which federal purchases meet the best efficiency available on the market. Please see Section 3 (Methodology) for a full description of scenarios; see Section 4 (Results) for annual cost and CO_2 savings estimates by product category, as well as savings results for individual products.

Approximately 15 more energy-using products are covered by EEPP requirements, but were not possible to include in this analysis due to insufficient information. The full energy savings impact of the FEMP EEPP is likely larger than we estimate due to the savings achieved through the products we were unable to cover.

We also evaluate the savings that could have been achieved if all federal energy-using product purchases had met FEMP efficiency requirements. As shown in the following chart, while a substantial amount of energy is saved each year due to the current level of compliance with energy efficient procurement requirements, much greater savings are possible if full compliance, or better yet, purchase of only the most efficient products available, can be achieved. In light of recent failure to meet EISA 2007 annual federal energy reduction targets in 2010 and 2011, it is increasingly important to capitalize on these potential savings.

Achieved and Potential Savings by Product Category



It should be noted that federal energy-efficient procurement requirements can provide a framework for state and private sector procurement requirements (Johnson and Harris 2000). This in essence creates a multiplier effect, to the degree that federal guidance enables the savings achieved through state and private sector energy-efficient procurement. Future work should seek methods to improve compliance rates within the federal sector, and also to improve understanding of the links between federal, state, and private sector procurement practices.

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1. Background and Introduction

The federal government spends a significant amount on the energy consumed by its buildings; in 2011, for example, federal building energy use was estimated to cost $7.2 billion. Consuming less energy in the federal sector could help the nation address several important policy goals, including: (1) increasing energy security; (2) reducing greenhouse gas emissions and other negative externalities of electric power generation; (3) increasing the return on taxpayer dollars; and (4) increasing private sector innovative activity in efficient technologies through increased demand for these technologies.

Of the policy tools available to the federal government to encourage the efficient use of energy, federal energy-efficient procurement requirements are among the least visible and least studied, although they have had a substantial impact on federal energy use and have the potential to induce greater energy savings in the future. This report provides the most comprehensive analysis to date of the impact of the Federal Energy Management Program's (FEMP) Energy Efficient Product Procurement (EEPP) requirements on national energy use.

As required by the Energy Policy Act of 1992, Executive Order 13123, the Energy Policy Act of 2005, and the Energy Independence and Security Act of 2007, for approximately 90 appliances and energy-consuming products, federal agencies must purchase Energy Star qualified or FEMP designated products unless it can be demonstrated that such products will not meet functional requirements or will not be cost-effective over the product's lifetime.[1] Energy Star qualified and FEMP designated products are substantially more efficient than baseline efficiency models. FEMP designated products are generally in the top quartile of efficiency among available models. Similarly, Energy Star products typically use 20 to 60% less energy than baseline efficiency models to perform the same operations and provide the same level of service.

This report is modeled after two reports completed in 2000 by Jeffrey Harris and Francis Johnson on the potential energy impact of FEMP EEPP requirements for the twenty-one products that were covered by the program at that time (Harris and Johnson 2000; Johnson and Harris 2000). Where possible, this report follows the methodologies established in these reports, updating the savings estimates for the original twenty-one products, as well as providing estimates for products that have since been covered by the EEPP requirements. Table 1 lists the products included in this analysis.

[1] Please see Appendix B: Relevant Legal Authorities for additional information on these Acts and Executive Orders.

Table 1: Products Included in Primary Analysis

Product Category	Included Products
Residential Appliances	Refrigerators, Freezers, Dishwashers, Clothes Washers, Room Air Conditioners, Dehumidifiers, Room Air Cleaners, Microwave Ovens
Residential Equipment	Central Air Conditioners, Heat Pumps, Furnaces, Boilers, Electric Storage Water Heaters, Gas Storage Water Heaters
Commercial Appliances	Commercial Clothes Washers
Commercial and Industrial Equipment	Central Air Conditioners, Heat Pumps, Chillers, Boilers, Motors, Distribution Transformers, Commercial Water Heaters
Lighting and Fans	CFLs, Fluorescent Tube Lamps, Fluorescent Ballasts
Office Equipment	Desktop Computers, Computer Monitors, Computer Servers, Laptop Computers, Docking Stations, Printers, Fax Machines, Copiers, Scanners, Multifunction Devices, Mailing Machines
Home Electronics	Televisions, DVD Players, Set-Top and Cable Boxes
Food Service Equipment	Dishwashers, Fryers, Griddles, Hot Food Holding Cabinets, Ice Machines, Ovens, Refrigerators and Freezers, Steam Cookers, Pre-Rinse Spray Valves
Construction and Plumbing	Lavatory Faucets, Showerheads

Additionally, the products listed in Table 2 are considered separately in a supplemental analysis of alternative product adoption scenarios. These products are not included in the main analysis because they are either substitutes for more commonly used products or they achieve energy savings through changes in product densities which require building renovation.

Table 2: Additional Products Analyzed

Product Category	Included Products
Lighting and Fans	Residential LED, Fluorescent Luminaires, Commercial Downlight Luminaires, Industrial Luminaires
Residential Equipment	Electric Heat Pump Water Heaters, Gas Condensing Water Heaters, Tankless Water Heaters

Currently, incandescent light bulbs are generally replaced with CFLs when an end user wants to improve the efficiency of their lighting. Over recent years, LED bulbs have become available on the market for use in incandescent bulb replacement applications. While it is unlikely that many of these LED bulbs are currently used in federal buildings, we examine an additional scenario in which a growing proportion of incandescent bulbs are replaced with LED bulbs rather than CFL. Another potential lighting scenario, which we do not explore, is the case in which other types of lighting, such as fluorescent tube lamps, are replaces with LED alternatives.

Similarly, there are several options for federal buyers who wish to replace an inefficient water heater with a higher efficiency model. Natural gas or electric storage water heaters are the most common types of water heater used in residential housing in general[2], and we assume that this holds true in the federal sector. Alternatively, federal buyers could replace inefficient electric storage water heaters with heat pump water heaters, and they could replace inefficient gas storage water heaters with tankless or gas condensing water heaters. Heat pump, tankless, and condensing water heaters currently have very small market shares in the U.S. In the alternative water heater scenario, we estimate the additional savings that could be achieved if a growing proportion of inefficient water heaters are replaced with these three alternative types, rather than conventional storage water heaters.

Luminaires are excluded from the primary analysis because of the way in which they lead to energy savings. All other components held equal, a higher efficiency luminaire allows a greater output of light for the same input of electricity; this permits a lower density of lighting fixtures, while maintaining the desired level of illumination. Lamp and ballast savings are estimated assuming a constant level of illumination and constant product density. Because of this, luminaire savings, calculated based on an implicitly changing product density, are presented separately. Adding our estimates of luminaire savings to lamp and ballast savings will result in some degree of double counting.

The products listed in Table 3 are also subject to FEMP EEPP requirements, but were not included in this analysis primarily because of a lack of sufficient data.

Table 3: Products Excluded from this Analysis

Cool roofing	Digital-to-analog converter boxes	Low flow toilets
Home sealing & insulation	VCRs	Urinals
Solar water heaters	Home audio	Ground source commercial heat pumps
Battery-charging systems	External power adapters (power supplies)	Centrifugal pumping systems
Digital duplicators	Ventilation fans	Commercial faucets
Set-top and cable boxes	Beverage vending machines	Water coolers

[2] Approximately 56% and 39% of residential water heaters are natural gas or electric storage, respectively, according to 2009 RECS data collected by the U.S. Energy Information Administration. The 2009 RECS data sample includes a small percentage of propane, heat pump, or tankless water heaters, as well as some housing units that claim to have no water heating. However, for simplicity, we apply the relative proportions of gas and electric storage water heaters to the federal sector, assuming that these two types make up the vast majority of water heaters currently in use in this sector.

2. Data Sources

To estimate the total number of appliances and energy-using products operated in federal buildings, we rely on three primary types of data: estimated product densities for EEPP products in the federal building stock (products per household or products per 1000 square feet), estimated compliance rates with the EEPP (% of total products), and per product energy savings (Btu) and energy cost-savings (2010 U.S. dollars).

Product Densities in Federal Buildings

Federal floor space is categorized into three main types: residential, office, and all other non-residential (including warehouses, service, and laboratories). Federal office and other non-residential floor space are drawn from General Services Administration Federal Property Reports and the Department of Defense Base Structure Reports (U.S. General Services Administration 2002-2010; U. S. Department of Defense 2010c).[3] The GSA reports include "family housing" and "dormitories/barracks" categories, but they do not include property held outside the 50 states (territories and bases in other countries) and based on the difference in reported housing units compared to the DOD reports, appear to include privatized military housing. Number of buildings and square feet of space are provided for 10 use type categories (including family and troop housing), broken down by ownership type and location (US, territories, overseas). The territories and overseas government-owned and leased property square footage is added to the GSA data to arrive at an estimate of total federal building space. Table 4 summarizes the floor space and housing unit data we use in our estimates.

Table 4: **Federal Floor Space and Housing Units**

Sector	Units	1980	1990	2000	2010	2015
Office	1000 sqft	411,364	506,941	556,980	572,163	565,144
Other Commercial	1000 sqft	1,603,449	1,939,865	2,111,674	2,140,686	1,958,358
Barracks	1000 sqft	162,000	117,000	203,912	297,733	274,323
Single Family	housing units	413,333	436,667	361,507	265,156	200,156

(U.S. General Services Administration 2002-2010; U. S. Department of Defense 2010c); USPS floor space has been excluded because USPS is not subject to FEMP EEPP requirements

In order to derive the approximate quantity of FEMP EEPP products used in the federal building stock, we estimated the product density of equipment and appliances covered by the FEMP EEPP in commercial and residential buildings (note that product density is expressed either in terms of products per household or products per 1,000 square feet). For this task, we turned to the two standard sources employed in the literature, the Residential Energy Consumption Survey (RECS) and the Commercial Buildings Energy Consumption Survey (CBECS), which are nationally representative surveys of energy-using equipment ownership and

[3] Comparison between CBECS and GSA suggests that CBECS does not represent all federally-owned space. Based on building weights and square footage, CBECS represents about 1.9 billion sqft of federal space, while GSA includes approximately 2.3 billion sqft of federal space for 2003 (increasing slightly through 2009). Note that the DOD Base Structure Report includes real property in U.S. territories and overseas (excluded from the GSA reports).

energy use (U.S. Energy Information Agency 2003; U.S. Energy Information Agency 2009). For commercial heating, cooling, and lighting equipment, the percent of space that is heated, cooled, or lit by specific equipment types is extracted from CBECS and applied to total federal floor space. Note that in some cases, product densities are drawn from outside sources, such as those used in the previous analysis of the FEMP procurement program (Harris and Johnson 2000). Shipments are used to disaggregate product types that are included in RECS or CBECS in a general manner into the specific categories of products covered by FEMP EEPP requirements (U.S. Department of Energy 2010a).[4]

Compliance with EEPP Requirements

Ideally, all appliances and energy-using products purchased for use by the federal government would conform to FEMP EEPP requirements. However, in practice, many non-compliant appliances and products enter use in federal buildings every year. In some cases, no compliant product is available to meet the needs of the purchasing agency. In many other cases, however, non-compliant products are purchased due to factors such as poor enforcement of efficiency requirements, lack of knowledge of efficiency requirements among procurement officers, and difficulty in determining compliant models.

The Alliance to Save Energy (ASE) has produced two recent reports on the level of compliance with EEPP requirements. We use the findings of these reports to inform the compliance assumptions in our model. In 2008, the ASE reviewed procurement solicitations for FEMP EEPP required products on fedbizopps.gov, a website that reports federal procurement solicitations of more than $25,000. Of the 164 solicitations the ASE examined, only 7% appeared to be compliant (Capanna, Devranoglu et al. 2008). Interviews with procurement officials also revealed a low level of knowledge about the FEMP EEPP requirements. A follow-up study was released by the ASE in 2011 (Siciliano 2011). Again, procurement solicitations were reviewed for language indicating compliance with EEPP requirements. Approximately 46% of solicitations included a reference to Energy Star, FEMP EEPP requirements, or related laws and regulations somewhere in the text of the solicitation. However, only 24% of solicitations included a reference to the procurement requirement within the product specification section of the solicitation. Review of solicitation language tracks compliance in only one of several procurement methods; the true rate of compliance is potentially even lower than these reports suggest, as many energy-consuming products enter federal space through the use of purchase cards and other methods that by-pass procurement officials with expertise on FEMP EEPP and relevant regulations (Taylor and Fujita 2012b). [5]

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[4] For example, CBECS includes "number of computers," but not whether these computers are desktops or laptops; RECS notes when heating or cooling is provided by a heat pump, but not whether this is a ground or air source heat pump.

[5] Note that ASE studies focus on the compliance rate of contract language with EEPP requirements. There are several paths that appliances and equipment follow from manufacturer to federal agency (contract, e-retail, procurement card, etc), and we recognize that the rate of compliance may differ depending on how the product is purchased. However, as the ASE studies provide the only data on compliance that we are aware of, we assume that

Due to a trend toward the decentralization of federal purchases over the last twenty years, the bulk of federal purchasing today is done directly through purchase cards (p-cards) or other so-called "rapid purchasing techniques" like electronic retailers/supply catalogs. P-cards are particularly noteworthy; these credit cards, which are primarily used for "micro-purchases" under $3,000, account for roughly 85% of total procurement transactions, although only 2% of federal spending (Gupta and Palmer 2008). Based on average product prices and the coverage of blanket purchase agreements, between one third and half of the covered products are likely to be purchased with p-cards (Taylor and Fujita 2012c). Note that there are hundreds of thousands of p-card holders throughout the federal government, generally with little to no knowledge of FEMP EEPP requirements. Finally, although the FAR clause requirement states that the scope applies to all buildings under federal control, whether owned or leased, typical federal leases are signed for the duration of 10-20 years, with approximately 90% of leases renewed (Norris 2010). A very large portion of the buildings under federal lease was built and leased before the relevant FEMP EEPP mandates (ibid.).

Per Appliance Energy Savings

The aggregate impact of the FEMP EEPP requirements depends both on the total number of compliant products used in the federal sector and the savings accrued by each individual product. To estimate per appliance savings, we rely primarily on FEMP and Energy Star cost savings examples, cost savings calculators, and qualified product lists (U.S. Department of Energy Federal Energy Management Program 2012; U.S. Environmental Protection Agency 2012a). Per appliance annual energy and energy cost savings for each product, as well as the data sources for these estimates, are included in Appendix F: Product-specific Assumptions.

3. Methodology

Estimates of the stock of equipment and appliances are combined with expected lifetimes to estimate the number of each type of equipment and appliance replaced in a given year. Several procurement compliance scenarios were evaluated to determine the likely impact of the FEMP EEPP in its current form and the additional energy savings that could be achieved with greater compliance.

Five sequential calculations were used to derive energy and cost savings estimates:

1) Annual federal appliance/equipment stock
2) Annual federal purchases
3) Annual product cohort survivorship
4) Annual potentially compliant federal stock
5) Annual energy, energy cost, and CO_2 savings

all products follow these compliance rates. Ideally, compliance rates would be product- and procurement-method-dependent.

Energy, energy cost, and CO_2 savings should be interpreted as the savings compared to a scenario in which only baseline efficiency models of appliances/equipment are purchased by the federal government.[6] While some federal purchases of efficient products would likely occur in the absence of FEMP EEPP requirements, we do not currently have the necessary information to identify these purchases.

Stock Estimate

For the years 2003 to 2010, total office, other commercial, and dorms/barracks floor space and residential housing units are taken from the GSA and DOD reports mentioned above. For 1995, 1990, 1985, and 1980, estimates of floor space and housing units are taken from Harris and Johnson (2000).[7] Federal commercial floor space in 2015 is projected based on floor space trends over the last five years. Federal residential floor space in 2015 is adjusted to account for the continued shift from federally supplied housing to privatized military housing.[8] Depending on the form of product density data we have, one of two equations is used to estimate annual federal stock from floor space:

1) $Stock\ [\#\ units] = (Floor\ space\ [1000\ sqft]\ )\ \ x\ (\%\ Floor\ space\ with\ product)\ \ x\ (Product\ density\ [units/1000\ sqft]\ )\ x\ (Shipments\ modifier)$
2) $Stock\ [\#\ units] = (Floor\ space\ [1000\ sqft]\ )\ \ x\ (Product\ density\ [units/1000\ sqft]\ )x\ (Shipments\ modifier)$

Shipments modifiers are used for products like chillers or computers, where CBECS uses only one aggregate category that we need to split apart to match FEMP categories. For example, for computers we use shipments modifiers of 0.53 and 0.47 for desktops and laptops respectively (U.S. Department of Energy 2010a).[9] A shipments modifier of 1 is used in the cases in which categories do not need to be disaggregated.

Purchases Estimate

For the aggregate stock, purchases and retirements are assumed to be fairly uniform over time. Using this assumption, federal purchases in each year are assumed to be: [10]

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[6] For products covered by federal minimum efficiency standards, baseline efficiency is defined as a product that just meets the federal standard. For other products, we rely on the FEMP or ENERGY STAR definitions of baseline efficiency; these generally refer to standards set by industry organizations or market averages.
[7] The GSA and DOD reports used by Harris and Johnson (2000) are no longer released by these agencies, or are released under different titles.
[8] The Department of Defense expects to privatize roughly 190,000 to 195,000 housing units (http://www.acq.osd.mil/housing/faqs.htm#10). We assume this shift toward privatization continues through 2025.
[9] Thus we implicitly assume that federal purchases adhere to the general market ratio of desktops and laptops.
[10] Each year's cohort of purchases is assumed to follow a specific distribution of survival, but the stock in each year is assumed to be a mix of products of many ages in many stages of life cycle. The time series of data available is not

$$Annual\ purchases\ [\#\ units] = \frac{Avg\ Stock\ [\#\ units]}{Lifetime\ [years]}$$

where *Avg Stock* is a running average of the stock in the previous four years.

Modeled this way, purchases change over time, but in general they do so gradually. The volume of actual purchases in any given year will be subject to many influences other than appliance lifetimes, including price changes, availability of funds, and scheduled renovations. On average, over the period considered, this simplified estimate of annual purchases should be reasonable. Estimated annual purchases are presented in Appendix E: Estimated Annual Federal Purchases.

Cohort Survivorship

A Weibull distribution of lifetimes is applied to each year's cohort of purchases to estimate how many remain in operation in later years.[11] Coefficients are taken from U.S. Department of Energy appliance energy efficiency standards Technical Support Documents (TSD) when possible. When no TSD was available, coefficients were applied from TSDs of other products of similar types and lifetimes, such that the average lifetime produced by the distribution matches the known product lifetime. For each future year, a survivorship matrix records the number of surviving products of previous purchase cohorts, based on the assumed lifetime distribution.

Potentially FEMP-compliant Stock

The survivorship matrix is multiplied by four compliance vectors, each representing a different compliance scenario. This results in four matrices of surviving compliant purchases. For each year, current compliant purchases are added to the surviving compliant products from each previous year's cohort to arrive at a total FEMP-compliant stock.

$$Compliant\ purchases_y = \sum_{t=0}^{T} Cohort\ survivors_{y,t} \times Compliance\ rate_{y,t}\ ,$$

where *y* is the index of the year for which we are summing the stock and *t* is the index of cohort age.

Compliance scenario assumptions are described below. In the results section of the report, we will often refer to the Low Scenario (our conservative estimate of achieved savings), the Full Scenario (the savings that could have been achieved with full compliance), and the Best

sufficient to build a full stock – retirement model. The average that we use should be a sufficiently accurate approximation.

[11] This is consistent with the methodology used in setting federal minimum efficiency standard: as stated in the home appliances Technical Support Document (U.S. Department of Energy 2011b) "the Weibull distribution is a probability distribution commonly used to measure failure rates. Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion."

Available – Full Scenario (the maximum potential savings from procurement). The Transition Scenario is also used in an analysis of agency – level energy savings and energy efficiency goals. All other scenarios represent intermediate levels of compliance and savings.

1. **Low**: This bounding scenario is conservative with respect to legal scope and compliance rates. It assumes that for construction products requiring skilled installers (e.g., electricians, plumbers, etc.) or facilities people to install the product, in leased buildings, property management will typically take care of product purchase and installation, and will be unlikely to comply with FEMP EEPP legal authority (this de facto leasing exemption of installed products limits their total square footage to 79% of federal floor space). It also assumes that product purchases involving a contracting officer may be compliant; a 0% compliance rate is assumed for products purchased directly by the end user (i.e. products under the $3000 threshold and not covered by a government-wide acquisition contract). In keeping with the studies of procurement compliance described above, only 7% of all product purchases involving a contracting officer are assumed to be compliant with recommended efficiency levels starting at the point that any individual product is first covered by FEMP, and extending until 2008. By 2010, that compliance rate increases to 24%, and continues to increase at the same rate until the 95% threshold is reached.
2. **Low-Batch**: This is a variation on the Low Compliance scenario, providing a sensitivity analysis on the assignment of products to the p-card purchasing vehicle or the contracting officer purchasing vehicle. By assuming that products will be purchased in batches of 10 units, as might be the case for planned renovation rather than piecemeal replacement, a greater number of products exceed the $3000 micro-purchase threshold and are thus purchased under the guidance of a contracting officer. This leads us to apply a non-zero compliance rate to a greater number of products.
3. **Medium**: This is a variation on the Low scenario, increasing the rate of compliance. We assume 7% compliance from 1996 through 2008, increasing to 46% in 2010, and increasing at this constant rate until the maximum of 95% compliance is reached. As in the Low scenario, the compliance vector of construction products in scaled by 79%, while the compliance vector is applied to 100% of floor space for commodity products.
4. **Full - Contracting Vehicle Products (Full – CVP)**: This is a hybrid of the Low and Full scenarios. Rather than assuming that all products are purchased at 95% compliance, this scenario models the hypothetical situation in which efforts are focused on improving contracting officer compliance. For the products assigned to the contracting officer vehicle under the Low Compliance scenario, the Full – CVP scenario assumes 95% compliance in all years. For construction products, only federally owned space is considered. For all other products (i.e. those purchased through p-cards and those installed in leased space), 0% compliance is assumed. Products are assigned to the

contracting officer vehicle based on the price point of a single, rather than batch, purchase.

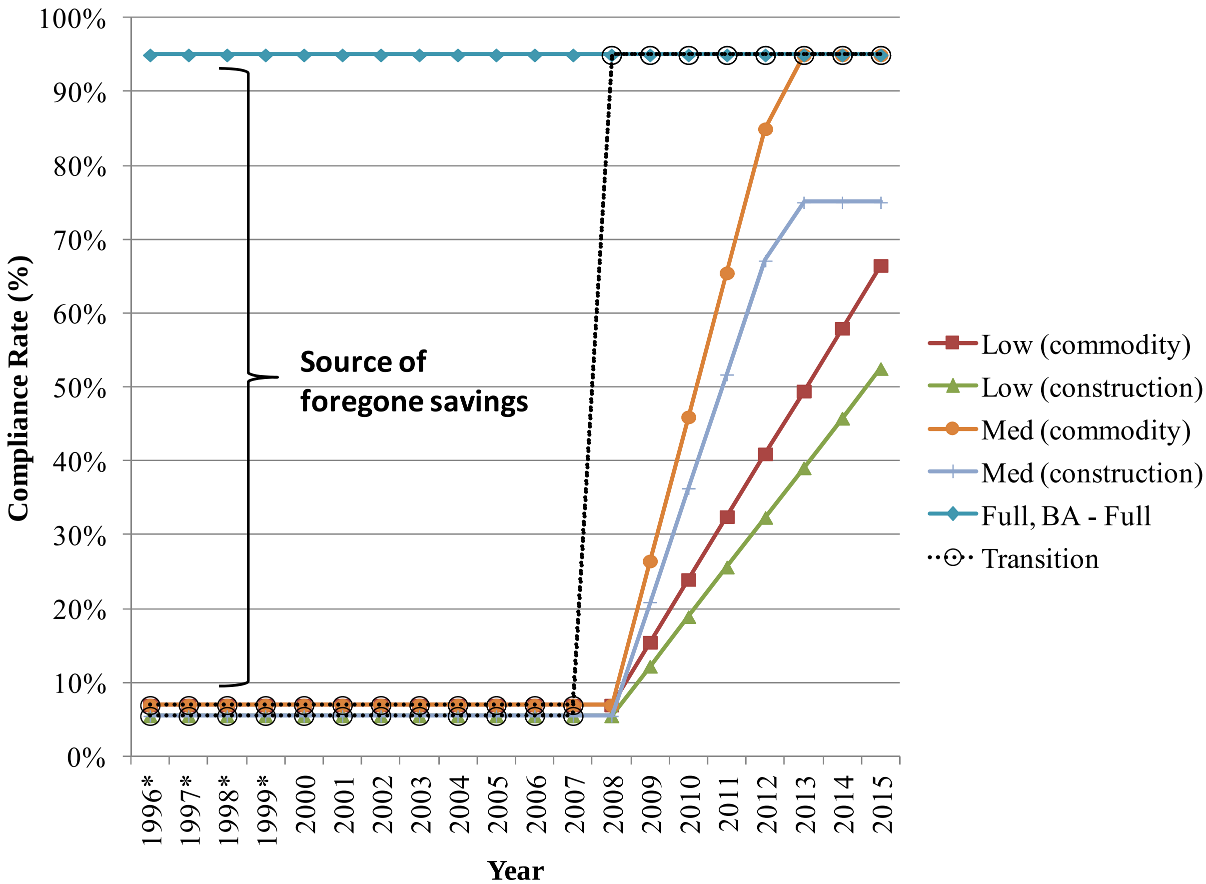
5. **Full**: This bounding scenario is optimistic with respect to legal scope and compliance rates. It assumes that there is no de facto leasing exemption and that 95% of product purchases are compliant with FEMP EEPP mandates, and have been since they were first covered by FEMP. This scenario serves as a counterfactual, projecting the savings that could potentially have been achieved in the best of all possible worlds, given recommended efficiency levels as they were actually set; the difference between savings estimated in this scenario and those of the Low Compliance scenario can be interpreted as forgone savings that agencies could have achieved if they complied with procurement requirements.
6. **Best Available – Full (BA – Full)**[12]: This scenario provides the upper bound on the savings potential that could be achieved if per product energy savings were to increase beyond the recommended efficiency levels of existing FEMP EEPP coverage and instead were to be set at the efficiency levels of the best-demonstrated products available on the market today. Like the Full Compliance scenario, this scenario assumes that 95% of product purchases in each year comply with FEMP EEPP mandates.
7. **Transition:** This scenario assumes annual compliance rates that match the Low Compliance scenario for 1996 – 2007 and the Full Compliance scenario in later years. This models a situation in which federal agencies could have responded to EISA 2007 by quickly ramping up to fully compliant procurement to contribute to energy intensity goals. Note that results from this scenario will not be equivalent to subtracting savings under Low Compliance from savings under Full Compliance. The Full Compliance scenario captures savings from efficient stock built up over the 1996 – 2007 period, which is not captured in the Transition scenario because it assumes Low Compliance in early years, with the switch to Full Compliance triggered by EISA 2007.

Compliance scenarios for an example product that is first covered by procurement requirements in 1996 are presented below in Figure 1. While FEMP EEPP provided efficiency recommendations beginning in 1996, these did not have the power of law until 1999; these years of recommendation rather than requirement are denoted with (*).

Compliance vectors also take into account the year in which a product first became subject to FEMP EEPP requirements (and if relevant, the year in which they were not longer subject to these requirements). Survivorship of cohorts purchased in years when FEMP procurement requirements were not in effect were excluded from the total FEMP-compliant stock estimate.

[12] We use the term “best available” to the highest efficiency products that are currently commercially available. This should not be confused with the highest efficiency technologically feasible (sometimes referred to as “max tech”), which may not yet be commercially available.

Figure 1. Compliance scenarios: assumed percentage of compliant purchases in each year



Energy and Cost Savings

Having estimated the FEMP-compliant stock for each year, the number of products is then multiplied by the average per unit energy savings achieved by choosing ENERGY STAR qualified/FEMP-designated rather than standard efficiency, arriving at the total annual energy savings for the product category. Savings are estimated both for products at FEMP or ENERGY STAR recommended efficiency level and for product at the maximum efficiency available on the market (Best Available).

$$Total\ product\ category\ savings = (Compliant\ stock)x\ (Per\ unit\ energy\ savings)$$

Energy cost savings are calculated similarly, assuming federal energy costs of $0.09 per kWh and $0.93 per therm, as used in FEMP acquisition guidelines (U.S. Department of Energy 2010b). Annual energy savings and cost savings from 2005 to 2010 are averaged to estimate the average annual savings in current years. Energy savings and cost savings are summed across product categories to arrive at total savings figures. For 2015 savings projections, we continue to assume current prices of energy.

CO_2 Savings

Federal energy savings are associated with reduced emissions of CO_2 from the combustion of fossil fuels, either from electricity generation or from natural gas used for onsite heating services. To estimate the CO_2 savings, we multiply the quantity of energy saved (Btu) by national average CO_2 intensity factors for electricity and natural gas.

$$Total\ product\ category\ CO_2\ savings =$$
$$(Electricity\ savings)x(Electricity\ CO_2\ intensity) +$$
$$(Natural\ gas\ savings)x(Natural\ gas\ CO_2\ intensity)\ ,$$

where the national average electricity CO_2 intensity is assumed to be 1.341 lb CO_2/kwh and the national average natural gas CO_2 intensity is assumed to be 13.446 lb CO_2/therm (U.S. Environmental Protection Agency and U.S. Environmental Protection Agency 2000; Pacific Gas and Electric Company 2012).

Calculation Example: Example Calculation for Printers

This section provides a more detailed example calculation walk-through for a sample product: printers. How much energy was saved in the year 2000 through federal purchases of energy-efficient printers (under the Low Compliance scenario)? We use the five steps described in the Methodology to estimate savings:

What is the total stock of federally owned printers in each year of the analysis?

From 2003 CBECS, we find that federal office buildings have a product density of approximately 1.11 printers per 1000 sqft of building floor space, while other federal non-residential buildings have a product density of approximately 0.276 printers per 1000 sqft of building floor space.

From GSA and DOD reports on federal buildings and Harris and Johnson (2000), we estimate federal floor space of each type for each year of the analysis. Federal floor space in select years is assumed to be as follows:

Federal Floor Space in Select Years

Type	1980	1985	1990	1995	2000
Office	411,364	441,949	506,941	551,289	556,980
Other	1,603,449	1,763,694	1,939,865	2,018,494	2,111,674

Multiplying product density by floor space for each building type and year, then summing across building types, we arrive at an estimate of the total federal stock of printers in each year.

(printer product density in office) x (office floor space in 1980) + (printer product density in other) x (other floor space in 1980) = federal printer stock in 1980

:
:
(printer product density in office) x (office floor space in 2000) + (printer product density in other) x (other floor space in 2000) = federal printer stock in 2000

We calculate the estimated stock for all years 1980- 2000.

Given the annual stock of federally owned printers, how many federal printer purchases happen each year?
Ideally, we would use a complete stock – retirement model to estimate purchases in each year. Due to data limitations, we estimate purchases based on the average stock over the previous four years. We then divide this average stock by the average printer lifetime (5 years), to arrive at the annual estimate of purchases. For example:

[(printer stock in 1999) + (printer stock in 1998) + (printer stock in 1997) + (printer stock in 1996)] / 4 = average stock for 2000 purchases

(average stock for 2000 purchases) / (lifetime) = 2000 annual purchases

We calculate the estimated annual purchases for all years 1980- 2000.

In what future years of our model do printers of each annual purchase cohort contribute to energy savings?
Any single printer's contribution to federal energy savings will depend on how long it remains in the federal stock. As stated above, on average, printers are assumed to last for five years. However, there is substantial variation in how long an individual printer will last before it is replaced. We use a Weibull distribution to estimate how many printers from a single year's purchase cohort remain in the federal stock in future years. In increments of 1 year, the distribution provides an estimate of the percent of the cohort that remain in the stock. Ideally, annual purchases would be based on such a distribution (rather than the previous 4 years of stock), but data constraints do not allow this.

Survivorship by Cohort Age (Years 1 – 10)

Age	1	2	3	4	5	6	7	8	9	10
% surviving	100.0%	93.3%	82.0%	68.0%	53.5%	39.9%	28.3%	19.2%	12.4%	7.8%

(Weibull parameters: shape = 1.90, scale = 5.70, delay = 1)

For example, the number of printers from the 2000 stock from previous purchase cohorts is estimated as follows:

(age 20 survival %) x (1980 annual purchases) = 1980 purchase cohort contribution to 2000 stock
(age 19 survival %) x (1981 annual purchases) = 1981 purchase cohort contribution to 2000 stock
:
:
(age 1 survival %) x (1999 annual purchases) =1999 purchase cohort contribution to 2000 stock

Of the stock in each year, how many printers are energy-efficient?
Since printers are covered by a blanket purchase agreement, we base our estimated compliance rates (the percent of federal purchases that meet FEMP energy-efficiency requirements) on two studies by the Alliance to Save Energy, conducted in 2008 and 2010. ASE found compliance rates of approximately 7% in 2008 and 24 – 46% in 2010 (depending on the stringency of the definition of compliant contract language). In our conservative scenario, we assume 7% in all years up to and including 2008, growing at a constant rate to 24% in 2010. This same rate of growth in applied through 2015. In all scenarios, compliance is capped at 95%, due to exemptions allowed by law. Leased space is not subject to the same regulations as federally owned space, so we apply different compliance vectors to commodity and construction products. Printers are considered a commodity product. “Compliance” does not exist before 1997, the first year this product was covered, so following the assumptions of the Low Compliance scenario, we apply a compliance rate of 7% to each years purchases, 1997 – 2000.

The compliant stock in a given year is a function of the compliance rate and survival of all previous year purchase cohorts. For the stock in 2000:

(1997 purchase cohort contribution to 2000 stock) x (1997 compliance rate) + (1998 purchase cohort contribution to 2000 stock) x (1998 compliance rate) + (1999 purchase cohort contribution to 2000 stock) x (1999 compliance rate) + (new purchases in 2000) x (2000 compliance rate) = # energy-efficient printers in 2000 stock

Given the number of energy-efficient printers in the stock each year, how much energy is saved annually?
Annual federal energy savings from efficient printers depends on the number of efficient printers in the stock and the energy savings attributable to each printer. Based on an average of three common printer types, we estimate per printer savings of 67 kwh per year for energy-efficient printers, which we then convert to TBtu.

(energy-efficient printers in 2000 stock) x (average per printer annual savings) x (TBtu/kwh) = total energy-efficient printer savings in 2000

Notes on Calculations for Other Products

The previous example is one of the simplest calculations in our model. Additional levels of complexity are involved in many product calculations. Below, we list some of the most common complicating factors and provide a description of how we modify our calculations to address them.

1) **Products used in both residential and commercial buildings:**

We apply separate calculations to residential and commercial space, basing residential product density on RECS and commercial product density on CBECS. For many products, residential and commercial intensity of use is also assumed to differ. See Appendix F: Product-specific Assumptions for detailed savings assumptions.

2) **Products may use gas and/or electricity:**

Based on RECS and/or CBECS we estimate the ratio of gas and electricity use for these products, and scale the product stocks, purchases, and savings estimates accordingly.

3) **Percent of floor space rather than product density provided for commercial lighting and HVAC:**

CBECS does not provide the necessary data to estimate product density for lighting and HVAC in commercial buildings. It provides the percent of total building floor space served by each type of lighting and HVAC equipment. We use these percentages to estimate the amount of federal floor space of each type served by these products, and then apply product densities from Harris and Johnson (2000) to arrive at our estimate of product stock.

4. Federal Results

In this report, we see that even the conservative, Low Compliance scenario (in which compliance only reaches 24% in 2010 and products in leased buildings or purchased with p-cards are excluded from the analysis for a substantial portion of products), results in significant savings to the federal government of energy (5.2 TBtu/year) and money ($102 million/year), as well as carbon dioxide (CO2) emissions reductions (0.7 million tons/year) in a snapshot of 2015.
If compliance had been at Executive Order 13514 rates, fulfilling the intent of the law regarding the extension of scope to buildings not owned by the federal government, for the entire time period that products have been covered by the FEMP EEPP (the upper bounding Full scenario), savings in 2015 would be considerably greater. We note that low compliance during the 1996 – 2011 period has cost the federal government a total of approximately $4.4 billion dollars, while wasting 217 TBtu of energy and emitting an additional 29 million tons of CO2. This emphasizes the importance of ensuring that efficient products are purchased and raises interesting questions of how to increase compliance, as well as how to ensure that the scope of legal authority for the FEMP EEPP matches the intent of the law.

With 95% compliance of all government controlled buildings and government purposefully serving as a "demand-pull" for underutilized technologies that are at the maximum efficiency currently available in the marketplace, the savings would be even greater in 2015. Energy savings would be 46.7 TBtu/year, $937 million/year would be saved from annual building operating costs, and 6.3 million tons of CO2 would not be emitted as a result of this function of government. Making such a scenario practical, however, would require overcoming obstacles regarding implementation of and compliance with existing regulation and law, although it would show important U.S. leadership on energy issues. Note that there are existing examples of government using purchasing as a test-bed/demonstration laboratory through which to document lessons-learned, that could be turned to as a model.

Finally, it is important to recognize that the federal government's approach to energy-efficient procurement can readily provide a framework for state, international, and private sector procurement requirements. This, in essence, creates a multiplier effect, to the degree that federal guidance enables these auxiliary savings.

Product Category Summary

The following tables present a snapshot of the savings achieved by the federal government in 2015 under the various scenarios detailed above (Table 5 - Table 7). The results of our analysis of all scenarios are displayed as figures in Appendix C: Charts of Analysis Results, which also includes detailed pie charts of individual product savings for the Low scenario.

Table 5: Product Category Annual Savings Summary by Scenario in 2015 ($ Million)

Product Category	Low	Low-Batch	Medium	Transition	Full	Full (CVP)	BA-Full
Commercial and Industrial Equipment	32.3	33.8	54.6	99.5	198.6	137.5	421.0
Lighting and Fans	25.6	25.6	59.9	103.1	164.7	107.7	182.7
Office Equipment	30.3	30.3	52.6	59.6	61.1	61.1	112.3
Food Service Equipment	13.9	13.9	25.8	44.5	59.2	44.0	84.5
Residential Equipment	-	7.1	11.7	20.7	36.8	-	53.8
Home Electronics	-	3.1	7.9	10.2	12.6	-	16.5
Commercial Appliances	-	0.1	0.2	0.4	0.5	-	0.7
Residential Appliances	-	3.6	7.6	10.6	16.0	-	34.0
Plumbing Products	-	-	5.2	8.6	9.5	-	31.7
Total	102	118	226	357	559	350	937

Table 6: Product Category Annual Savings Summary by Scenario in 2015 (TBtu)

Product Category	Low	Low-Batch	Medium	Transition	Full	Full (CVP)	BA-Full
Commercial and Industrial Equipment	2.0	2.0	3.3	6.0	11.5	8.3	21.6
Lighting and Fans	1.0	1.0	2.4	4.1	6.4	4.1	7.1
Office Equipment	1.2	1.2	2.0	2.3	2.3	2.3	4.3
Food Service Equipment	1.1	1.1	2.1	3.6	4.8	3.5	6.6
Residential Equipment	-	0.4	0.7	1.2	2.2	-	3.4
Home Electronics	-	0.1	0.3	0.4	0.5	-	0.6
Commercial Appliances	-	0.0	0.0	0.0	0.0	-	0.1
Residential Appliances	-	0.2	0.3	0.4	0.7	-	1.4
Plumbing Products	-	-	0.4	0.6	0.7	-	1.7
Total	5.2	6.0	11.5	18.6	29.0	18.2	46.7

Table 7: Product Category Annual Savings Summary by Scenario in 2015 (Million Tons CO_2)

Product Category	Low	Low-Batch	Medium	Transition	Full	Full (CVP)	BA-Full
Commercial and Industrial Equipment	0.2	0.2	0.4	0.6	1.3	0.2	2.8
Lighting and Fans	0.2	0.2	0.4	0.7	1.1	0.1	1.3
Office Equipment	0.2	0.2	0.4	0.4	0.4	0.2	0.8
Food Service Equipment	0.1	0.1	0.2	0.3	0.4	0.1	0.6
Residential Equipment	-	0.0	0.1	0.1	0.2	-	0.4
Home Electronics	-	0.0	0.1	0.1	0.1	-	0.1
Commercial Appliances	-	0.0	0.0	0.0	0.0	-	0.0
Residential Appliances	-	0.0	0.1	0.1	0.1	-	0.2
Plumbing Products	-	-	0.0	0.1	0.1	-	0.2
Total	0.7	0.8	1.5	2.4	3.7	0.6	6.3

Results by Product

This section presents a more detailed breakdown of the estimated savings associated with the FEMP EEPP, according to specific products. Note that results from hypothetical scenarios are shaded gray; results from scenarios intended to represent likely historical procurement compliance rates are not shaded.

Table 8. Scenario Results by Product: Federal Savings in 2015

Product	$ Million / yr							Tbtu / yr							Million Ton CO_2 / yr						
	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F
Compact Fluorescent Lamps	0.0	0.0	12.1	14.5	15.0	0.0	16.4	0.0	0.0	0.6	0.7	0.7	0.0	0.8	0	0	105	126	131	0	143
Fluorescent (Tube) Lamps	0.0	0.0	5.5	11.3	12.8	0.0	14.1	0.0	0.0	0.2	0.4	0.5	0.0	0.5	0	0	37	77	87	0	95
Fluorescent Ballasts	24.5	24.5	40.9	72.3	117.6	92.9	129.3	0.9	0.9	1.6	2.7	4.5	3.5	4.9	166	166	276	489	794	131	874
Exit Signs	1.1	1.1	1.1	4.6	18.8	14.8	20.6	0.0	0.0	0.0	0.2	0.7	0.6	0.8	7	7	7	31	127	6	139
Decorative Light Strings	0.0	0.0	0.1	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	1	1	1	0	1
Ceiling Fans	0.0	0.0	0.2	0.3	0.4	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	0	1	2	3	0	14
Com Central Air Conditioners	2.3	2.3	3.8	6.7	11.0	8.7	54.0	0.1	0.1	0.1	0.3	0.4	0.3	2.0	15	15	26	45	74	12	365
Com Air-Source Heat Pumps	1.2	1.2	2.0	3.5	5.8	4.6	14.8	0.0	0.0	0.1	0.1	0.2	0.2	0.6	8	8	13	23	39	6	100
Air-Cooled Chillers	6.1	6.1	9.9	17.6	34.3	27.1	154.2	0.2	0.2	0.4	0.7	1.3	1.0	5.8	41	41	67	119	232	32	1042
Water-Cooled Chillers	11.8	11.8	19.2	34.2	66.2	52.3	90.1	0.4	0.4	0.7	1.3	2.5	2.0	3.4	80	80	130	231	447	63	609
Com Boilers	7.9	7.9	12.9	23.1	44.1	34.8	64.6	0.8	0.8	1.4	2.5	4.7	3.7	6.9	52	52	84	151	289	41	424
Distribution Transformers	0.0	1.1	1.3	4.0	17.6	0.0	17.6	0.0	0.0	0.0	0.1	0.7	0.0	0.7	0	3	3	9	41	0	41
Motors	0.0	0.5	0.5	1.9	7.0	0.0	9.2	0.0	0.0	0.0	0.1	0.3	0.0	0.3	0	3	4	13	47	0	62
Com Water Heater	3.0	3.0	5.1	8.5	12.7	10.1	16.4	0.3	0.3	0.5	0.9	1.4	1.1	1.8	20	20	33	56	83	16	108
Com Dishwashers	4.0	4.0	6.8	12.2	16.3	12.9	20.6	0.4	0.4	0.6	1.1	1.5	1.2	1.9	26	26	45	80	108	21	136
Com Fryers	2.3	2.3	3.8	6.6	9.3	7.3	13.5	0.2	0.2	0.4	0.6	0.9	0.7	1.3	15	15	25	43	61	12	89
Com Griddles	0.8	0.8	1.3	2.3	3.1	2.4	4.8	0.0	0.0	0.1	0.1	0.2	0.2	0.2	5	5	9	15	20	4	32
Com Hot Food Cabinets	0.7	0.7	1.2	2.1	2.8	2.2	4.9	0.0	0.0	0.0	0.1	0.1	0.1	0.2	5	5	8	14	19	4	33
Com (Air-Cooled) Ice Machines	0.3	0.3	0.5	0.9	1.1	0.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2	2	4	6	7	2	11
Com Ovens	3.2	3.2	5.5	9.4	12.7	10.0	14.0	0.3	0.3	0.5	0.8	1.1	0.9	1.2	21	21	36	62	84	17	93
Com Refrigerators & Freezers	0.4	0.4	0.6	1.1	1.5	1.2	5.9	0.0	0.0	0.0	0.0	0.1	0.0	0.2	2	2	4	7	10	2	40
Com Steam Cookers	1.8	1.8	3.1	5.4	7.5	5.9	8.6	0.1	0.1	0.2	0.3	0.5	0.4	0.6	12	12	21	36	50	10	61

Table 8. Scenario Results by Product: Federal Savings in 2015 (continued)

Product	$ Million / yr							Tbtu / yr							Million Ton CO_2 / yr						
	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F
Water-Cooled Ice Machines	0.4	0.4	0.7	1.2	1.4	1.1	1.9	0.0	0.0	0.0	0.0	0.1	0.0	0.1	3	3	5	8	10	2	13
Pre-Rinse Spray Valves	0.0	0.0	2.3	3.4	3.4	0.0	8.9	0.0	0.0	0.2	0.4	0.4	0.0	1.0	0	0	15	22	23	0	58
Commercial Clothes Washers	0.0	0.1	0.2	0.4	0.5	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	1	2	3	3	0	5
Desktop Computer	8.5	8.5	14.6	16.1	16.5	16.5	30.7	0.3	0.3	0.6	0.6	0.6	0.6	1.2	58	58	99	109	112	58	208
Computer Monitor	1.9	1.9	3.3	3.6	3.7	3.7	16.2	0.1	0.1	0.1	0.1	0.1	0.1	0.6	13	13	22	24	25	13	110
Enterprise Servers	11.5	11.5	19.8	22.2	22.2	22.2	26.7	0.4	0.4	0.7	0.8	0.8	0.8	1.0	78	78	134	150	150	78	180
Notebook Computers	2.3	2.3	3.9	4.3	4.4	4.4	4.5	0.1	0.1	0.1	0.2	0.2	0.2	0.2	15	15	26	29	30	15	30
Docking Stations	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	1	1	1	0	2
Printer	3.7	3.7	6.5	8.1	8.8	8.8	23.9	0.1	0.1	0.2	0.3	0.3	0.3	0.9	25	25	44	55	59	25	161
Fax Machine	0.0	0.0	0.5	0.6	0.6	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	4	4	4	2	4
Copier	0.7	0.7	1.3	1.6	1.7	1.7	3.2	0.0	0.0	0.0	0.1	0.1	0.1	0.1	5	5	8	11	12	5	22
Scanners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0
Multifunction Devices	1.6	1.6	2.7	3.0	3.1	3.1	6.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	11	11	18	20	21	11	41
Mailing Machines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0
Televisions	0.0	3.1	5.3	7.3	9.6	0.0	11.9	0.0	0.1	0.2	0.3	0.4	0.0	0.5	0	21	36	49	65	0	81
DVD Players	0.0	0.0	0.2	0.3	0.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	2	2	2	0	3
Phones	0.0	0.0	2.4	2.6	2.7	0.0	4.1	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0	0	16	18	18	0	28
Residential Refrigerators	0.0	2.4	3.9	5.4	9.0	0.0	20.9	0.0	0.1	0.1	0.2	0.3	0.0	0.8	0	16	26	37	60	0	142
Residential Freezers	0.0	0.1	0.2	0.2	0.3	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	1	1	2	2	0	13
Residential Dishwashers	0.0	0.2	0.4	0.5	0.9	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	2	3	4	6	0	16
Clothes Washers	0.0	0.6	0.9	1.3	2.3	0.0	3.8	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0	4	6	9	15	0	25
Room Air Conditioners	0.0	0.3	0.6	0.8	0.9	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	2	4	5	6	0	8

Table 8. Scenario Results by Product: Federal Savings in 2015 (continued)

Product	$ Million / yr							Tbtu / yr							Million Ton CO_2 / yr						
	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F	L	L-B	M	T	F	F-CVP	BA-F
Dehumidifiers	0.0	0.0	0.3	0.6	0.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	2	4	4	0	6
Room Air Cleaners	0.0	0.0	1.0	1.4	1.6	0.0	2.5	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0	0	7	9	11	0	17
Microwave Ovens	0.0	0.0	0.3	0.4	0.4	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	2	3	3	0	5
(Res) Central Air Conditioners	0.0	3.2	5.3	9.5	16.6	0.0	24.3	0.0	0.1	0.2	0.4	0.6	0.0	0.9	0	22	36	64	112	0	164
(Res) Air-Source Heat Pumps	0.0	1.3	2.1	3.7	7.0	0.0	7.4	0.0	0.0	0.1	0.1	0.3	0.0	0.3	0	9	14	25	47	0	50
(Res Gas) Furnaces	0.0	1.2	1.8	3.3	7.8	0.0	12.1	0.0	0.1	0.2	0.4	0.8	0.0	1.3	0	8	12	22	51	0	80
(Res) Boilers	0.0	0.1	0.1	0.2	0.4	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	1	1	2	3	0	3
Electric Storage Water Heaters	0.0	0.5	0.8	1.4	1.8	0.0	2.7	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0	3	6	10	12	0	18
(High Eff.) Gas Storage Water Heaters	0.0	0.9	1.5	2.5	3.2	0.0	6.7	0.0	0.1	0.2	0.3	0.3	0.0	0.7	0	6	10	17	21	0	44
(Res) Lavatory Faucets	0.0	0.0	1.7	2.9	3.2	0.0	10.5	0.0	0.0	0.1	0.2	0.2	0.0	0.7	0	0	12	19	21	0	70
Showerheads	0.0	0.0	3.4	5.7	6.3	0.0	21.3	0.0	0.0	0.2	0.4	0.4	0.0	1.0	0	0	23	38	42	0	142

5. Agency Results

Accounting for Federal Agency Differences

Differences in federal agencies' size, type of building stock, and mission influence energy use and potential savings from energy efficient procurement. All federal agencies can benefit from efficient heating and cooling equipment, but the use of other products depends largely on building type.

Table 9 provides a breakdown of federal agency floor space types, aggregated into the major categories used in our model of energy savings from procurement. Due to a wide range of uses within the "all other" category, our estimates of agency-level energy savings and potential energy savings should be considered as first order results; if agency-specific product densities become available in the future, this analysis should be updated to improve its accuracy.

Table 9. Floor Space Type by Federal Agency (1000 square feet)

Agency	Family/Barrack Housing	Office	All other	Total
DOD	626,912	180,943	1,180,641	1,988,495
GSA	100	177,500	39,617	217,217
VA	4,478	7,342	124,111	135,932
DOE	695	16,095	99,478	116,268
DOJ	1,220	323	41,529	43,073
All other	35,642	32,322	155,523	223,488

Source: These values are based on preliminary data submitted by Federal agencies to DOE FEMP.

An agency's mission will influence its priorities when procuring energy-using products. Agencies with high priority on performance of equipment or speed of acquisition, or those facing tight budgetary constraint may be less likely to purchase efficient products if they are noticeably more expensive than lower efficiency substitutes.

We estimate achieved savings and forgone savings for three large agencies (DOD, VA, GSA) based on recent estimates of floor space by building type for each agency (Table 10), assuming that agencies' current shares of total federal space are accurately representative of the analysis time period.[13] The current analysis is constrained to approximations based on aggregated data from a single time period. Ideally, compliance rates with energy efficient procurement requirements and product densities would vary by agency. As these data are not available, we continue to apply the same compliance scenarios and product densities by floor space type as used in the aggregate federal analysis. While we recognize that necessary assumptions and simplifications in our analysis influence the accuracy of our results, we hope these findings will increase federal agencies' interest in the potential energy savings from procurement and increase their involvement in future projections of savings by agency.

[13] While USPS is one of the largest agencies in terms of floor space, we do not include it in this analysis because it is not subject to FEMP EEPP requirements.

Table 10. Percent of Total Federal Floor Space by Agency and Building Type

Agency	Office	Family Housing	Dorm /Barracks	All Other
DOD	33.4%	84.0%	97.6%	71.6%
GSA	32.7%	0.0%	0.0%	2.4%
VA	1.4%	2.1%	0.1%	7.5%

Energy Savings by Federal Agency

This section includes estimates of achieved and potential savings for the five large agencies, as well as comparison to each agency's energy reduction goal. See Appendix D: for additional information on federal agencies, including detailed analysis results by agency.[14] Table 11 displays the current difference between the energy use of the federal government as a whole, as well as the top five federal agencies according to building energy use (with the exception of the USPS, which is excluded for statutory reasons) and the EISA 2007 goals (30% reduction over the ten years ending in 2015). This table includes the total federal sector, as well as the top five federal agencies according to building energy use (with the exception of the USPS, which is excluded for statutory reasons), and considers the variations among agencies with respect to their mission and related building stock. It also displays the energy and associated monetary savings that the federal sector and the top five agencies have foregone by not following the Transition scenario. Note that the accuracy of savings estimates for individual agencies is expected to be lower than the accuracy of savings estimates for the entire federal sector, due to agency-specific factors that may cause unpredictable variations in purchase volumes, compliance rates, and other key variables.

The first column lays out the gap between the 2011 energy use of the federal sector and the top five agencies and the EISA 2007 target for 2011. The second column shows the potential savings that the federal sector and the top five agencies could have achieved if they had begun to purchase only compliant products after EISA 2007 (i.e. if they had followed the Transition Scenario).

[14] Note that the way in which the analysis methodology was applied to individual agencies implicitly assumes that within a given type of floor space, all federal agencies will have similar product densities and similar energy use patterns. There may be significant differences across agencies that will lead such calculations to be less accurate at the level of a single agency than at the level of the aggregate federal government.

Table 11: Estimated savings in the context of federal energy goals and energy expenditures

Government Entity	Gap between Energy Use and EISA Target[a], 2011 (TBtu)	Forgone Annual Energy Savings[b], 2011 (TBtu)	Forgone Annual Energy Cost Savings, 2011 ($ million)
Department of Defense (DOD)	16.6	7.5	149
Veterans Affairs (VA)	4.9	0.5	10
General Services Administration (GSA)	0.4	1.0	23
Federal Government	20.6	9.4	209

[a] Note that the sum of DOD, VA, and GSA energy use gaps is greater than the estimated energy use gap of the total federal government. This is due to several smaller agencies, not disaggregated in our analysis, which have a "negative" energy use gap (i.e. they are currently savings more energy than needed to meet the EISA target)
[b] Forgone savings refers to the difference in savings between current rates of compliance and compliance rates that transitioned from low to high when EISA 2007 was enacted.

6. Alternate Product Scenarios

In this section we explore three additional scenarios involving: (1) the adoption of substitute products (e.g., an inefficient electric storage water heater could be replaced with a higher efficiency conventional electric storage water heater; alternatively, it could be replaced with a heat pump water heater); (2) the additional savings associated with bringing privatized military housing under FEMP EEPP requirements.

Leap-frogging to Substitute Products

LED Lighting

Currently, incandescent bulbs are commonly replaced with CFLs. Alternatively, LED lighting could potentially take on a greater market share, substituting for either incandescent bulbs or CFLs. This alternate lighting scenario assumes that LED lighting grows from 0% market share in 2010 to 5% of the combined market for CFLs and LED in 2015.

In this case, we estimate that increasing penetration of LED lighting could lead to savings of $0.04 million, 0.001 TBtu, and 244 tons of CO_2 in 2015.[15] Note that these savings are in addition to those estimated above for CFLs, as they represent the incremental savings achieved by replacing an incandescent with LED lighting rather than a CFL.

It is likely that most LED lighting will replace either CFLs or incandescent bulbs that would otherwise be replaced by CFLs, and thus save only the difference in energy use between an LED and a CFL. In some cases, LED lighting may replace incandescent bulbs that would not have otherwise been replaced by CFLs, thereby achieving greater energy savings.

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[15] For comparison, complete replacement of CFLs by LED lighting is projected to lead to an additional savings of $1.04 million, 0.04 TBtu, and 7,400 tons CO_2 per year. We consider this to be unlikely in the near term, however.

LEDs could also potentially replace products other than CFLs and incandescent bulbs, such as fluorescent tube lighting. We do not include an analysis of this type of use of LEDs because it is not likely to occur in the near future.

Alternative Water Heaters

We previously assumed that inefficient electric and gas storage water heaters would be replaced with higher efficiency conventional electric and gas storage water heaters. In these alternative scenarios, we assume that different types of water heater (electric heat pump, gas tankless, and gas condensing) replace a portion of the inefficient conventional storage water heaters.

In the low growth scenario, tankless and condensing gas water heaters each increase in market share from 2.6% and 0% in 2006, respectively, to 5% of gas water heater purchases in 2015; heat pump electric water heaters increase in market share from 0% in 2006 to 5% of electric water heater purchases in 2015. In the high growth scenario, tankless and condensing gas water heaters each increase in market share to 25% of gas water heater purchases in 2015; heat pump electric water heaters increase in market share to 50% of electric water heater purchases in 2015 (see Table 12).

Table 12: Annual energy and cost savings of water heaters (2015)

Product Category	Low Growth Scenario			High Growth Scenario		
	$ million /yr	TBtu/yr	1000 Tons CO_2/yr	$ million /yr	TBtu/yr	1000 Tons CO_2/yr
Heat Pump	0.37	0.01	2.5	3.67	0.14	25
Gas Condensing	0.02	0.00	0.11	0.09	0.01	0.57
Tankless	0.02	0.00	0.14	0.09	0.01	0.68

Note that these savings are in addition to those estimated in the primary analysis for Energy Star gas and electric storage water heaters, as they represent the incremental savings achieved by replacing baseline efficiency storage water heaters with these three technologies, rather than with higher efficiency traditional storage water heaters.

Luminaires

Fluorescent, industrial, and commercial downlight luminaires are excluded from the main energy savings estimate because luminaires do not directly consume energy. For a given wattage, FEMP-designated luminaires produce more light than baseline luminaires. FEMP-designated luminaires can be more widely spaced and still provide the same level of lighting, thus reducing the average lighting-related energy consumption per square foot of building. Unlike the previous estimates of achieved and potential energy savings from lamps and ballasts, the following estimated savings from luminaires implicitly assume that product density will decrease, holding the leveling of lighting constant (see

Table 13). This is presented as an alternative scenario because changing luminaire density will in many cases require reconfiguration and renovation of federal spaces, rather than the more straightforward switching of equipment analyzed in the main body of this report.

Table 13: Scenario results for luminaires (2015)

$ Million		
Product	**Low**	**Full**
Fluorescent	10.6	51.0
Commercial /Industrial	7.8	36.8
TBtu		
Fluorescent	0.40	1.93
Commercial /Industrial	0.30	1.40
1000 Tons CO2		
Fluorescent	71	345
Commercial /Industrial	53	249

These savings should not be directly summed with the savings from fluorescent ballasts and tube lamps because the product density has implicitly changed; there will be fewer ballasts and lamps under this scenario and combining the two will result in some double counting of savings.

Privatized Military Housing

In recent years, there has been a shift from federally provided and administrated military residential housing to privatized military housing. This trend is currently expected to continue until approximately 195,000 housing units are privatized (approximately 75% of the military housing stock in the early 2000s) (Office of the Deputy Under Secretary of Defense 2012). The above analysis considers only the remaining federally administrated housing, as housing managed by private companies is not currently subject to FEMP EEPP requirements. Because the companies administrating privatized housing do not face a mandate to procure efficient appliances and equipment, it is uncertain whether these housing units will be provided with efficient products.[16]

In this section, we explore a potential situation in which either all housing is federally managed or privatized military housing is subject to EEPP requirements. Military housing privatization was initiated by the Military Housing Privatization Initiative of 1996. To estimate the additional savings achievable if privatized housing were subject to EEPP requirements, we first estimate the total number of housing units in each year. Since the affects of the Military

[16] While it is possible that efficient products will be installed in privatized housing units, we evaluate a scenario in which only baseline efficiency products are installed in privatized housing. Savings estimates in this section should be considered as the upper bound on potential savings from imposing EEPP requirements on privatized housing.

Housing Privatization Initiative were not likely felt before 1997, we take the military housing stock in 1997 to represent total military housing (privatized and federally administrated) in all future years.[17] Subtracting the federally administrated housing units used in the primary analysis from this estimate of total military housing, we arrive at an annual estimate of the number of privatized military housing units. We then calculate energy, energy cost, and CO_2 savings as described in Section 3 (Methodology), using this estimate of privatized military housing units.

Table 14 presents summary results for the privatized military housing scenario. Compliance scenarios are defined as in Section 3 (Methodology). The privatized housing scenario assumes that all military housing floor space will become subject to procurement requirements.

Table 14: Additional savings from applying efficient procurement requirements to privatized military housing

Product Category	Low	Full	BA - Full
$ Million			
Residential Equip	0	11.8	15.0
Residential Apl	0	3.7	7.2
Plumbing	0	6.8	22.7
TBtu			
Residential Equip	0	0.6	1.0
Residential Apl	0	0.2	0.3
Plumbing	0	0.5	1.2
1000 Tons CO2			
Residential Equip	0	68	100
Residential Apl	0	25	49
Plumbing	0	138	151

[17] We recognize that there are other factors that cause the stock of military housing to change over time, but data availability necessitates this simplification.

7. Limitations and Remaining Questions

There are several limitations to this study that it is prudent to point out. Limitations and potential sources of inaccuracy cluster around the issues of exogenous changes to the markets for energy-using products, applicability of current trends to past and future time periods, and data availability.

Two major exogenous market changes that could influence the future savings potential of FEMP EEPP are changes to the availability of product inputs and component materials and major technological advances in efficiency that alter the distribution of product efficiencies available on the market. Changes to the availability of product inputs may lead to substantial changes in product prices; large enough changes in price may convince federal buyers to delay replacement of aging products (in the case of price increase) or to either replace products early or increase product stocks (in the case of price decrease). As new innovations in energy efficiency are incorporated into covered products, there may be periods of time when the energy use differential between baseline and FEMP / ENERGY STAR requirements widens, resulting in an increased value to meeting these requirements.

Many inputs to our model are based on current technologies and current markets (e.g. annual energy savings, average product lifetimes, product densities). If any of these factors were significantly different in the past, it will reduce the accuracy of our estimates of achieved savings. Similarly, if any of these factors change significantly in the future, it will reduce the accuracy of our projections of FEMP EEPP potential.

Due to lack of available data, our estimates of savings do not include all products covered by FEMP EEPP (see Appendix F: Product-specific Assumptions: Products Excluded from Analysis). Similarly, in future research it would be very helpful to have more detailed data on the baseline market share of ENERGY STAR products in commercial and residential buildings. Because little is known about the stock of covered products in federal buildings, we model the federal stock based on national averages of commercial and residential buildings; this method will lead to inaccuracy if the federal sector is substantially more or less likely to use certain products than predicted by these national averages. Finally, an additional data refinement of this study would include more detail on the distribution of leased buildings by type, agency, and expiration date.

The remainder of this section lays out four primary areas which we believe show potential for valuable future research and analysis.

Procurement Pathways:

While we estimated the stock and annual purchase rate of appliances and equipment, we did not evaluate the ways in which these products came to be in federally owned buildings. Products may be purchased by individual employees through e-retailers, through contracts with approved vendors, through special order by procurement officials, and likely other pathways as well. Compliance with federal EEPP requirements depends heavily on the knowledge of the buyer. Some failure to comply may be intentional, with buyers choosing lower purchase prices over efficiency, but some failure to comply is likely due to a lack of awareness on the part of the buyer that EEPP requirements exist.

Several large agencies, in particular the Department of Defense, account for the majority of energy use and energy-using product procurement. Evaluating the procurement practices of large agencies may reveal methods to quickly improve compliance across a significant proportion of federal purchasing. See Taylor and Fujita (2012b; 2012c) for further discussion of procurement methods and insights for increasing compliance.

Non-covered Products:

Some products (clothes dryers, residential ovens and ranges, fume hoods and other common laboratory equipment, air compressors and other common mechanical and machine shop equipment) are not currently subject to EEPP requirements. Further research is necessary to determine whether there are additional products used in high volume by the federal government and/or that consume a substantial amount of energy that should be added to FEMP EEPP coverage.

Recently Added Products:

Some products have only been covered by FEMP EEPP requirements for a few years, so the savings have not yet been fully realized (servers, for example). It will be valuable to track not only how procurement policy impacts the energy consumption of these products in the federal sector in the future, but also to investigate changes in the average efficiency level of servers available in the market in the early years of the policy. Servers may be a particularly valuable example, as they have a relatively short expected lifetime, so a large demand for high efficiency servers will have manifested immediately after the procurement requirements came into effect, assuming some degree of compliance with the new requirement.

Interface between Federal, State, and Private Procurement Policy:

FEMP energy-efficient procurement specifications can provide guidance for state and private sector procurement policies. The influence of federal energy-efficient procurement policies on state and private sector procurement policies should be investigated to uncover any positive spillover effects. At the same time, FEMP may be able to improve its specifications-setting methodologies and the federal compliance rate by studying successful state and private sector policy and implementation practices.

8. Appendices

Appendix A: Note on Comparison with Previous Study

In their pair of reports from 2000, Harris and Johnson analyze 21 products (residential appliances and equipment, office equipment, lighting, commercial HVAC, motors, distribution transformers), and project savings in 2010 of 10.5 to 41.8 TBtu per year ($160 to $620 million per year). Our savings estimate for this group of products is substantially lower. Several assumptions underlying the 2000 reports have changed, notably: reduced federal floor space; changes in product densities; changes in product characteristics; and lower compliance rates.

First, there has been a significant shift to privatized military housing since 2000, so the number of housing units owned and operated by the federal government is substantially lower than projected by Harris and Johnson.[18] Currently, privatized military housing is not subject to FEMP EEPP requirements, as private contractors, not the Department of Defense, are in charge of construction and building management. Additionally, product densities in some cases appear to be lower than those projected by Harris and Johnson (2000). For our product densities, we rely primarily on more recent RECS and CBECS surveys than those used by Harris and Johnson.

When possible, we have updated product lifetimes, energy savings, and energy cost savings; in some cases, these changes led to reduced estimates of per appliance savings. The average federal costs for electricity and natural gas have both increased since 2000, but for some products, the energy use differential between Energy Star (or FEMP designated) products and baseline efficiency products has decreased. The net effect is, in some cases, a reduced impact of procurement requirements on energy use and energy cost on a per appliance basis.

We base our compliance rate assumptions on two reports by the Alliance to Save Energy, which suggest compliance rates between 7% and 46% in recent years (Capanna, Devranoglu et al. 2008; Siciliano 2011). Harris and Johnson (2000), by contrast, assume an initial compliance rate of 20%, increasing to 80% or 100% by 2010. The ASE reports suggest that the Harris and Johnson (2000) scenarios were overly optimistic about compliance in the time period we are studying.

In some scenarios, Harris and Johnson (2000) assume that compliance will be achieved through procurement of the highest efficiency products available, not just Energy Star qualified or FEMP-designated. We follow a similar procedure in our Best Available scenarios. These estimates should not be expected to match those of Harris and Johnson (2000), however, due to changes in floor space, product density, and assumptions regarding the energy use differential between best available and baseline efficient products.

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[18] While not identical, our estimates of the area of office and other non-residential floor space are similar to those used in Harris and Johnson (2000).

Appendix B: Relevant Legal Authorities

Legal Authority	Year	Details
Executive Order 13514	2009	Requires 95 percent of new contract actions, task orders, and delivery orders for products and services to be energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or non-toxic or less toxic alternatives where such products meet agency performance requirements.
Energy Independence and Security Act of 2007 (EISA)	2007	Requires federal agencies to purchase energy-consuming products with a low-standby power level of 1 watt or less.
Executive Order 13423	2007	Requires federal agencies to purchase energy-consuming products that are ENERGY-STAR qualified or meet FEMP-designated efficiency requirements (i.e., is in the upper 25 percent of efficiency for all similar products).
		Requires federal agencies to purchase energy-consuming products with a low-standby power level of 1 watt or less.
Energy Policy Act (EPAct) of 2005	2005	Requires federal agencies to purchase energy-consuming products that are ENERGY-STAR qualified or meet FEMP-designated efficiency requirements.
		Requires federal agencies to incorporate energy efficiency criteria into relevant contracts and specifications.
		Establishes an exception for ENERGY STAR or FEMP-designated purchase based on written notice from the head of the agency that "no ENERGY STAR or FEMP-designated product is reasonably available that meets the functional requirements of the agency" or "no ENERGY STAR or FEMP-designated product is cost effective over the life of the product taking energy cost savings into account"
Executive Order 13221	2001	Requires federal agencies to purchase energy-consuming products with a low-standby power level of 1 watt or less.
EPAct 1992	1992	Required the General Services Administration (GSA) and Department of Defense (DOD) to include energy-efficient products across procurement and supply functions. It also required the GSA and DOD to implement programs that designate and identify these energy-efficient products.
Federal Acquisition Regulation (FAR) Part 23	Ongoing	Codifies the above, including the exception provision in EPAct 2005
		Requires federal agencies to incorporate a clause from FAR Part 52.223-15 in all contracts and solicitations when energy-consuming products listed in the ENERGY STAR program or FEMP will be: "delivered; acquired by the contractor for use in performing services at a federally-controlled facility; furnished by the contractor for use by the government; or specified in the design of a building or work, or incorporated during its construction, renovation, or maintenance."
Code of Federal Regulations: 10 USC 436	Ongoing	The above applies only to energy-consuming products within a product category covered by ENERGY STAR or FEMP. Other energy-consuming product categories do not have to meet these mandates.
Code of Federal Regulations: 5 USC 7902(a)	Ongoing	Defines an agency as "an agency in any branch of the Government of the United States (not including the United States Postal Service), including an instrumentality wholly owned by the United States, and the government of the District of Columbia."
Code of Federal Regulations: 42 USC 8259b	Ongoing	States that the term "product does not include energy-consuming products or systems designed or procured for combat or combat related missions.

Other relevant legal authority includes: Energy Policy and Conservation Act (1975); DOE Organization Act (1977); National Energy Conservation Policy Act (1978); Federal Energy Management Improvement Act (1988); Executive Order 12759 (1991); Energy Policy Act (1992); Executive Order 12902 (1994); and Executive Order 13123 (1999).

Appendix C: Charts of Analysis Results

Figure 2: Low Scenario Results Summary

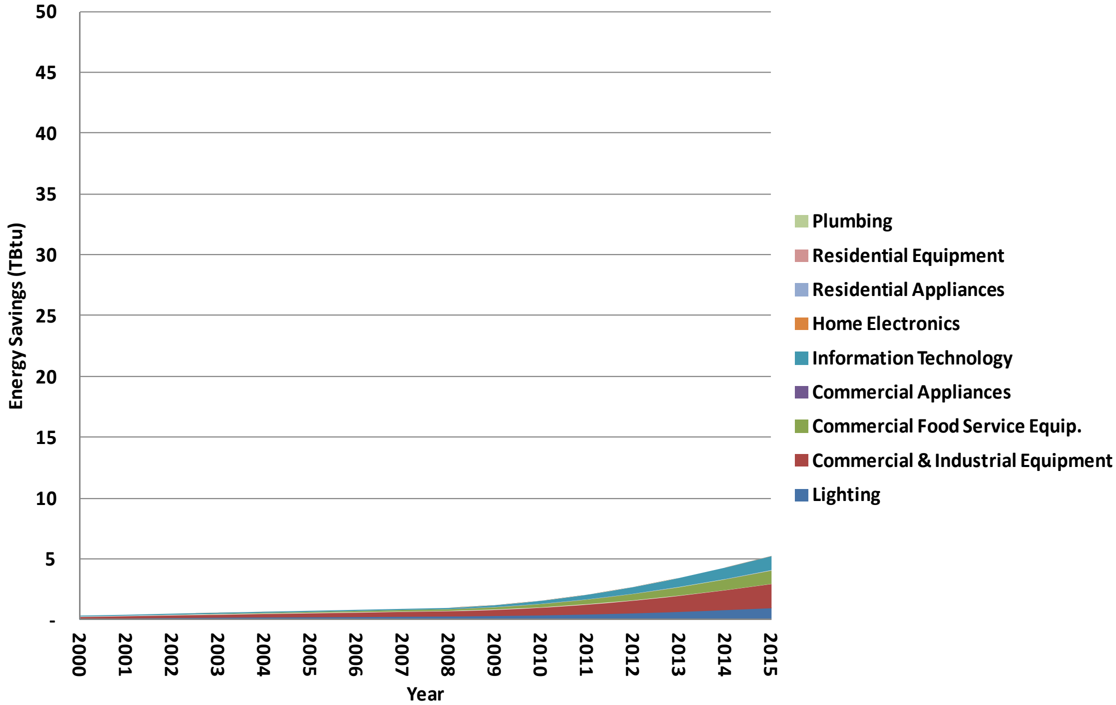


Figure 3: Low-Batch Scenario Results Summary

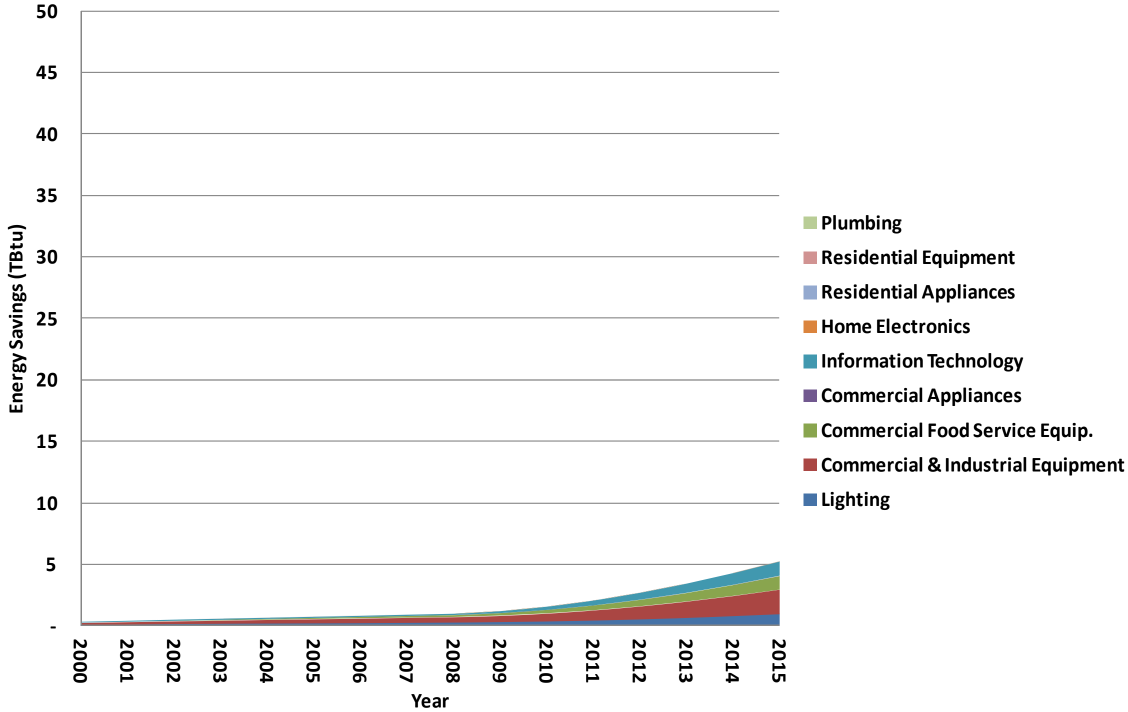


Figure 4: Transition Scenario Results Summary

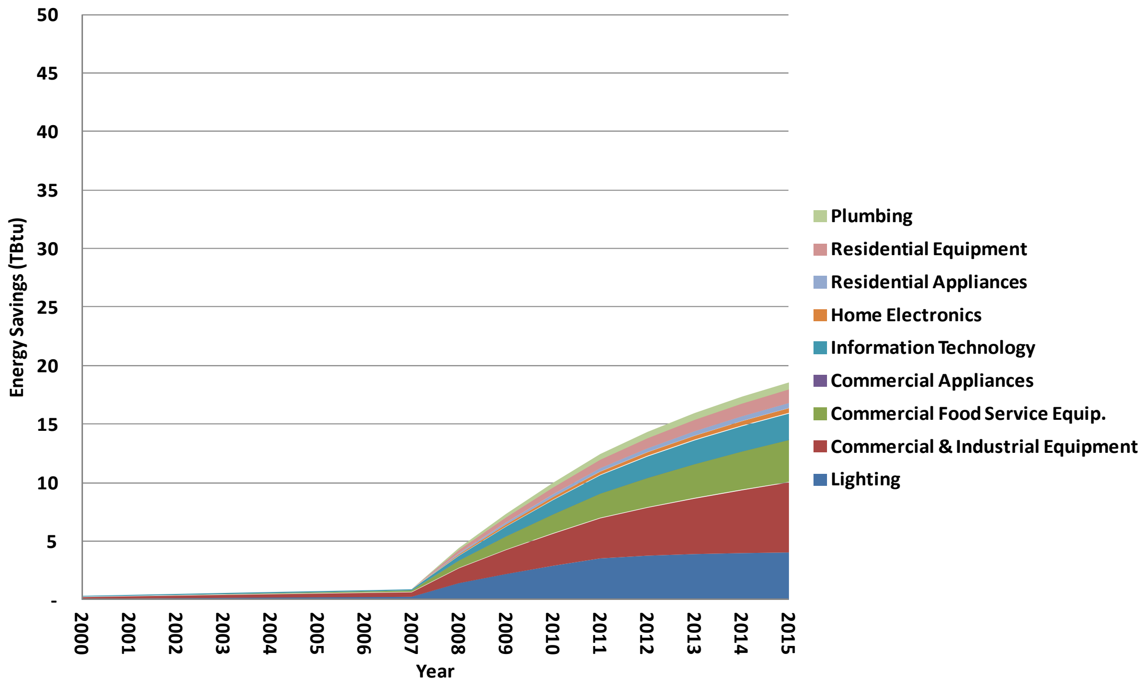


Figure 5: Full – Contracting Vehicle Products Scenario Results Summary

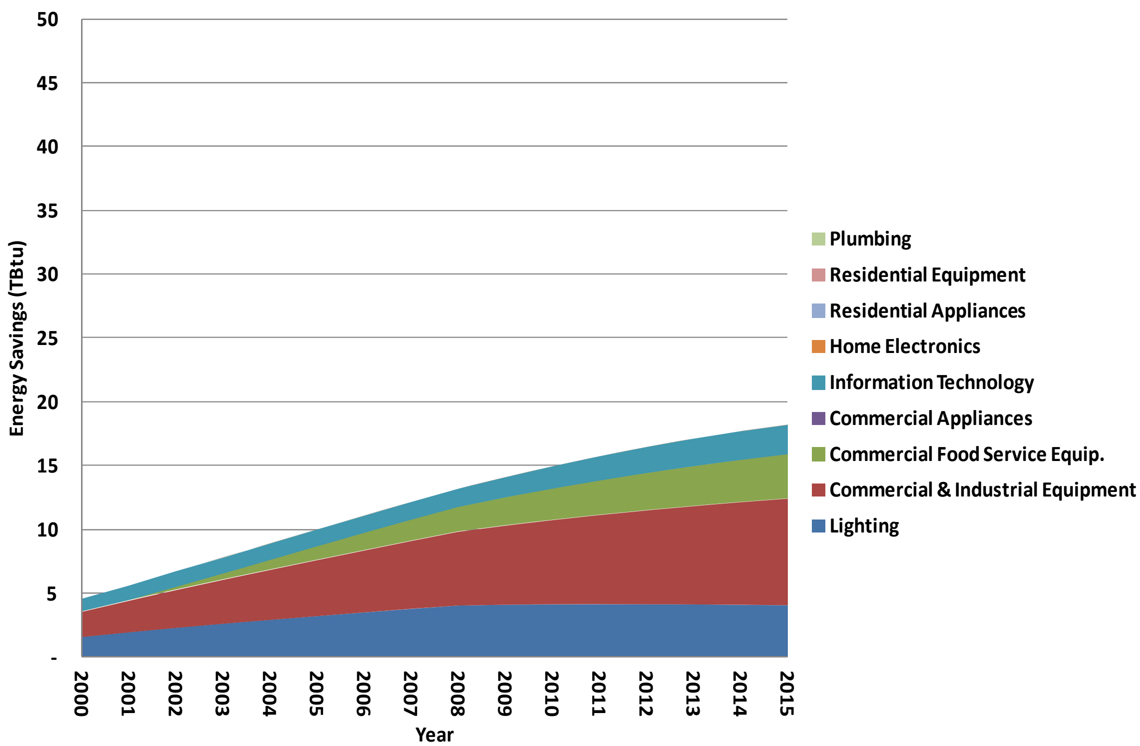


Figure 6: Full Scenario Results Summary

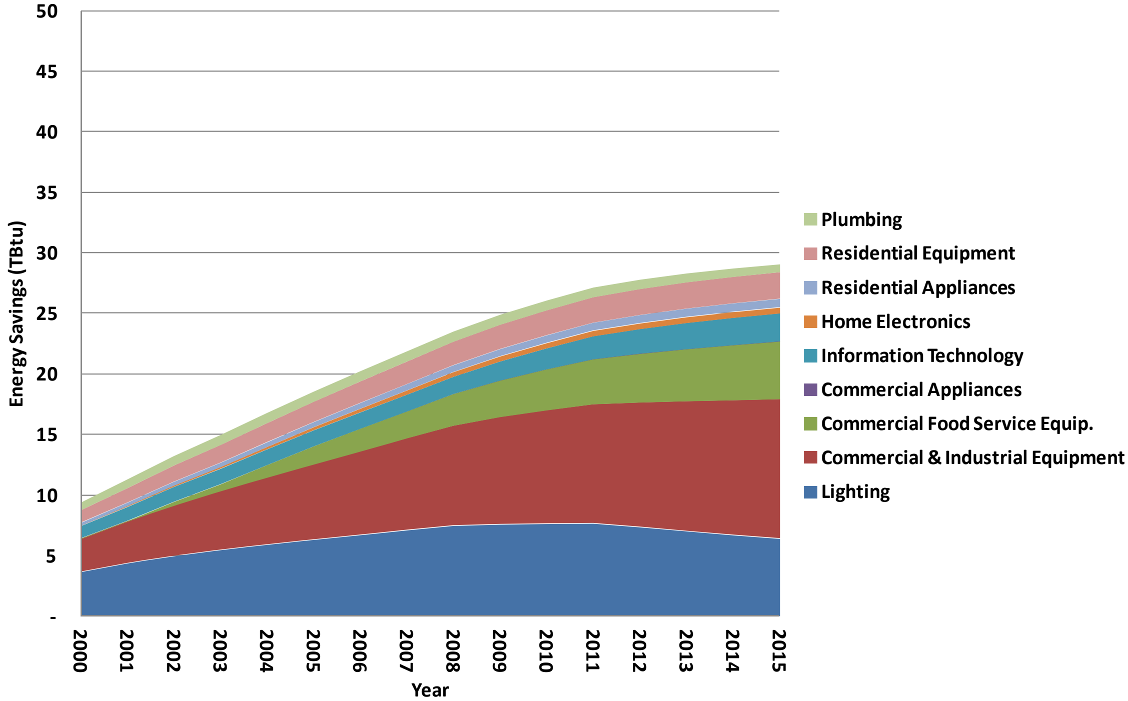


Figure 7: Best Available - Full Scenario Results Summary

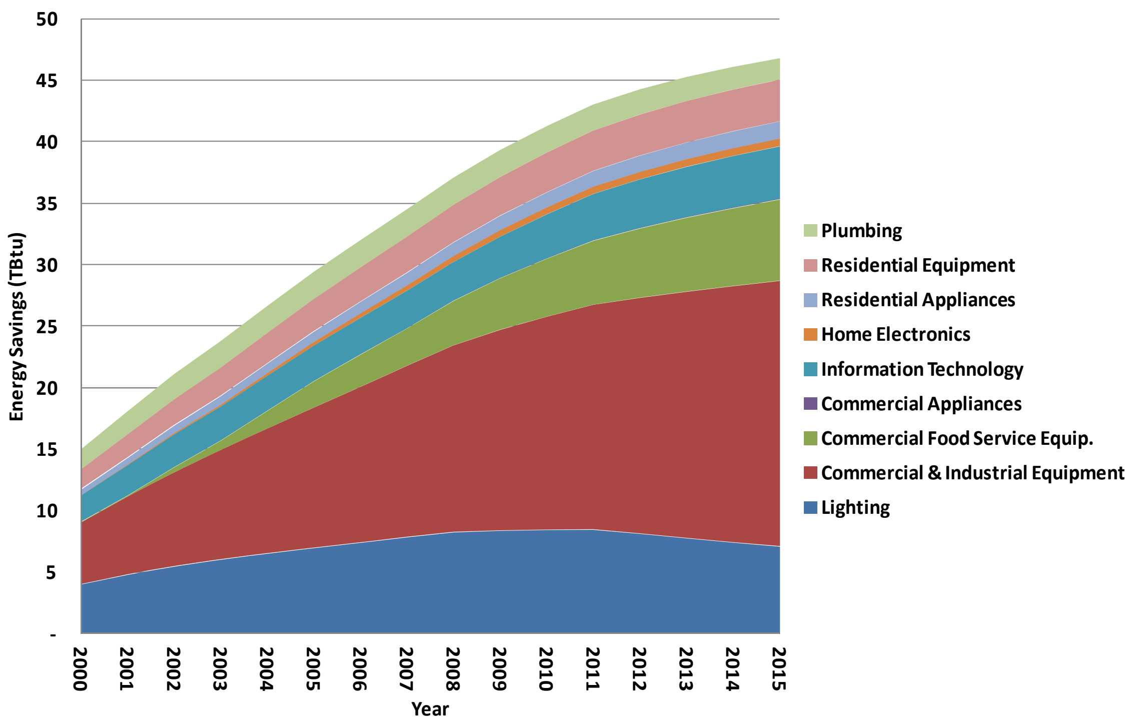


Figure 8: Comparison of Savings by Product Category across Scenarios

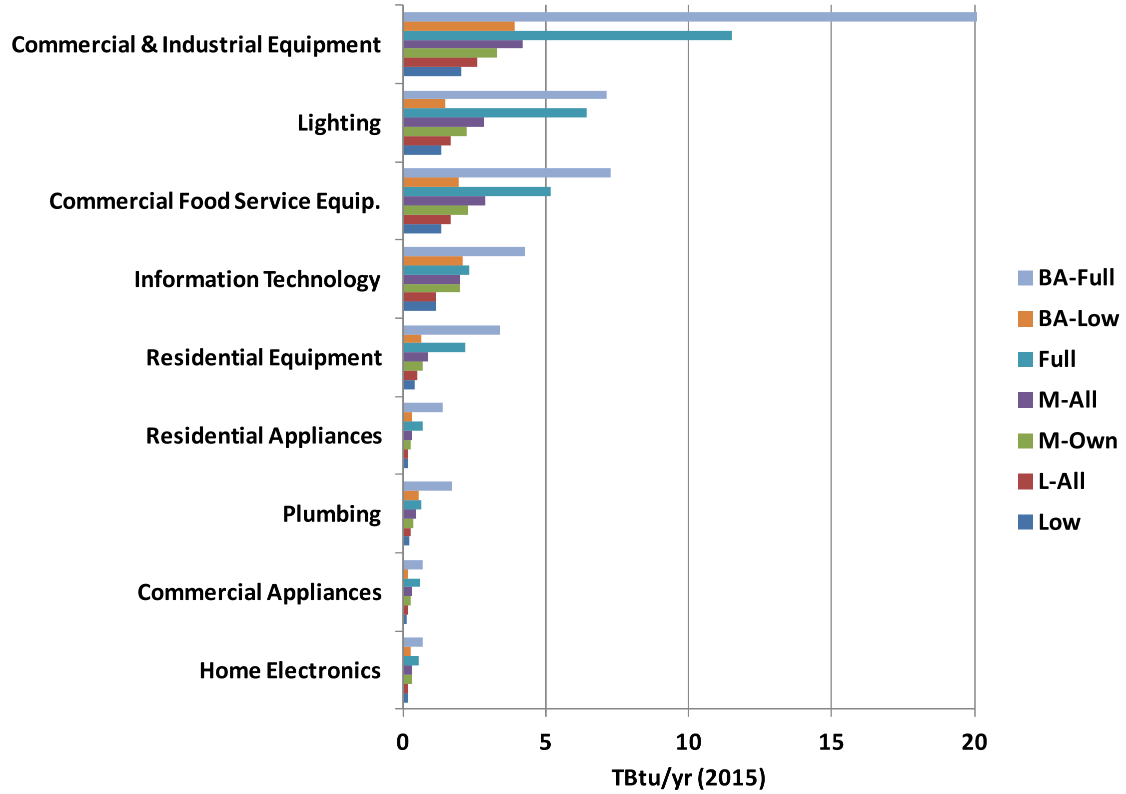


Figure 9. Commercial & Industrial Equip Low Scenario Energy Savings, TBtu (2015)

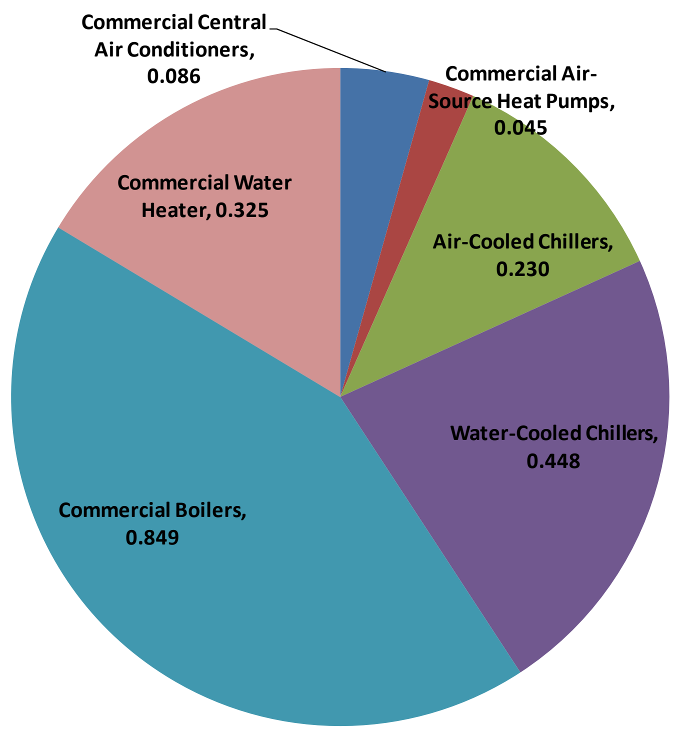


Figure 10. Lighting and Fans Low Scenario Energy Savings, TBtu (2015)

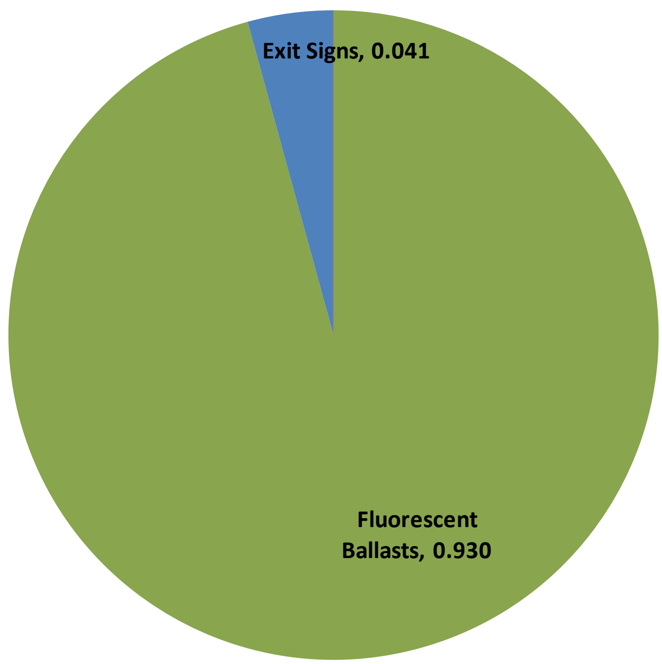


Figure 11. Office Equipment Low Scenario Energy Savings, TBtu (2015)

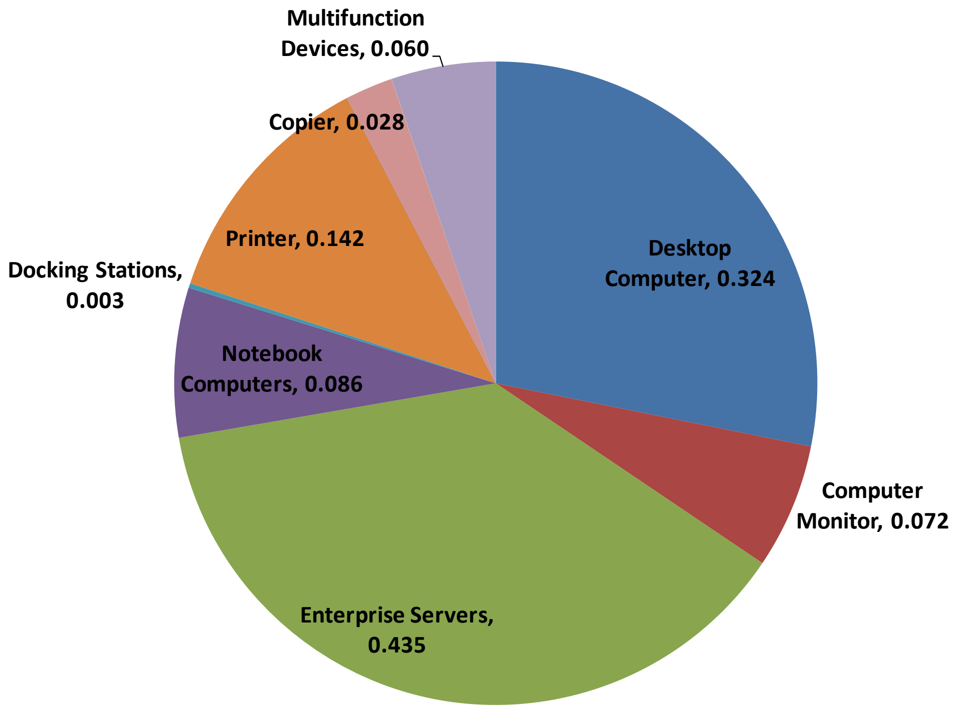


Figure 12. Food Service Equipment Low Scenario Energy Savings, TBtu (2015)

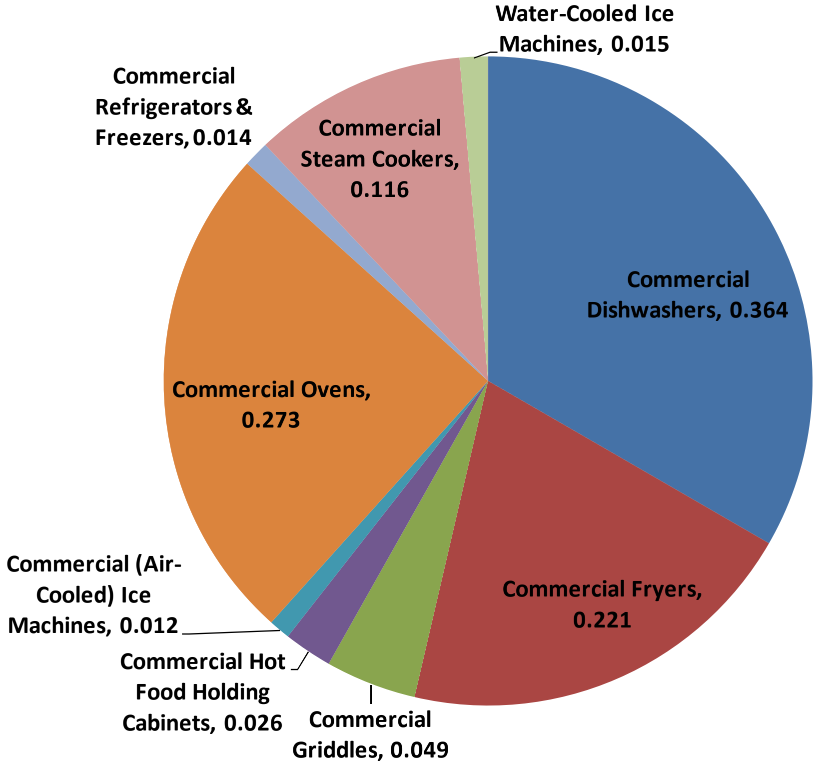
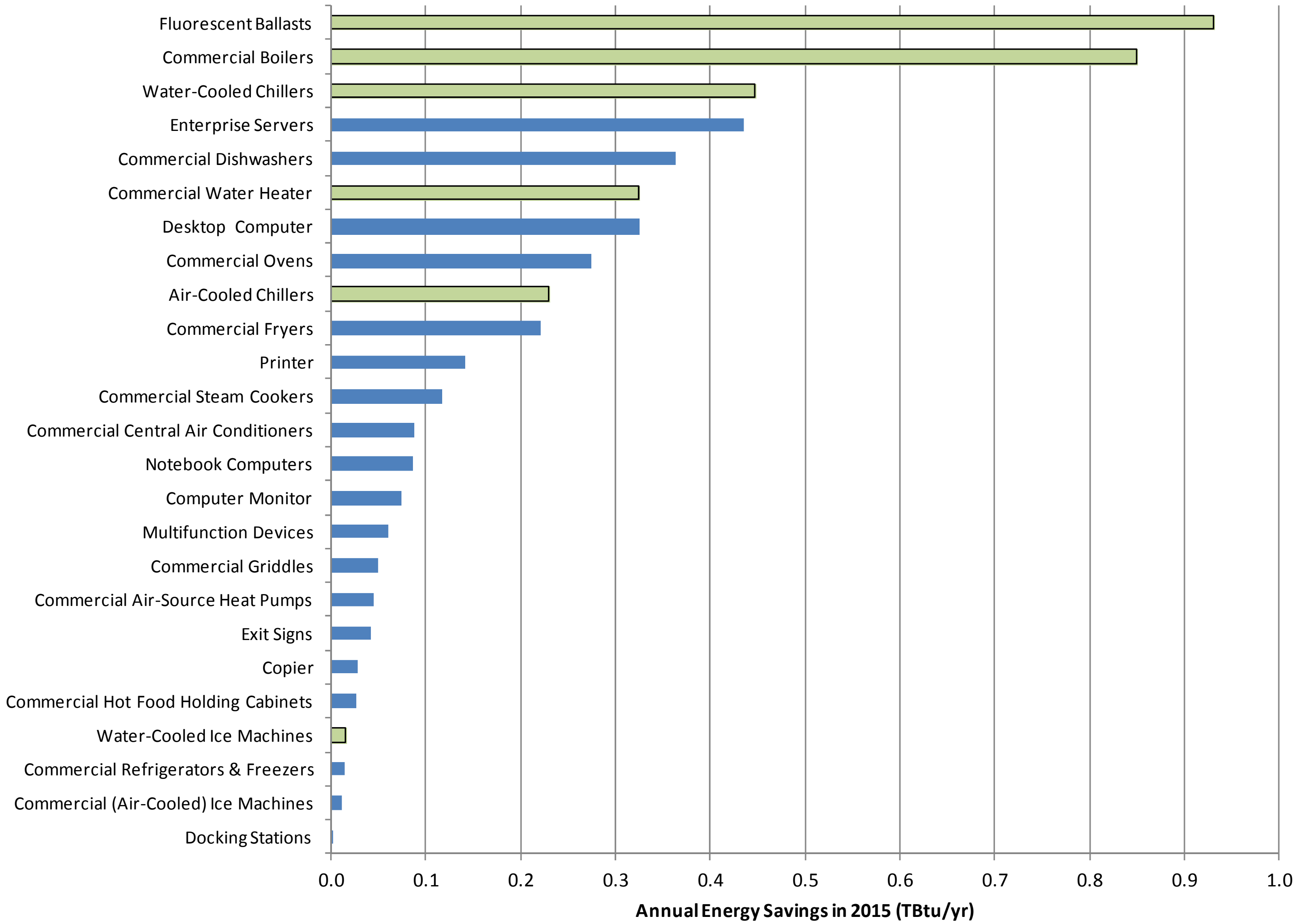
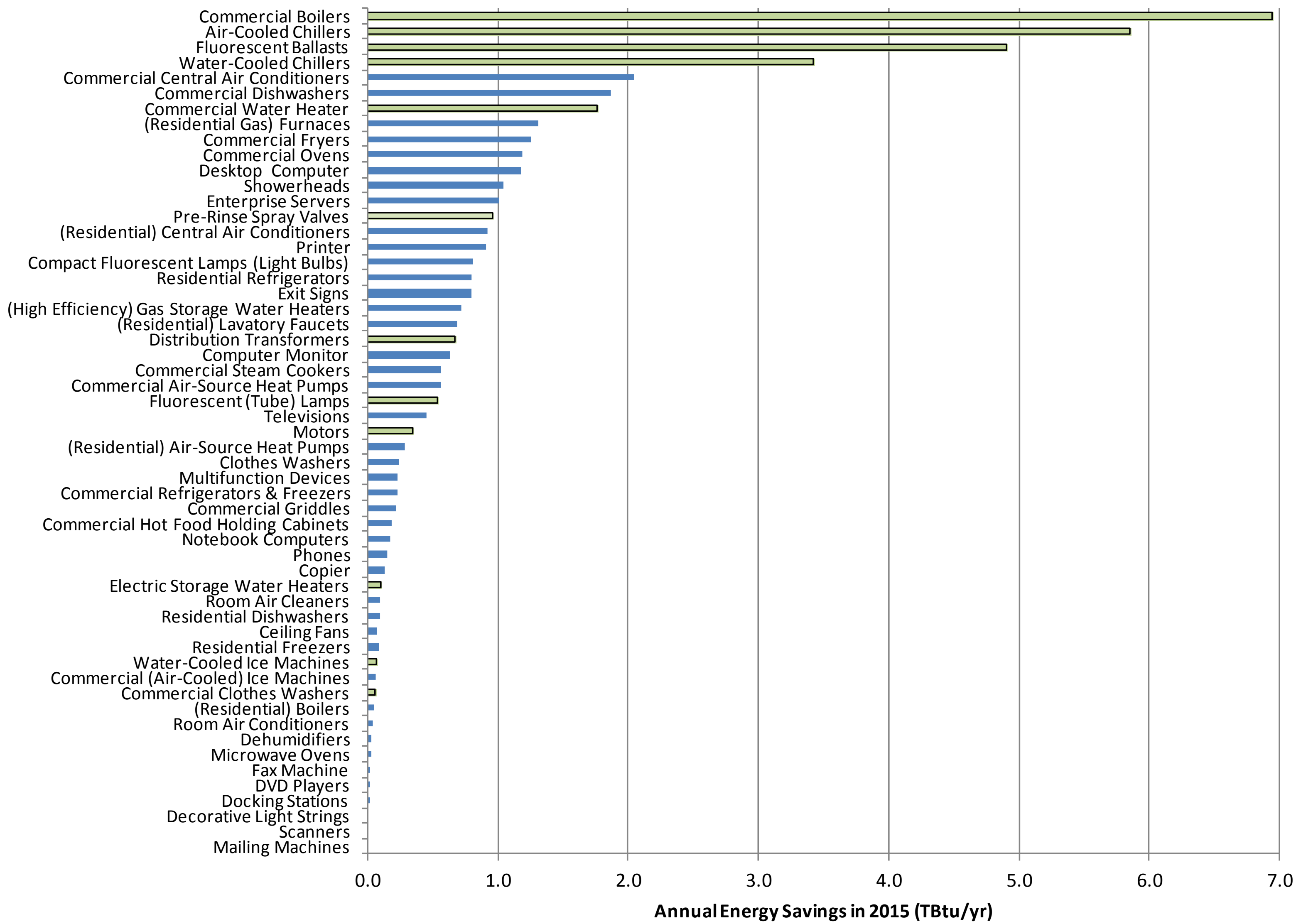


Figure 13: Products ranked by annual savings in 2015 under the Low scenario (TBtu/yr)



*green denotes products that were considered “FEMP-designated” for most or all of the analysis period

Figure 14: Products ranked by annual savings in 2015 under the Max Tech High-All scenario (TBtu/yr)



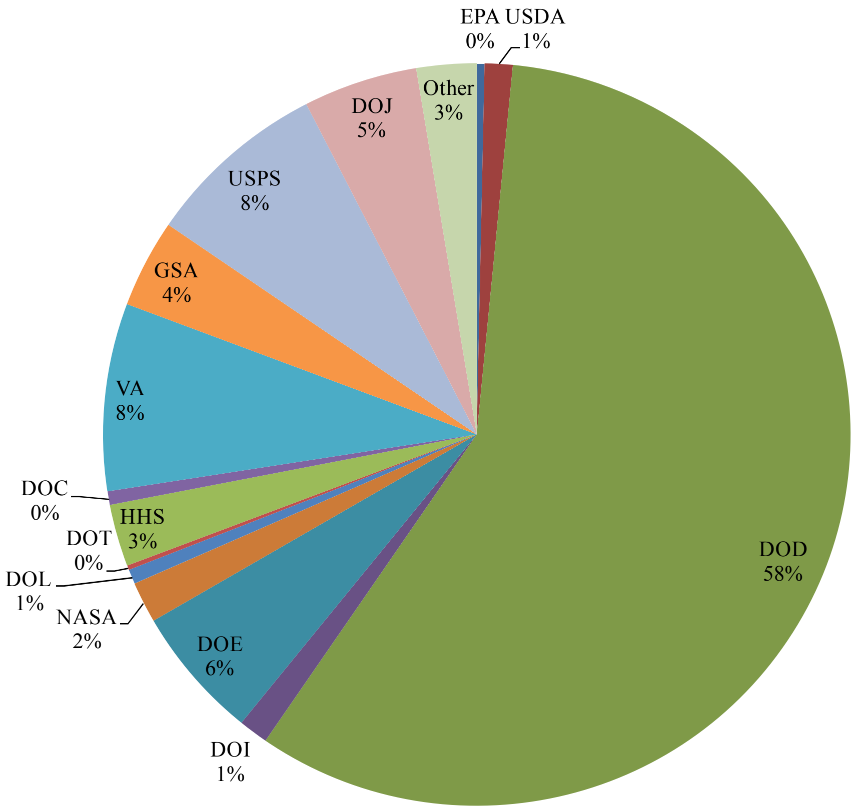
*green denotes products that were considered “FEMP-designated” for most or all of the analysis period

Appendix D: Background Information and Additional Results for Federal Agencies

This appendix provides background information on building energy use and procurement by federal agencies, including: the share of federal building energy consumption accounted for by major agencies (Figure 15); the distribution of major building types across departments and agencies (Figure 17); an analysis of the progress the federal sector is making towards its mandated energy savings of 30% over the ten years ending in 2015, as codified in the Energy Independence and Security Act (EISA) of 2007; and a model of the federal procurement system as it relates to energy-consuming products.

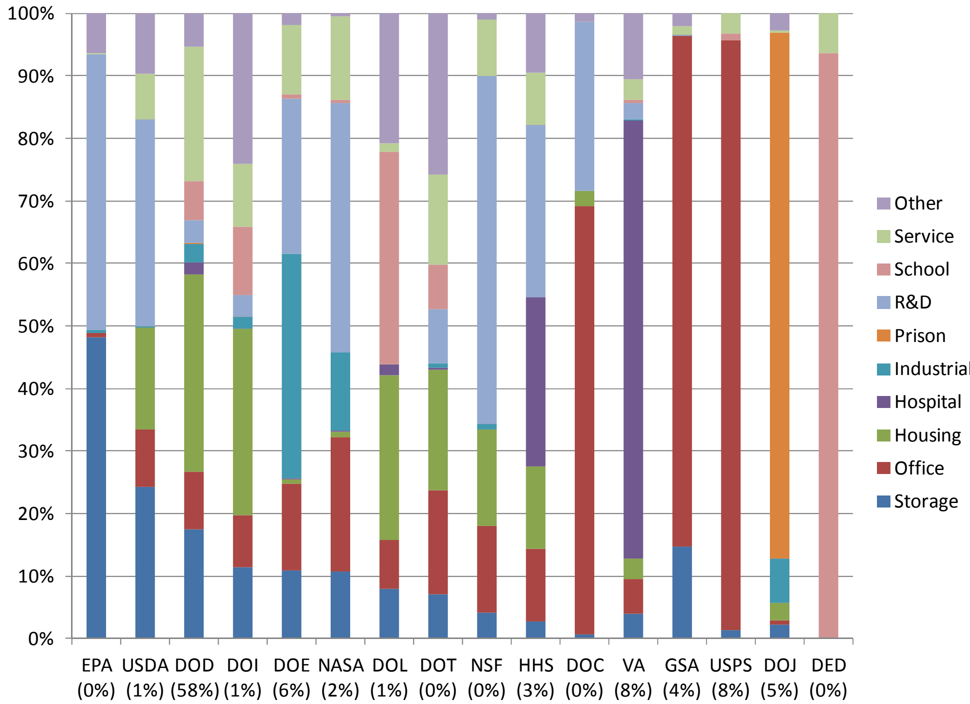
Federal Agency Energy Use and Building Types

Figure 15: Percentage of building energy use by federal agencies



Agency	2011 Building Energy Cost ($ million)
DOC	60
DOD	3,899
DOE	426
DOI	124
DOJ	195
DOL	42
DOT	146
EPA	21
GSA	424
HHS	169
NASA	148
USDA	74
USPS	578
VA	499
Other	262

Figure 16: Major federal departments and independent agencies according to share of federal energy consumption and distribution of building type



Source: Author calculations based on data on federal energy usage compiled by Pacific Northwest National Labs from reports to Congress under FEMP. Source of total building floor space by Federal agency: 2007 Annual Report to Congress. Source of break down of floor space by major building type: 2000 Federal facility data base.
Note: Percentage in parentheses below the agency abbreviation is each agency's approximate share of total federal energy consumption.

Federal Energy Reduction Goals

Executive Order (EO) 13423, signed in January 2007, required federal agencies to reduce energy intensity by 3% each year, leading to a 30% by 2015 compared to a 2003 baseline. This goal was ratified to law by the Energy Independence and Security Act of 2007, which modified Section 543(a)(1) of the National Energy Conservation Policy Act to include the requirement that "each agency shall apply energy conservation measures to, and shall improve the design for the construction of, the Federal buildings of the agency (including each industrial or laboratory facility) so that the energy consumption per gross square foot of the Federal buildings of the agency in fiscal years 2006 through 2015 is reduced, as compared with the energy consumption per gross square foot of the Federal buildings of the agency in fiscal year 2003." Annual federal energy use, in terms of energy intensity per square foot of building floor space, and the required energy intensity to meet the EISA energy reduction goal are listed by year in Table 15.

Annual federal energy use, in terms of energy intensity per square foot of building floor space, and the required energy intensity to meet the EISA energy reduction goal are listed by year in Table 15. Depending on the method used to quantify average annual energy intensity, the federal government as a whole began to fall short of target energy intensity in either 2008 or 2010.

Table 15: Annual federal energy use and EISA 2007 energy goals

Year	Annual average Btu/sqft (with credits)[a]	Annual average Btu/sqft (without credits)[a]	Annual goal Btu/sqft
2003	125,958	125,958	125,958
2004	115,657	116,975	124,699
2005	111,778	115,372	123,859
2006	114,085	118,332	122,179
2007	112,915	117,495	118,401
2008	110,913	114,694	114,622
2009	110,062	114,697	110,843
2010	107,751	113,105	107,065
2011	105,253	109,360	103,286
2012	--	--	99,507
2013	--	--	95,728
2014	--	--	91,950
2015	--	--	88,171

[a] Two methods of tracking progress toward the energy goals are used: one subtracts source energy savings and use of renewable energy from agency totals ("with credits"), one considers only total agency site energy use, regardless of energy source ("without credits"). Shaded cells represent years in which the annual energy use goal was not met. Source: Author calculations based on data on federal energy usage compiled by Pacific Northwest National Labs from reports to Congress under FEMP.

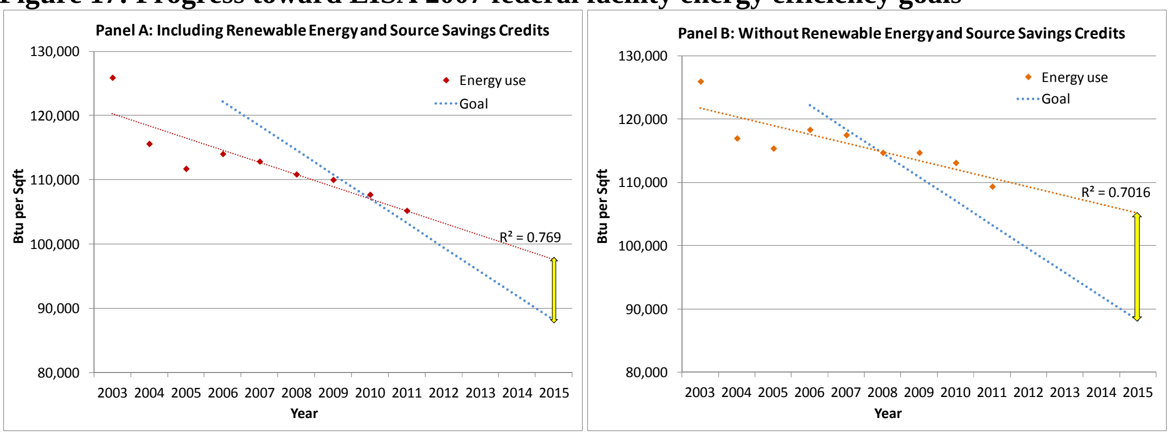
As shown in Figure 17, federal energy use was greater than the annual target set out in the EISA energy reduction goals in both 2010 and 2011. In 2010, energy use was 687 Btu/sqft higher than the target; in 2011, energy use was 1,968 Btu/sqft higher than the target. Given the current size of federal floor space, these energy intensities translate to missed saving of 2 TBtu/yr in 2010 and 6 TBtu/yr in 2011 applying the "with credits" metric; 18 TBtu/yr in 2010 and 21 TBtu/yr in 2011 applying the "without credits" metric). For comparison, Table 11and Table 15 are based on the "without credits" metric.

Figure 17, Panel A displays annual energy use (red diamonds) and the annual target energy use (blue line). Though efforts were quite strong in early years, the general trend in energy reduction has not matched the required trajectory to reach the EISA 2007 goal of a 30% reduction in 2015. Annual energy use is projected linearly (red line) to estimate, at current rates of conservation, how 2015 energy use will compare with the EISA 2007 energy reduction goal. Without additional efforts to reduce energy use, the 2015 target can be expected to be missed by 9,423 Btu/sqft, which is equivalent to approximately 28.7 TBtu/yr, based on current estimates of federal floor space (yellow arrow).

The above estimates include renewable energy purchases and source savings as credits toward the reduction goal. Excluding these and considering only site energy savings through efficiency improvements and other conservation measures, achieving the goal appears much less likely (Figure 17 Panel B), with annual energy use projected to exceed the goal by 51.8 TBtu/yr in 2015.

Compared to the amount by which the energy reduction goals have been missed in the past two years or are projected to be missed in 2015, increasing compliance with federal energy efficient procurement requirements to benefit from these previously forgone energy savings appears to be a viable method to improve the rate of federal energy reduction and increase the likelihood of meeting the target energy intensity in 2015.

Figure 17: Progress toward EISA 2007 federal facility energy efficiency goals



Concept Mapping of Federal Procurement of Energy-Consuming Products

The variation in agency mission and energy consumption described above indicates that the purchase of the wide variety of products covered by the FEMP EEPP is unlikely to be uniform across the federal sector. Indeed, interview studies with a sample of officials involved in federal contracting indicate that procurement activities are organized quite differently across agencies (Alliance to Save Energy 2012). There is great potential for variation in the people, products, and processes of purchase for energy-consuming products in the federal sector. An improved understanding of this variation could not only help the FEMP EEPP target its resources more strategically and increase its effectiveness, but also inform the development of the policy lever of public sector procurement for climate and energy goals more generally. The first step in doing this was to establish the vocabulary and known trends of the system in which the FEMP EEPP operates through a review of: the literature on public sector procurement generally, relevant sections of the FAR, and previous research on federal sector energy-consumption.

Actors. A large variety of actors potentially play roles in the purchase of energy-consuming products in the federal sector. Perhaps only two are involved in every purchase, by definition: the "end-user," who is the employee that will need the product to perform his or her government duties; and the "manufacturer" of the product. Since manufacturers typically deliver their products to customers (end-users) via "vendors," these actors also play a prominent role in most purchases, regardless of the type of product.

Other actors involved in meeting the purchasing needs of government employees are more specific to the federal procurement system. This system is commonly depicted as having five core elements which involve many different actors: (1) high-level policy making and management; (2) authorization and appropriation; (3) procurement regulations; (4) procurement functions in operations; and (5) feedback (see, e.g., Thai 2001).[19] A number of actors within the "procurement functions in operations" element will be involved to varying degrees in energy-consuming product purchases for end-users. Although these actors have a range of titles (see footnote 19), for simplicity they can be referred to collectively as "procurement officials." Note that the literature on public sector procurement consistently points to the many competing demands on procurement officials. Memorably, Thai (2001) groups these demands between "procurement goals," such as "quality, timeliness, cost…, minimizing business, financial, and technical risks, maximizing competition, and maintaining integrity," and "non-procurement goals," such as "economic goals (preferring domestic or local firms), environment protection or green procurement …, social goals (assisting minority and woman-owned business concerns), and international relations goals."

Procurement officials handle a wide variety of products, but some energy-consuming products may be purchased by third-parties that provide ongoing services to the federal government. One example of such a "service vendor" would be an energy service company (ESCO) which might purchase products covered by the FEMP EEPP (e.g., commercial and industrial equipment) through the course of designing and implementing energy efficiency projects for government facilities.

Pathways. There are multiple channels through which a product can be purchased for an end-user in the federal government. The largest distinction between these "pathways" is whether there is a role for the procurement official as part of the transaction: end-users can purchase products directly from vendors through rapid purchasing techniques like purchase cards and electronic procurement (referred to here as "direct" pathways); or they can purchase products

[19] "Policy-making and management" in the U.S. primarily occurs from congressional laws and oversight (especially through the GAO), as well as through executive orders and guidance as to the "make or buy" decision of whether government functions should be performed in-house or via external contract. "Authorization and appropriations" are performed by Congress, with input from agencies. "Procurement regulations" include the FAR (which is developed and maintained through an executive agency, the Office of Federal Procurement Policy, with assistance from three Acquisition Regulatory Councils representing departments and agencies) and agency supplements that are consistent with the FAR. "Procurement functions in operations" are conducted by a variety of professionals, including: senior procurement executives; contracting officers; contract specialists; contract negotiators; contract administrators; contract price/cost analysts; contract termination specialists; procurement analysts; buyers; procurement officers; program managers, etc. These professionals are often directly involved in the purchase of "goods, services, and capital assets as authorized and funded" as well as in ensuring compliance with applicable regulations. Procurement operations can occur at multiple organizational levels, including sub-agency operations and more centralized agency procurement offices. "Feedback" comes from procurement professionals within departments and agencies, as well as from government organizations tasked with oversight. See Thai (2001) for more detail.

indirectly from vendors through the cooperation of procurement officials who can issue purchase orders and solicit product and service contracts (referred to here as "indirect" pathways).[20] Table 16 illustrates the comparative volume and expenditures associated with two of these pathways, the direct pathway of p-cards and the indirect pathway of contracts (procurements reported through Standard Forms 281 and 279 are all contracts).

Table 16: Procurements by reporting method

Reporting Method	**# of Purchases**	**Dollars/Purchase**	**Million Dollars**
Purchase Cards	23,343,003	$523	$12.23
Standard Form 281* (<=$ 25,000)	9,328,187	$1,644	$15.34
Standard Form 279* (>$25,000)	519,780	$391,528	$203.50
Total	33,190,879		$231.07

Source: Thai (2001)

Concept Map. We synthesized this material and generated an initial "concept map" to capture what we believed were the key actors, pathways, and relationships involved in the purchase of energy-consuming products in the federal system (Novak 1998). We then shared the resulting concept map with a focus group of a dozen FEMP EEPP experts (with an additional telephone interview conducted a week later) and modified the concept map in order to reflect the shared understanding of the group. Figure 18 presents the modified figure, which was incorporated into the interview protocol with federal procurement officials.

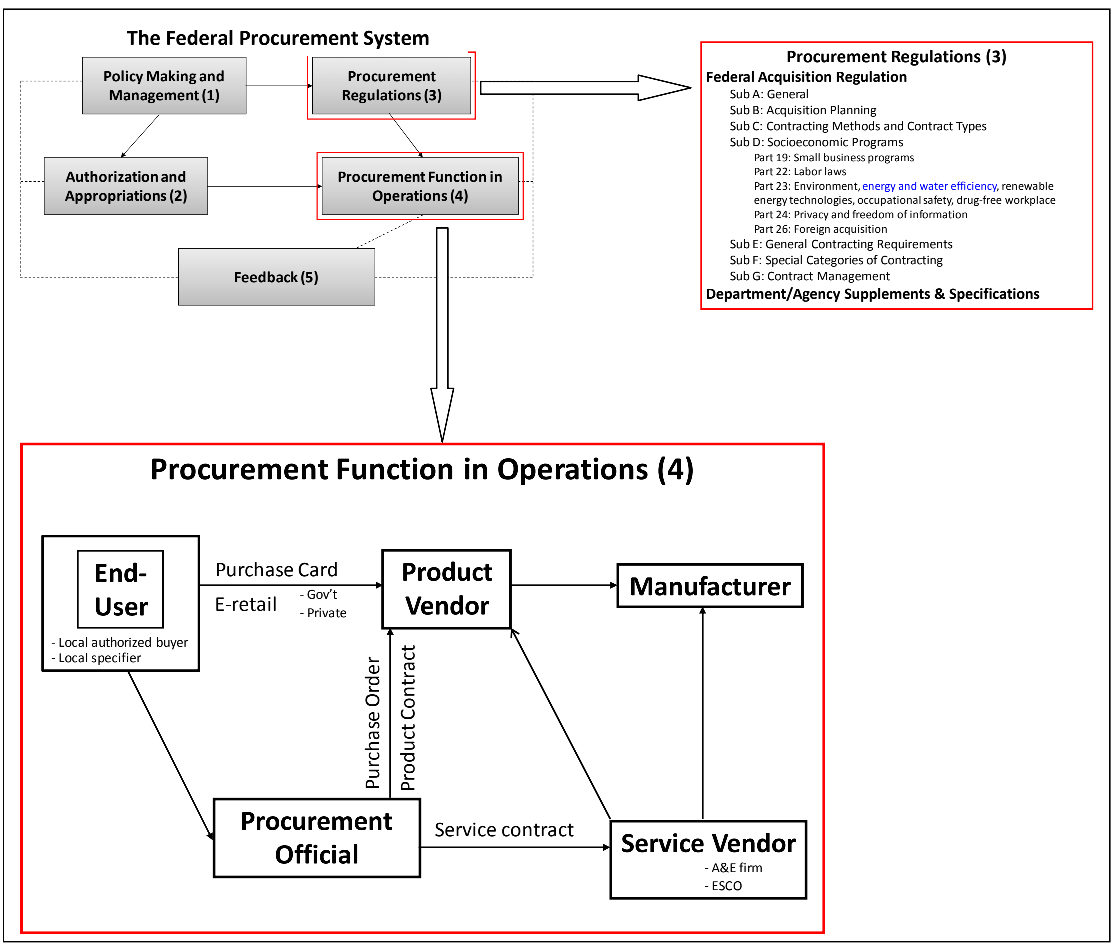
This concept map has three parts. First, the upper left hand part represents the five core elements of the general federal procurement system. Second, the upper right hand part breaks out the third element of the procurement system, "procurement regulations." It presents the major sections of the FAR, with a special emphasis on the distinction between "procurement goals" (sub-sections A, B, C, E, F, and G) and "non-procurement goals" (sub-section D, with only one of its parts related to energy and water efficiency in a cluster of affirmative acquisition goals that includes occupational safety and a drug-free workplace). It also provides a placeholder for agency supplemental regulations. Finally, as a result of the focus group with FEMP EEPP

[20] A "purchase card" is a business credit card that is primarily used for micro-purchases under $3,000. "Electronic procurement" (or "e-procurement") refers to the use of internet-based systems to search for, source, negotiate, order, and track purchases, usually through portals that have pre-competed products, such as GSAadvantage Vaidya, K., S. A. Sajeev, et al. (2006). "Critical Factors that Influence e-Procurement Implementation Success in the Public Sector." Journal of Public Procurement **6**(1&3): 70-99. A "purchase order" is "an offer by the government to buy supplies or services, including construction and research and development, upon specified terms and conditions, using simplified acquisition procedures" (FAR 2.101). A "contract" is a "mutually binding legal relationship obligating the seller to furnish the supplies or services (including construction) and the buyer to pay for them." (FAR 2.101). In this paper, we distinguish between "product contracts' and "service contracts" based on the presence or absence of service vendors in the procurement. Much of construction is done via contract, with solicitation of contract bids by vendors.

experts, the upper right hand part of the concept map also includes a call-out to the guide and/or master specifications put together centrally by some agencies.[21]

The bottom part of the concept map, which breaks out the fourth element of the procurement system, "procurement functions in operations," represents the bulk of the activity that occurs in order to meet end-user needs for energy-consuming products in the federal sector. It represents actors in boxes and purchasing pathways as labels on arrows that link actors. Note that the box "orbiting" the end-user box represent two actors that operate in the purchase process at a level that is administratively closer to the end-user than the more centralized operations overseen by procurement officials. The first of these actors, the "local authorized buyer," represents authorized p-card holders and similar actors who may undertake direct purchases on behalf of the end-user. The second of these actors, the "local specifier," represents those who are tasked with maintaining federal facilities and who therefore play a role in defining purchase needs for items such as construction and industrial equipment (e.g., boilers, chillers, etc.), which many end-users benefit from.

Figure 18: Model of federal procurement for energy-consuming products that emerged from focus group discussion amongst FEMP EEPP experts



[21] These specifications provide explicit requirements for materials and equipment to be used in construction or renovation of federal facilities (e.g., the Unified Facilities Guide Specifications, the Federal Guide for Green Construction, etc.)

Detailed Analysis Results by Federal Agency

Table 17. Department of Defense: Energy, Energy Cost and CO2 Savings (2015)

Product	$ Million / yr						Tbtu / yr						Million Ton CO_2 / yr					
	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F
Commercial and Industrial Equipment	1.6	1.8	37.1	67.8	134.9	285.4	0.1	0.1	2.3	4.1	7.9	14.7	0.0	0.0	0.2	0.4	0.8	1.9
Lighting and Fans	2.1	2.1	40.8	69.8	111.2	123.6	0.1	0.1	1.6	2.8	4.3	4.8	0.0	0.0	0.3	0.5	0.8	0.9
Office Equipment	1.0	1.0	41.1	46.7	47.5	78.9	0.0	0.0	1.6	1.8	1.8	3.0	0.0	0.0	0.3	0.3	0.3	0.5
Food Service Equipment	0.0	0.0	18.1	31.1	41.4	59.1	0.0	0.0	1.5	2.5	3.3	4.6	0.0	0.0	0.1	0.2	0.3	0.4
Residential Equipment	-	0.8	9.4	16.7	30.0	43.8	-	0.0	0.6	1.0	1.8	2.8	-	0.0	0.1	0.1	0.2	0.3
Home Electronics	-	0.0	5.1	6.7	8.4	10.8	-	0.0	0.2	0.3	0.3	0.4	-	0.0	0.0	0.0	0.1	0.1
Commercial Appliances	-	-	0.2	0.3	0.3	0.5	-	-	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0
Residential Appliances	-	0.3	6.5	9.1	13.7	29.2	-	0.0	0.3	0.4	0.6	1.2	-	0.0	0.0	0.1	0.1	0.2
Plumbing Products	-	-	4.1	6.9	7.7	25.7	-	-	0.3	0.5	0.5	1.4	-	-	0.0	0.0	0.1	0.2
Total	4.7	6.2	162.4	255.1	395.1	657.1	0.22	0.29	8.3	13.29	20.6	33.0	0.0	0.0	1.1	1.7	2.6	4.4

Table 18. General Services Administration: Energy, Energy Cost and CO2 Savings (2015)

Product	$ Million / yr						Tbtu / yr						Million Ton CO_2 / yr					
	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F
Commercial and Industrial Equipment	2.1	4.5	7.2	12.8	24.6	54.3	0.2	0.2	0.4	0.7	1.3	2.5	0.0	0.0	0.0	0.1	0.2	0.4
Lighting and Fans	4.4	3.5	7.1	12.6	20.2	22.3	0.1	0.1	0.3	0.5	0.8	0.9	0.0	0.0	0.0	0.1	0.1	0.2
Office Equipment	0.0	6.5	11.3	12.8	13.2	25.8	0.2	0.2	0.4	0.5	0.5	1.0	0.0	0.0	0.1	0.1	0.1	0.2
Food Service Equipment	0.0	1.2	2.2	3.8	5.1	7.5	0.1	0.1	0.2	0.3	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.1
Residential Equipment	0.0	0.1	0.2	0.3	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Home Electronics	0.0	0.3	1.2	1.5	1.7	2.3	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Appliances	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential Appliances	0.0	0.1	0.1	0.2	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plumbing Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.5	16.1	29.4	44.0	65.6	113.5	0.7	0.7	1.3	2.0	3.0	5.0	0.1	0.1	0.2	0.3	0.4	0.8

Table 19. Department of Veterans Affairs: Energy, Energy Cost and CO2 Savings (2015)

Product	$ Million / yr						Tbtu / yr						Million Ton CO_2 / yr					
	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F	L	L-B	M	T	F	BA-F
Commercial and Industrial Equipment	1.6	1.7	2.7	4.9	9.9	20.7	0.1	0.1	0.2	0.3	0.6	1.1	0.0	0.0	0.0	0.0	0.1	0.1
Lighting and Fans	1.4	1.4	3.0	5.2	8.6	9.5	0.1	0.1	0.1	0.2	0.3	0.4	0.0	0.0	0.0	0.0	0.1	0.1
Office Equipment	1.7	1.7	2.9	3.3	3.4	5.7	0.1	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Food Service Equipment	1.1	1.1	1.9	3.3	4.4	6.6	0.1	0.1	0.1	0.2	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Residential Equipment	0.0	0.2	0.3	0.6	1.0	1.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Home Electronics	0.0	0.2	0.4	0.5	0.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Appliances	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential Appliances	0.0	0.1	0.1	0.2	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plumbing Products	0.0	0.0	0.1	0.2	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.7	6.2	11.6	18.4	28.4	46.1	0.3	0.3	0.6	1.0	1.5	2.3	0.0	0.0	0.1	0.1	0.2	0.3

Appendix E: Estimated Annual Federal Purchases

FEMP product category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Compact Fluorescent Lamps (Light Bulbs)	650,119	676,730	689,280	678,779	695,248	671,202	657,474	660,111	640,550	617,998	595,446
Fluorescent (Tube) Lamps	8,278,788	8,586,719	8,820,202	9,011,457	8,775,367	8,667,357	8,635,699	8,585,554	8,494,134	8,382,710	8,271,286
Fluorescent Ballasts	2,099,816	2,177,902	2,237,130	2,285,665	2,225,815	2,198,441	2,190,415	2,177,705	2,154,527	2,126,279	2,098,032
Exit Signs	230,291	239,265	245,595	250,401	243,090	239,618	238,687	237,081	234,356	230,972	227,587
Decorative Light Strings	7,239	7,521	7,720	7,871	7,641	7,532	7,503	7,453	7,367	7,261	7,154
Ceiling Fans	71,695	74,507	75,341	72,337	70,827	67,240	64,969	65,792	62,863	59,537	56,210
Commercial Central Air Conditioners	13,937	14,519	14,920	15,196	14,694	14,460	14,399	14,290	14,116	13,893	13,670
Commercial Air-Source Heat Pumps	1,455	1,511	1,550	1,581	1,537	1,516	1,510	1,500	1,483	1,463	1,442
Air-Cooled Chillers	393	406	416	425	416	411	410	408	404	399	394
Water-Cooled Chillers	393	406	416	425	416	411	410	408	404	399	394
Commercial Boilers	680	708	727	741	717	706	703	698	689	678	668
Distribution Transformers	7,898	7,945	8,006	8,062	8,112	8,143	8,154	8,146	8,127	8,107	8,086
Motors	3,765	3,914	4,032	4,124	4,005	3,956	3,940	3,917	3,875	3,823	3,770
Commercial Water Heater	4,126	4,233	4,517	4,413	3,774	3,931	4,084	4,238	4,392	4,545	4,699
Commercial Dishwashers	4,344	4,368	4,408	4,455	4,472	4,460	4,416	4,348	4,281	4,217	4,153
Commercial Fryers	3,092	3,146	3,217	3,290	3,688	3,741	3,784	3,818	3,850	3,884	3,918
Commercial Griddles	2,111	2,145	2,188	2,233	2,274	2,307	2,333	2,355	2,374	2,395	2,416
Commercial Hot Food Holding Cabinets	806	830	845	862	848	840	837	834	825	816	807
Commercial (Air-Cooled) Ice Machines	2,172	2,256	2,316	2,361	2,292	2,260	2,251	2,236	2,210	2,178	2,146
Commercial Ovens	7,018	7,129	7,274	7,424	7,560	7,668	7,757	7,827	7,892	7,962	8,032
Commercial Refrigerators & Freezers	2,783	2,892	2,969	3,027	2,937	2,895	2,883	2,864	2,831	2,790	2,748
Commercial Steam Cookers	1,152	1,137	1,122	1,104	1,099	1,105	1,115	1,130	1,141	1,150	1,160
Water-Cooled Ice Machines	2,172	2,256	2,316	2,361	2,292	2,260	2,251	2,236	2,210	2,178	2,146
Pre-Rinse Spray Valves	13,031	13,105	13,223	13,364	13,416	13,379	13,249	13,044	12,844	12,651	12,459
Family-Size (Commercial) Clothes Washers	3,214	3,187	3,159	3,156	3,142	3,119	3,095	3,068	3,044	3,025	3,006
Desktop (Personal) Computer	319,131	330,111	340,396	350,784	345,216	343,570	342,634	341,745	339,232	336,436	333,639

FEMP product category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Computer Monitor	632,241	653,993	674,369	694,950	683,918	680,658	678,804	677,042	672,063	666,523	660,984
Enterprise (Computer) Servers	91,293	100,085	110,615	121,145	131,675	142,205	150,629	156,947	161,159	163,265	165,371
Notebook (Laptop) Computers - Tablet PCs	283,003	292,740	301,860	311,073	306,135	304,676	303,845	303,057	300,828	298,348	295,869
Docking Stations	60,395	62,285	64,226	66,186	65,135	64,825	64,648	64,480	64,006	63,478	62,951
(Computer) Printer	233,821	242,343	249,778	256,830	251,833	250,088	249,328	248,439	246,384	243,991	241,598
Fax Machine	33,850	34,909	35,997	37,095	36,507	36,333	36,234	36,140	35,875	35,579	35,284
Copier	23,578	24,392	25,150	25,913	25,495	25,369	25,299	25,232	25,045	24,835	24,626
Scanners	3,627	3,740	3,857	3,975	3,911	3,893	3,882	3,872	3,844	3,812	3,780
Multifunction Devices	172,730	178,135	183,685	189,291	186,286	185,398	184,893	184,413	183,057	181,548	180,039
Mailing Machines	2,901	2,992	3,085	3,180	3,129	3,114	3,106	3,098	3,075	3,050	3,024
Televisions	44,755	46,499	47,729	48,663	47,242	46,568	46,387	46,075	45,545	44,887	44,230
Digital Video Display (DVD) Players	39,640	41,185	42,274	43,102	41,843	41,246	41,085	40,809	40,340	39,757	39,175
Phones	406,441	420,424	433,523	446,753	439,662	437,566	436,374	435,241	432,040	428,479	424,918
Residential Refrigerators	137,907	141,957	142,275	140,779	138,236	134,151	132,658	132,323	129,264	125,965	122,666
Residential Freezers	5,395	5,606	5,669	5,443	5,329	5,059	4,888	4,950	4,730	4,480	4,229
Residential Dishwashers	14,461	15,028	15,196	14,591	14,286	13,562	13,104	13,270	12,680	12,009	11,338
Clothes Washers	20,689	21,501	21,742	20,875	20,439	19,404	18,748	18,986	18,141	17,181	16,221
Room Air Conditioners	12,772	13,276	13,471	13,111	12,807	12,264	11,937	12,030	11,589	11,085	10,580
Dehumidifiers	4,062	4,222	4,269	4,099	4,013	3,810	3,681	3,728	3,562	3,374	3,185
Room Air Cleaners	5,417	5,629	5,692	5,465	5,351	5,080	4,908	4,971	4,749	4,498	4,247
Microwave Ovens	39,366	40,579	41,267	40,511	39,757	38,338	37,441	37,727	36,521	35,158	33,795
(Residential) Central Air Conditioners	14,801	15,398	15,641	15,262	14,882	14,269	13,907	13,999	13,505	12,936	12,366
(Residential) Air-Source Heat Pumps	2,112	2,194	2,219	2,131	2,086	1,980	1,914	1,938	1,851	1,754	1,656
(Residential Gas) Furnaces	6,850	7,119	7,198	6,911	6,767	6,306	5,977	5,949	5,569	5,274	4,979
(Residential) Boilers	841	873	883	848	830	788	762	771	737	698	659
Electric Storage Water Heaters	10,888	11,274	11,456	11,202	11,019	10,605	10,332	10,433	10,076	9,676	9,275
(High Efficiency) Gas Storage Water Heaters	13,146	13,662	13,815	13,264	12,987	12,329	11,913	12,064	11,527	10,917	10,307
(Residential) Lavatory Faucets	87,893	91,340	92,363	88,680	86,829	82,431	75,568	72,499	64,831	56,674	56,674
Showerheads	72,363	75,202	76,044	73,012	71,487	67,866	62,217	59,690	53,376	46,661	46,661

Appendix F: Product-specific Assumptions

While we attempt to keep estimation procedures consistent and uniform across appliance and equipment types, our ability to do so is limited by the data available. Where RECS and CBECS do not provide all the information needed to estimate product density, estimation methods may differ across products. Key assumptions for each product are listed below:

RESIDENTIAL APPLIANCES

Single family product density (CAC/household) is estimated from RECS and applied to the number of federal residential units (from GSA and DOD). We implicitly assume that federally owned family residential housing is not significantly different than other residential housing, on average.

Residential Refrigerators

1) As in the 2000 study, residential refrigerators are categorized as full-sized or compact. Based on RECS data, refrigerators with cooled volume less than 6.5 cubic feet are categorized as compact (U.S. Energy Information Agency 2009)
2) Full size refrigerator energy savings taken from Energy Star cost savings calculator, top mount freezer (106 kWh/yr) (U.S. Environmental Protection Agency 2012a)
3) Compact refrigerator energy savings (46 kWh/yr) from refrigerator standards Technical Support Document (U.S. Department of Energy 2011a)
4) Lifetime (17.4 yrs full size, 5.6 compact) from refrigerator standards Technical Support Document (U.S. Department of Energy 2011a)
5) Max tech annual energy use from Energy Star qualified refrigerators list, savings (222 kWh/yr full size, 108 kWh/yr compact) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Residential Freezers

1) Energy savings (67 kWh/yr) taken from Energy Star cost savings calculator, using default values (U.S. Environmental Protection Agency 2012a)
2) Lifetime (22.3 yrs) from refrigerator standards Technical Support Document (U.S. Department of Energy 2011a)
3) Max tech annual energy use from Energy Star qualified freezers list, savings (387 kWh/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Dehumidifiers

1) Lifetime and energy savings (12 yrs, 213 kWh/yr) taken from Energy Star cost savings calculator, using default values (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy use from Energy Star qualified dehumidifiers list, savings (290 kWh/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Room Air Conditioners

1) From RECS, in homes cooled primarily with RAC, there is on average 1 RAC per 1,181 sqft of space; for federal non-residential space cooled primarily with RAC, this same product density is assumed (U.S. Energy Information Agency 2009)
2) Lifetime (10.5 yrs) from room air conditioner efficiency standard Technical Support Document (U.S. Department of Energy 2011b)
3) Energy savings (125 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)

4) Max tech annual energy use from Energy Star qualified room air conditioners list, savings (147 kWh/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Residential Dishwashers

1) Lifetime and energy savings (13 yrs, 74 kWh/yr with electric water heating, 33 kWh/yr and 2 therms/yr with gas water heating) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
3) Max tech annual energy use from Energy Star qualified dishwashers list, savings (188 kWh/yr with electric water heating, 84 kWh/yr and 5 therms/yr with gas water heating) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Residential Clothes Washers

1) Lifetime and energy savings from Energy Star cost savings calculator (13 yrs, 141 kWh/yr with electric water heating, 24 kWh/yr and 6 therms/yr with gas water heating) (U.S. Environmental Protection Agency 2012a)
2) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
3) Max tech annual energy use from Energy Star qualified clothes washers list, savings (237 kWh/yr with electric water heating, 40 kWh/yr and 10 therms/yr with gas water heating) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Microwave Ovens

1) Assuming that microwaves in residential housing are purchased by the occupant, not through federal procurement channels
2) CBECS does not include the presence of microwaves in commercial buildings. Assuming 1 microwave per residential-style refrigerator plus 1 per commercial kitchen.
3) It is possible that microwaves used in commercial buildings are also purchased individually by occupants, not through federal procurement channels.
4) FEMP low standby product; requires 2w or less in standby, baseline 3w standby power consumption, so assume 1w savings constantly (8.76 kWh/yr) (Lawrence Berkeley National Laboratory 2012; U.S. Department of Energy Federal Energy Management Program 2012)
5) Max tech savings (30 kWh/yr) estimated from difference between average and minimum standby power (Lawrence Berkeley National Laboratory 2012)

RESIDENTIAL EQUIPMENT

Residential Central Air Conditioners

1) From RECS, average single family residential home (including attached and detached) is 2,775 sqft; for federal non-residential buildings using residential CAC for primary cooling, 1 residential CAC per 2,775 sqft of space is assumed (U.S. Energy Information Agency 2009)
2) Lifetime and energy savings (14 yrs, 1024 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified residential CAC list, savings (1500 kWh/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Residential Air-Source Heat Pump

1) Assuming 0.9 of total heat pumps are air-source rather than ground-source
2) Energy savings (2888 kWh/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Lifetime (16.24 yrs) from furnace, central air conditioner and heat pump efficiency standard TSD (U.S. Department of Energy 2011c)
4) Max tech annual energy use from Energy Star qualified residential heat pump list, savings (3071 kWh/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Residential Boilers

1) RECS does not specifically note the use of boilers, but does identify fuel type and whether heat is provided by steam. We assume that steam heat indicates the use of a residential boiler.
2) Energy Star specifications state that a qualified boiler (85% AFUE) is 6% more efficient than models that meet the minimum efficiency standard (U.S. Environmental Protection Agency 2012a)
3) At 85% AFUE, boiler uses on average 72 MMBtu (720 therms) per year; Energy Star boiler assumed to use 6% less, or 677 therms/yr, so 43 therms/yr saved with Energy Star boiler (U.S. Department of Energy 2007; U.S. Environmental Protection Agency 2012a)
4) Lifetime assumed to be 25 years (U.S. Department of Energy 2007)
5) Max tech annual energy use from Energy Star qualified residential boiler list, savings (50 therms/yr) estimated based on boiler standard Technical Support Document baseline energy use (U.S. Department of Energy 2007)

Residential Gas Furnaces

1) Energy savings (73 therms/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Lifetime (23.6 yrs) from furnace, central air conditioner and heat pump efficiency standard TSD (U.S. Department of Energy 2011c)
3) Max tech annual energy use from Energy Star qualified residential furnace list, savings (113 therm/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

High Efficiency Gas Storage Water Heater

1) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
4) Lifetime and savings (13 yrs, 37 therms/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
5) Max tech annual energy use from Energy Star qualified gas storage water heater list, savings (78 therm/yr) estimated based on Energy Star cost calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Electric Storage Water Heater

1) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
2) Lifetime and savings (13 years, 246 kwh/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)
3) Max tech annual energy use from Energy Star qualified electric storage water heater list, savings (371 kWh/yr) estimated based FEMP cost effectiveness example baseline energy use (U.S. Department of Energy Federal Energy Management Program 2012)

Gas Tankless Water Heater

1) Of the general market for gas water heaters, tankless represented approximately 2.6% in 2006 (U.S. Environmental Protection Agency 2007a)
2) Lifetime assumed 13 years, as with other types of water heaters (U.S. Department of Energy 2010c)
3) Additional savings above gas storage water heater (41 therms/yr) from Energy Star criteria and cost savings calculator (U.S. Environmental Protection Agency 2007a)
4)

Electric Heat Pump Water Heater

1) In 2006, fewer than 2000 heat pump water heaters were shipped per year in the U.S. We assume 0 were purchased for use in federal residential buildings (U.S. Environmental Protection Agency 2007a)
2) Lifetime assumed 13 years, as with other types of water heaters (U.S. Department of Energy 2010c)
3) Additional savings above electric storage water heater (2526 kWh/yr) from Energy Star criteria and cost savings calculator (U.S. Environmental Protection Agency 2012a)

Gas Condensing Water Heater

1) In 2006, gas condensing water heaters were generally not used in the residential sector. We assume 0 were purchased for use in federal residential buildings (U.S. Environmental Protection Agency 2007a)
2) Lifetime assumed 13 years, as with other types of water heaters (U.S. Department of Energy 2010c)
3) Additional savings above gas storage water heater (41 therms/yr) from Energy Star criteria and cost savings calculator (U.S. Environmental Protection Agency 2012a)

LIGHTING & FANS

The max tech scenarios for lighting require additional explanation. In these scenarios, we refer to the maximum savings that can be achieved by replacing baseline efficiency lighting with the highest available efficiency of the *same type* of lighting. Considerably higher savings could be achieved through changes in lighting type (e.g. conversion of all lighting to LED) or improved use of natural lighting in building design/renovation.

Fluorescent Tube Lamps

1) Though no FEMP efficiency specification is provided for fluorescent tube lamps as of September 2011, the savings that have accrued due to purchase of efficient fluorescent tube lamps over the period of years they were covered are considered in this analysis.
2) RECS notes only “efficient” lighting, which is assumed to mean fluorescent (either CFL or tube fluorescent) (U.S. Energy Information Agency 2009)
3) Lifetime and savings (7 yrs, 67 kWh/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)
4) FEMP energy savings values for ballasts modified so as not to double count savings from lamps
5) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)

Fluorescent Ballasts

1) RECS notes only “efficient” lighting, which is assumed to mean fluorescent (either CFL or tube fluorescent) (U.S. Energy Information Agency 2009)
2) Lifetime and savings (14 yrs, 50 kWh/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)
3) FEMP energy savings values for ballasts modified so as not to double count savings from lamps

4) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)

Fluorescent Luminaires

1) Lifetime and energy savings (15 yrs, 30 kWh/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)
2) RECS, CBECS notes only "efficient" lighting, which is assumed to mean fluorescent (either CFL or tube fluorescent) (U.S. Energy Information Agency 2003; U.S. Energy Information Agency 2009)
3) FEMP energy savings values for luminaires modified so as not to double count savings from lamps and ballasts
4) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)

Commercial and Industrial Luminaires

1) We take this category to represent all commercial and industrial luminaires except those for use with fluorescent tube lamps, which are covered separately in the category Fluorescent Luminaires
2) Lifetime from FEMP cost effectiveness example (15 yrs) (U.S. Department of Energy Federal Energy Management Program 2012)
3) CBECS categories CFL, HID, and incandescent combined to estimate the use of downlight luminaires. Commercial and industrial use cannot be disaggregated, so savings estimates reflect the combination of these uses (U.S. Energy Information Agency 2003)
4) Per unit savings (134 kWh/yr) are estimated based on FEMP cost effectiveness examples, weighting luminaire savings with CFL, incandescent, and metal halide lamps by their prevalence in the CBECS dataset (U.S. Department of Energy Federal Energy Management Program 2012)
5) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)
6) Adding these savings to CFL savings may result in some degree of double counting

Ceiling Fans

1) Number of ceiling fans estimated from RECS (U.S. Energy Information Agency 2009)
2) Lifetime and energy savings (10 yrs, 7 kWh/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Majority of savings from ceiling fans comes from replacing incandescent lights with CFL; savings for ceiling fans are estimated from Energy Star cost savings calculator, excluding CFL savings (and are quite small) (U.S. Environmental Protection Agency 2012a)
4) Savings from switching ceiling fan lights from incandescent to CFL are included in the total CFL savings
5) Max tech annual energy use from Energy Star qualified fan list, savings (36 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Compact Fluorescent Lamps

1) Number of CFLs is estimated from RECS (U.S. Energy Information Agency 2009)
2) Savings are based on the difference in energy use between a CFL bulb and an incandescent bulb providing the same level of illumination.
3) Commercial CFL energy and energy cost savings (67 kWh/yr) estimated using http://www.gelighting.com/na/home_lighting/products/pop_lighting_calc.htm

4) Residential CFL lifetime, energy and energy cost savings (5 years, 52 kWh/yr) (Harris and Johnson 2000)

Exit Signs

1) Total estimate of exit signs in the U.S. taken from Navigant niche lighting study, and adjusted for the federal percent of total commercial space to arrive at the federal product density estimate (Navigant Consulting Inc 2003)
2) Lifetime and energy savings from Navigant (10 yrs, 262 kWh/yr) (Navigant Consulting Inc 2003)
3) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)

Decorative Light Strings

1) Assuming 100 lamps per string, 4w for non-LED, 0.04w for LED, 150 operating hours per year (Navigant Consulting Inc 2003)
2) Assuming 0.01 strings per 1000 sqft commercial building floor space
3) Max tech savings estimated by assuming the same % efficiency improvement above baseline as average of the aggregate lighting product category (1.1 times more savings from max tech as from FEMP/Energy Star qualified)

Residential LED (Solid State) Lighting

1) Assuming that LED grows to 5% market share in 2015, with half of LED lights replacing CFLs and half replacing incandescent bulbs.
2) Based on the Energy Star list of qualified LED bulbs, LED lights are assumed to use 11.2 watts; at an average annual usage of 1000 hours, this corresponds to11 kwh/yr. From the Energy Star cost savings calculator, CFLs are estimated to use 21 kwh/, so savings achieved by switching to LED instead of CFL are 10 kwh/yr. If LEDs replace incandescent bulbs that would not have otherwise been replaced with CFLs, the energy savings will be several times greater. (U.S. Environmental Protection Agency 2012a)
3) The relevant lifetimes, in this case, are those of incandescent bulbs and CFLs, as this scenario assumes that they are replaced on failure by LEDs.

OFFICE EQUIPMENT

We assume that office equipment like computers and printers in federal single family and multifamily housing is purchased by the occupant, not the federal government, as is therefore not subject to FEMP procurement efficiency requirements.

Notebook (Laptop) Computers

1) 2010 Building Energy Data Book suggests that 47% of computer shipments are laptops and 53% are desktops; these ratios are applied to CBECS product densities (U.S. Department of Energy 2010a)
2) Lifetime and energy savings (4 yrs, 40 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified laptop computer list, savings (41 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Desktop Computers

1) 2010 Building Energy Data Book suggests that 47% of computer shipments are laptops and 53% are desktops; these ratios are applied to CBECS product densities (U.S. Department of Energy 2010a)

2) Lifetime and energy savings (4 yrs, 133 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified desktop computer list, savings (247 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Scanners

1) Total shipments ratio of scanners to computers used to estimate scanner product density (U.S. Department of Energy 2010a)
2) Lifetime assumed same as multifunction device (4 years)
3) Energy savings (5kWh/yr) from standby power database (Lawrence Berkeley National Laboratory 2012)
4) Max tech energy savings (19 kWh/yr) estimated from the difference of average and highest efficiency in standby power database (Lawrence Berkeley National Laboratory 2012)

Fax Machines

1) Product density assumed same as scanners (DOE 2010A)
2) Lifetime and energy savings (4 yrs, 46 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified fax list, savings (47 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Multifunction Devices

1) Total shipments ratio of scanners to computers used to estimate scanner product density (DOE 2010A)
2) Lifetime and energy savings (4 yrs, 46 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified multifunction device list, savings (90 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Copiers

1) Lifetime and energy savings (6 yrs, 129 kWh/yr) from Energy Star cost calculator (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy use from Energy Star qualified copier list, savings (244 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Printers

1) Lifetime and energy savings (5 yrs, 67 kWh/yr) from Energy Star cost calculator (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy use from Energy Star qualified printer list, savings (183 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Mailing Machines

1) Assuming 1 mailing machine per scanner, 5 year lifetime, and 1w energy savings constantly (8.76 kWh/yr)
2) Max tech savings (21 kWh/yr) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (2.38 times more savings from max tech as from FEMP/Energy Star qualified)

Docking Stations

1) Lifetime assumed same as laptop (4 years)

2) Energy savings estimate based on FEMP cost effectiveness calculation for monitors: 1w savings x 6000 hrs/yr x kw/1000w = 6 kWh/yr savings (U.S. Department of Energy Federal Energy Management Program 2012)
3) Assuming 0.1 docking stations per laptop
4) Max tech savings (14 kWh/yr) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (2.38 times more savings from max tech as from FEMP/Energy Star qualified)

Enterprise (Computer) Servers

1) CBECS data is not sufficient to estimate the number of enterprise servers used in federal buildings. The EPA report to Congress on data center energy efficiency provides an estimate of the total stock of enterprise servers in 2000 and 2010; this is weighted by the ratio of federal commercial floor space to total commercial floor space to arrive at our estimate of the number of federal enterprise servers. (U.S. Environmental Protection Agency 2007b)
2) Lifetime from Energy Star specifications for enterprise servers (5 yrs) (U.S. Environmental Protection Agency 2012a)
3) Energy savings approximated from Energy Star notes on enterprise server efficiency. The Energy Star website claims that an Energy Star server can save up to 1,000 kwh/yr; we conservatively assume that compliance with EEPP requirements will lead to 600 kwh/yr energy savings. (U.S. Environmental Protection Agency 2012a)
4) Note that energy efficiency specifications were developed for enterprise servers in 2009. The average 2005-2010 annual savings reported are substantially lower than the savings achieved in 2009 and 2010. The seemingly large jump in savings between 2010 and 2015 represents the relatively quick build up in efficient server stock (due to the 5 year expected lifetime) that occurs over the time period.
5) Max tech savings (1,428 kWh/yr) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (2.38 times more savings from max tech as from FEMP/Energy Star qualified)

HOME ELECTRONICS

We assume that home electronics in federal housing are generally purchased by the occupant, not the federal government, as are therefore not subject to FEMP EEPP requirements.

Televisions

1) Assumed 60 inch screen on average (used in conference rooms and other locations as a projector screen substitute)
2) From Energy Star qualified model list, 60 inch screen average annual energy use is approximately 172 kWh/yr
3) From Energy Star specifications, "an Energy Star qualified 60-inch television will be, on average, 60 percent more efficient than a standard model," so Energy Star savings estimated to be 258 kWh/yr
4) Assuming product density is the same as fax machines and scanners (U.S. Environmental Protection Agency 2012a)
5) Max tech annual energy use from Energy Star qualified TV list, savings (320 kWh/yr) estimated by applying ratio of highest to lowest efficiency on qualified list to estimated baseline – Energy Star savings (U.S. Environmental Protection Agency 2012a)

DVD Players

1) Assuming 0.62 DVD players per TV, based on product shipments data (Homan, Sanchez et al. 2010)

2) Energy savings (14 kWh/yr) and max tech energy savings (20 kWh/yr) estimated from sleep, idle, and play power consumption from Energy Star qualified model list and average sleep, idle, and play power consumption from LBNL standby power database (U.S. Environmental Protection Agency 2012a; Lawrence Berkeley National Laboratory 2012)
3) Assumed 19 hours per day sleep mode, 1 hour idle, 4 hours play mode

Phones and Answering Machines

1) We are not able to disaggregate the separate phone and answering machine products covered by FEMP; they are all treated as a single product group.
2) Assuming 0.675 phones products per computer
3) Lifetime and energy savings (4 yrs, 17.1 kWh/yr) from Energy Star savings calculator (U.S. Department of Energy 2012a)
4) Max tech savings (26.4 kWh/yr) from Energy Star qualified product list (U.S. Department of Energy 2012a)

COMMERCIAL & INDUSTRIAL EQUIPMENT

Commercial Central Air Conditioners

1) Assuming that CBECS cooling category "packaged cooling" indicates a commercial central air conditioner
2) We evaluate the savings of a stock of 10 ton units, with 1500 hrs/yr cooling
3) Lifetime and energy savings (15 yrs, 712 kWh/yr) from FEMP cost effectiveness calculator (U.S. Department of Energy Federal Energy Management Program 2012)
4) Max tech savings (3507 kWh/yr) from FEMP cost effectiveness calculator, best available (U.S. Department of Energy Federal Energy Management Program 2012)

Air Cooled Chillers

1) Lifetime and energy savings (23 yrs, 60,000 kWh/yr) from FEMP cost effectiveness calculator (U.S. Department of Energy Federal Energy Management Program 2012)
2) Assuming 50/50 split air cooled vs water cooled
3) We evaluate savings of the average of a 200 ton screw compressor chiller and a 60 ton scroll compressor chiller, with 1500 hrs/yr cooling, normalized to a 500 ton chiller (product density is in terms of 500 tons of cooling capacity)
4) Max tech energy savings (270,000 kWh/yr) from FEMP cost effectiveness calculator, best available (U.S. Department of Energy Federal Energy Management Program 2012)

Water Cooled Chillers

1) Lifetime and energy savings (23 yrs, 160,000 kWh/yr) from FEMP cost effectiveness calculator 1) (U.S. Department of Energy Federal Energy Management Program 2012)
2) Assuming 50/50 split air cooled vs water cooled
3) We evaluate the savings of the average of a 500 ton centrifugal chiller and a 250 ton screw compressor chiller, with 1500 hrs/yr cooling, normalized to a 500 ton chiller (product density is in terms of 500 tons of cooling capacity)
4) Max tech energy savings (235,000 kWh/yr) from FEMP cost effectiveness calculator, best available 1) (U.S. Department of Energy Federal Energy Management Program 2012)

Commercial Boilers

1) Lifetime and energy savings (25 yrs, 6250 therms) from FEMP cost effectiveness calculator (U.S. Department of Energy Federal Energy Management Program 2012)
2) We evaluate the savings of a stock of 5MMBtu boilers, with 1500 hrs/yr heating

3) Max tech energy savings (9856 therms/yr) from FEMP cost effectiveness example, best available (U.S. Department of Energy Federal Energy Management Program 2012)

Commercial Air-Source Heat Pumps

1) Lifetime and energy savings (15 yrs, 3502 kWh/yr) from FEMP cost effectiveness calculator (U.S. Department of Energy Federal Energy Management Program 2012)
2) We evaluate the savings of a stock of 10 ton heat pumps, with 1500 hrs/yr heating and 1500 hrs/yr cooling
3) CBECS notes use of heat pump, but does not specify the type; assuming 90% are air-source HP, rather than ground-source (U.S. Energy Information Agency 2003)
4) Max tech energy savings (8969 kWh/yr) from FEMP cost effectiveness calculator, best available (U.S. Department of Energy Federal Energy Management Program 2012)

Commercial Gas Storage Water Heaters

1) Product density cannot be estimated from CBECS, so we instead rely on 1992-2011 national shipments data from AHRI (http://www.ahrinet.org/commercial+storage+water+heaters+historical+data.aspx). We assume that federal purchases are 5% of total national shipments.
2) Lifetime and energy savings (10 yrs, 310 therms/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)
3) Max tech energy savings (400 therms/yr) from FEMP cost effectiveness example (U.S. Department of Energy Federal Energy Management Program 2012)

Motors

1) The stock and shipments of motors cannot be estimated in the same way as the majority of commercial products from CBECS data. We base our estimates on those used in Harris and Johnson (2000), which in turn rely on a report on motors in federal facilities. (Resource Dynamics Corporation 1994)
2) We follow Harris and Johnson (2000), representing the federal motor stock as 50-horsepower motors operated at 1800 rpm for 4000 full load hours per year.
3) The total estimated savings in Harris and Johnson (2000) suggests a total federal stock of approximately 68,000 motors. To project the federal stock in each year, we scale this stock of 68,000 motors by the ratio of each year's federal commercial floor space to the Harris and Johnson (2000) projection of federal floor space in 2010.
4) Energy savings at recommended efficiency level, energy savings at max tech, and lifetime (2,546 kWh/yr, 3,377 kWh/yr, 18 yrs) from Harris and Johnson (2000).

Distribution Transformers

1) The federal stock of distribution transformers is based on the national stock of transformers as estimated for the national impact analysis (NIA) of the distribution transformers minimum efficiency standards rulemaking (U.S. Department of Energy 2011d). The NIA provides an estimate of the total national stock of transformers in terms of megavolt-amperes (MVA) for the years 1990-2015. Based on the average annual change in transformer stock over this time period, we estimate national stock values for 1980 and 1985. We convert the annual totals to kilovolt-amperes (kVA) an d estimate the federal stock of transformers as 0.5% of the national total, based on the "government office" weighting used in the calculation of discount rates in the transformers rulemaking and the assumption that federal buildings are between 1/6 and 1/4 of total government buildings (U.S. Department of Energy 2011d; Harris and Johnson 2000)
2) To arrive at an estimate of the number of transformers in the federal stock, we build upon the method used by Harris and Johnson 2000. We model the federal stock as composed of 80 kVA transformers; this is the weighted average of national transformer shipments (U.S. Department of Energy 2011d). We divide our

estimate of federal transformer stock kVA (described above) by 80 to arrive at the annual number of transformers in the federal stock.

3) Energy savings and lifetime (2,252 kWh/yr, 32 yrs) from Harris and Johnson (2000). Energy savings is an average of the per savings expected for a 25 kVA transformer and a 1500 kVA transformer, scaled to 80 kVA.

FOOD SERVICE EQUIPMENT

Commercial Refrigerators

1) Lifetime and energy savings (12 yrs, 616 kWh/yr) from Energy Star cost savings calculator, average of refrigerator and freezer savings (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy use from Energy Star refrigerator list, savings (2418 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Commercial Dishwashers

1) Lifetime and energy savings (15 yrs, 10549 kWh/yr electric water heating, 489 therm/yr gas water heating) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Proportion of gas and electric water heaters estimated from CBECS, which provides Btus of electricity and gas used for water heating (U.S. Energy Information Agency 2003)
3) Stock in 2008 estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial dishwasher stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
4) Max tech annual energy use from Energy Star qualified dishwasher list, savings (17,617 kWh/yr electric water heating, 817 therms/yr gas water heating) estimated by applying ratio of highest to lowest efficiency on qualified list to estimated baseline – Energy Star savings (U.S. Environmental Protection Agency 2012a)

Commercial Fryers

1) Lifetime and energy savings (12 yrs, 1179 kWh/yr for electric, 505 therm/yr for gas) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Proportion of gas and electric fryers estimated from CBECS, which provides Btus of electricity and gas used for cooking (U.S. Energy Information Agency 2003)
3) Stock in 2008 estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial fryer stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
4) Max tech annual energy use from Energy Star qualified fryer list, savings (2670 kWh/yr electric, 670 therms/yr gas) estimated by applying ratio of highest to lowest efficiency on qualified list to estimated baseline – Energy Star savings (U.S. Environmental Protection Agency 2012a)

Commercial Griddles

1) Lifetime and energy savings (12 yrs, 2595 kWh/yr for electric, 149 therm/yr for gas) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Proportion of gas and electric griddles estimated from CBECS, which provides Btus of electricity and gas used for cooking (U.S. Energy Information Agency 2003)
3) Stock in 2008 estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial griddle stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
4) Max tech annual energy use from Energy Star qualified griddle list, savings (3656 kWh/yr electric, 271 therms/yr gas) estimated by applying ratio of highest to lowest efficiency on qualified list to estimated baseline – Energy Star savings (U.S. Environmental Protection Agency 2012a)

Commercial Hot Food Holding Cabinets

1) Lifetime and energy savings (12 yrs, 5293 kWh/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy savings (12,068 kWh/yr) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (1.92 times more savings from max tech as from FEMP/Energy Star qualified)

Commercial Air-Cooled Ice Machines

1) Lifetime and energy savings (8 yrs, 936 kWh/yr) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Stock in 2008 estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial ice machine stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
3) Max tech annual energy savings (1797 kWh/yr) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (1.92 times more savings from max tech as from FEMP/Energy Star qualified)

Commercial Ovens

1) Lifetime and energy savings (12 yrs, 1879 kWh/yr for electric, 306 therm/yr for gas) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Proportion of gas and electric ovens estimated from CBECS, which provides Btus of electricity and gas used for cooking (U.S. Energy Information Agency 2003)
3) Stock in 2008estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial oven stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
4) Max tech annual energy savings (2067 kWh/yr electric, 337 therms/yr gas) estimated by assuming the same % efficiency improvement above baseline as average of the aggregate office equipment product category (1.92 times more savings from max tech as from FEMP/Energy Star qualified)

Commercial Steam Cookers

1) Lifetime and energy savings (12 yrs, 9774 kWh/yr for electric, 1066 therm/yr for gas) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Proportion of gas and electric ovens estimated from CBECS, which provides Btus of electricity and gas used for cooking (U.S. Energy Information Agency 2003)
3) Stock in 2008 estimated by applying 5% multiplier (federal commercial space is approximately 5% of total commercial space) to Navigant estimate of commercial steam cooker stock; 2008 stock scaled by floor space to estimate other years (Navigant Consulting Inc 2009)
4) Max tech annual energy use from Energy Star qualified steam cooker list, savings (12,058 kWh/yr electric, 1261 therms/yr gas) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

Pre-Rinse Spray Valve

1) Assuming 1 pre-rinse spray valve per commercial dishwasher
2) Lifetime and energy savings (5 years, 88 therms or 1890 kWh) from FEMP cost effectiveness example (assumes 2 meals per day, 250 days per year) (U.S. Department of Energy Federal Energy Management Program 2012)

3) Max tech energy savings (226 therms/yr gas water heating, 4882 kWh/yr electric water heating) from FEMP cost effectiveness example, best available (U.S. Department of Energy Federal Energy Management Program 2012)
4) Electricity savings are estimated based on gas savings and the average per appliance ratio of electricity to gas savings of commercial dishwashers.

COMMERCIAL APPLIANCES

Commercial Clothes Washers

1) CBECS does not provide sufficient information to estimate the number of commercial clothes washers used in barracks/dormitories and other federal buildings; instead clothes washers are estimated from the National Impact Analysis spreadsheets provided among the supporting documents for the most recent efficiency standard rulemaking. The National Impact Analysis provides an estimate of the total stock of commercial clothes washers; this is weighted by the ratio of federal commercial floor space to total commercial floor space to arrive at our estimate of the number of federal commercial clothes washers. Water related energy use is apportioned between gas and electric based on CBECS, which reports use of gas and electricity for water heating. (U.S. Energy Information Agency 2003; U.S. Department of Energy 2009b)
2) Lifetime and energy savings (11 yrs, 342 kWh/yr for all electric, 15 therms/yr and 55 kWh/yr with gas water heater) from Energy Star cost savings calculator (U.S. Environmental Protection Agency 2012a)
3) Max tech annual energy use from Energy Star qualified clothes washer list, savings (513 kWh/yr electric water heating, 23 therms/yr and 83 kWh/yr gas water heating) estimated by applying ratio of highest to lowest efficiency on qualified list to estimated baseline – Energy Star savings (U.S. Environmental Protection Agency 2012a)

Beverage Vending Machines

1) Lifetime and energy savings (14 yrs, 1659 kWh/yr) from Energy Star energy cost savings calculator (U.S. Environmental Protection Agency 2012a)
2) Max tech annual energy use from Energy Star qualified printer list, savings (1737 kWh/yr) estimated based on Energy Star savings calculator baseline energy use (U.S. Environmental Protection Agency 2012a)

CONSTRUCTION/PLUMBING

Residential Lavatory Faucets

1) RECS does not directly provide the number of faucets, but does note the number of full and half bathrooms in each home surveyed. We assume that each full or half bathroom includes 1 faucet. (U.S. Energy Information Agency 2009)
2) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
3) From Water Sense savings calculator: faucet replacement per household (of 2.6 people, national avg) saves 6 therms/yr or 124 kWh/yr (U.S. Environmental Protection Agency 2012b)
4) WECalc Water-Energy-Climate calculator also reviewed (Pacific Institute 2011)
5) 7 year product lifetime assumed
6) Max tech annual energy use from qualified product list, savings (433 kWh/yr) estimated based on Water Sense savings calculator baseline energy use (U.S. Environmental Protection Agency 2012b)

Showerheads

1) RECS does not directly provide the number of showers, but does note the number of full and half bathrooms in each home surveyed. We assume that each full bathroom has 1 showerhead (U.S. Energy Information Agency 2009)

2) Gas and electric weights estimated from RECS ratio of gas to electric water heaters (0.39 electric, 0.61 gas) (U.S. Energy Information Agency 2009)
3) From Water Sense savings calculator: faucet replacement per household (of 2.6 people, national avg) saves 15 therms/yr or 285 kWh/yr (U.S. Environmental Protection Agency 2012b)
4) WECalc Water-Energy-Climate calculator also reviewed (Pacific Institute 2011)
5) 7 year product lifetime assumed
6) Max tech annual energy use from qualified product list, savings (949 kWh/yr) estimated based on Water Sense savings calculator baseline energy use (U.S. Environmental Protection Agency 2012b)

Products Excluded from Analysis

This analysis is intended to provide a comprehensive estimate of the energy impact of FEMP EEPP requirements. However, we are unable to provide estimates for some of the covered products. The following products were excluded from the analysis:

- Cool roofing
- Digital-to-analog converter boxes
- Low flow toilets
- Home sealing & insulation
- VCRs
- Urinals
- Solar water heaters
- Home audio
- Ground source commercial heat pumps
- Battery-charging systems
- External power adapters (power supplies)
- Centrifugal pumping systems
- Digital duplicators
- Ventilation fans
- Commercial faucets
- Set-top and cable boxes*
- Beverage vending machines*
- Water coolers*

There are several primary reasons that products were excluded: insufficient product density or energy savings data, low volumes of purchases through official procurement channels (items purchased with personal funds or brought from home), discontinued FEMP efficiency requirements for the product, or in the case of several WaterSense products, the lack of a direct energy impact.[22]

Those marked with a star (*) are excluded due to findings of the companion interview study (Taylor and Fujita 2012c). Set-top and cable boxes are excluded because these products are generally bundled with a pay-TV package, not individually selected and purchased. Beverage vending machines are excluded because they are generally leased rather than purchased, and would thus fall under federal leasing guidelines. Water coolers are excluded because the federal government is prohibited from purchasing bottled water and the FEMP

[22] Depending on the energy intensity of the water source of each federal building, WaterSense products may have a substantial indirect energy impact; reduced use of water for toilets and urinals will result in reduced use of energy to transport and treat water. While outside the scope of this study, this topic likely deserves future analysis.

purchasing specification is based on ENERGY STAR bottled water coolers, rather than coolers for piped water.

It is likely that many of these products are purchased only in low volume by the federal government and/or their contribution to total federal government energy consumption is minimal. We do not believe their exclusion has substantially impacted our estimates of federal energy and energy cost savings, although estimated savings would undoubtedly be somewhat higher if these products could be included.

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