REPORT TO THE U.S. DEPARTMENT OF ENERGY
FEDERAL ENERGY MANAGEMENT PROGRAM

Program Potential: Estimates of Federal Energy Cost Savings from Energy Efficient Procurement

Prepared for FEMP by
Margaret Taylor and K. Sydny Fujita

Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory

September 17, 2012

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Federal Energy Management Program, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Executive Summary

In 2011, energy used by federal buildings cost approximately $7 billion. Reducing federal energy use could help address several important national policy goals, including: (1) increased energy security; (2) lowered emissions of greenhouse gases and other air pollutants; (3) increased return on taxpayer dollars; and (4) increased private sector innovation in energy efficient technologies.

Targeted public sector procurement of more efficient energy-consuming goods and services, a policy tool in place since 1993, can help to reduce the energy consumption of federal buildings. The Federal Energy Management Program's Energy Efficient Product Purchasing program (FEMP EEPP) has been helping agencies reduce their energy use in this way for more than two decades. The FEMP EEPP mandate today is built on legislation and executive orders that require federal agencies to purchase more efficient products, as defined by ENERGY STAR and FEMP.

This report estimates the impact of efficient product procurement on reducing the amount of wasted energy (and, therefore, wasted money) associated with federal buildings, as well as on reducing the needless greenhouse gas emissions associated with these buildings. Three variables are key to these estimates: the product-by-product savings associated with efficient procurement (calculated based on the annual energy savings attributed to the combined purchase of new products and survivorship of the existing stock of better products), the scope of legal authority regarding covered agencies and buildings under government control; and the degree to which government procurement meets legal requirements.

The report shows that even in a very conservative scenario (called "Low Compliance" or "Low"), with limited compliance in purchases involving a contracting officer and leased buildings excluded from the analysis for a significant portion of products, the procurement of efficient products leads to significant annual savings of energy (5.2 TBtu) and money ($102 million), as well as carbon dioxide (CO_2) emissions reductions (0.69 million tons). The potential impact of the program is even greater, as estimated through two scenarios: "Full Compliance" (assumes 95% compliance, as called for in Executive Order 13514) and "Best Available – Full Compliance" (assumes 95% compliance, but with highest efficiency levels currently available in the marketplace rather than the more modest levels currently required by FEMP EEPP). With Full Compliance, the annual savings are 29.0 TBtu, $559 million, and 3.7 million tons CO_2. With Best Available – Full Compliance, the annual savings are 46.7 TBtu, $937 million, and 6.3 million tons of CO_2. This does not include the positive program spillovers of the latter scenario, through which government helps create a market signal for new and underutilized technologies and therefore magnifies the program's impact.

The report also provides results from several intermediate scenarios. The "Low – Batch" scenario is a sensitivity analysis that assumes contracting officer involvement in a greater proportion of purchases by allowing for batch purchases of products. The "Full – Contracting Vehicle Products" scenario is a variation on the "Full" scenario. It models a situation in which efforts are focused on contracting officers, bringing the compliance rate of purchases involving a contracting officer to 95%; compliance of other purchases is assumed to remain at 0%. The "Transition" scenario models a near-term change in agency priorities, in which federal agencies move rapidly from low compliance to full compliance as part of their goals under the Energy Independence and Security Act (EISA 2007) and Executive Order 13423 (30% reduction over the ten years ending in 2015).

Table A 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 goals of these entities in 2011. 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 (which involves transitioning from low compliance to full compliance when the EISA 2007 goals were established).

Table A: 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)
Federal Government	20.6	9.4	209
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

[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.

The report also documents the potential savings associated with 62 specific products that fall within nine overarching categories, such as "commercial and industrial equipment" and "lighting." It concludes with a discussion of potential policy design and implementation issues, as well as a reflection on some of the limitations of the study. Note that a comprehensive technical report has been compiled concurrently, and includes additional results and discussion (Fujita and Taylor 2012). Additionally, a contemporary project researching the details of the procurement process across federal agencies helped to inform scenario assumptions (Taylor and Fujita 2012).

Seven appendices (A-G) contain background and supplementary information. Appendix A provides a summary of relevant legal authority. Appendix B contains background material on the products analyzed in this report. Appendix C lists products covered by FEMP that were not analyzed in this report. Appendix D provides additional detail on the energy use and potential energy savings of individual federal agencies. Appendix E describes the methodology used to estimate energy, cost, and CO_2 savings. Appendix G presents the savings results for several additional scenarios, including the energy that could potentially be saved in privatized military housing (1.3 TBtu/year under the Full Compliance scenario).

Table of Contents

Executive Summary ii
1. Introduction 1
2. Background 2
3. Scenarios 4
Bounding Scenarios 4
Additional Scenarios 5
4. Estimated Savings 6
5. Conclusion 9
6. Limitations 10
Appendix A: Relevant Legal Authorities 12
Appendix B: Background Material on Products Covered by FEMP and Included in Estimated Savings Calculated in this Report 13
Appendix C: Covered Products Excluded from Estimated Savings Calculated in this Report 16
Appendix D: Background on building energy use and procurement by federal agencies 17
Federal Agency Energy Use and Building Types 17
Federal Energy Reduction Goals 18
Federal Procurement Processes 20
Appendix E: Methodology for calculating estimates of energy savings for FEMP covered products 21
General Methodology 21
Federal Stock Estimate 21
Federal Purchases Estimate 23
Product Cohort Survivorship 23
Potentially FEMP-Compliant Stock 24
Energy and Cost Savings 25
CO_2 Savings 26
Example Calculation: Printers 26
What is the total stock of federally owned printers in each year of the analysis? 26
Given the annual stock of federally owned printers, how many federal printer purchases happen each year? 27

In what future years of our model do printers of each annual purchase cohort contribute to energy savings? 28
Of the stock in each year, how many printers are energy-efficient? 28
Given the number of energy-efficient printers in the stock each year, how much energy is saved annually? 29
Notes on Calculations for Other Products 29
Appendix F: Additional Results: Savings by Product 31
Appendix G: Additional Scenario Results 36
Leap-frogging to Substitute Products 36
LED Lighting 36
Alternative Water Heaters 36
Luminaires 37
Privatized Military Housing 38
References 40

Table of Tables

Table 1: Annual estimated savings by the federal government in each scenario as of 2015 6
Table 2: Estimated savings in the context of federal energy goals and energy expenditures 8
Table 3: Annual federal energy use and EISA 2007 energy goals 19
Table 4: Federal floor space and housing units 22
Table 5. Energy Savings of FEMP-designated products in 2015 (TBtu/yr) under the Low scenario 31
Table 6: Low, Full, and Best Available – Full Scenario results by product: federal savings in 2015 32
Table 7: Annual energy and cost savings of water heaters (2015) 37
Table 8: Scenario results for luminaires (2015) 37
Table 9: Additional savings from applying efficient procurement requirements to privatized military housing 39

Table of Figures

Figure 1: Energy savings over time by product category for select scenarios at existing efficiency levels (Low, Full – CVP, Full) and the highest possible efficiency levels (Best Available - Full) 7
Figure 2: Achieved and potential savings by product category 8
Figure 3: Low scenario savings for commercial & industrial equipment (TBtu/yr in 2015) 9
Figure 4: Percentage of building energy use by federal agencies..... 17
Figure 5: Major federal departments and independent agencies according to share of federal energy consumption and distribution of building types..... 18
Figure 6: Progress toward EISA 2007 federal facility energy efficiency goals 20
Figure 7. Compliance scenarios: assumed percentage of compliant purchases in each year 25
Figure 8: Products ranked by annual savings in 2015 under the Low scenario (TBtu/yr) 34
Figure 9: Products ranked by annual savings in 2015 under the Best Available - Full scenario (TBtu/yr) 35

1. Introduction

In 2011, energy used by federal buildings cost approximately $7 billion. Reducing federal energy use could help address several important national policy goals, including: (1) increased energy security; (2) lowered emissions of greenhouse gases and other air pollutants; (3) increased return on taxpayer dollars; and (4) increased private sector innovation in energy efficient technologies.

Targeted public sector procurement of more efficient energy-consuming goods and services, a policy tool in place since 1993, can help to reduce the energy consumption of federal buildings. The Federal Energy Management Program's Energy Efficient Product Purchasing program (FEMP EEPP) has been helping agencies reduce their energy use in this way for more than two decades. The FEMP EEPP mandate today is built on legislation and executive orders that require federal agencies to purchase more efficient products, as defined by ENERGY STAR and FEMP. See Appendix A for a summary of the relevant legal authority.

This report estimates the impact of better purchasing on reducing the amount of wasted energy (and, therefore, wasted money) associated with federal buildings, as well as on reducing the needless greenhouse gas emissions associated with these buildings. Three variables are key to these estimates: the product-by-product savings associated with better purchasing (calculated based on the annual energy savings attributed to the combined purchase of new products and survivorship of the existing stock of better products), the scope of legal authority regarding covered agencies and buildings under government control; and the degree to which government procurement meets legal requirements. Through a conservative treatment of historical savings and projections of future savings under existing as well as potentially modified authority, this report seeks to inform policy design and implementation.

The report proceeds as follows. Section Two provides background material on covered products and agencies, as well as on estimates of compliance with existing legal authority. Section Three outlines the rationale behind several scenarios of historical and projected energy savings that we use in our estimates. Section Four presents the estimated energy savings associated with these scenarios for the aggregate federal sector and a subset of larger agencies. Section Five presents conclusions and discusses some of the key limitations to this study.

Seven appendices (A-G) contain background and supplementary information. Appendix A provides a summary of relevant legal authorities. Appendix B contains background material on products analyzed in this report. Appendix C lists products covered by FEMP that were not analyzed in this report. Appendix D provides additional detail on the energy use and potential energy savings of individual federal agencies. Appendix E describes the methodology used to estimate energy, cost, and CO_2 savings. Appendix F provides additional tables and figures of analysis results. Appendix G presents the savings results for several additional scenarios.

2. Background

The FEMP EEPP has traditionally focused on providing technical assistance and guidance to federal buyers of a set of products (roughly 80 today) that fit into the categories of: (1) commercial & industrial equipment; (2) lighting; (3) commercial food service equipment; (4) information technology; (5) commercial appliances; (6) residential appliances; (7) residential equipment; (8) plumbing; and (9) home electronics. Appendix B provides background information on 64 products covered by FEMP over time, which form the basis of the energy savings estimates presented in this report. Appendix C lists the 15 products that were excluded from this analysis, primarily due to limited data.

For each covered product, Appendix B details: the efficiency requirement of relevance (i.e., ENERGY STAR, FEMP-designated, low-standby power, or WaterSense); the savings associated with the efficiency level of the existing requirement; the savings associated with the highest efficiency model of the product that is currently commercially available ("best available"); the product's estimated lifetime; estimated average annual federal purchases of the product in recent years; and the years the product has been covered by FEMP. Note that some products have been suspended from FEMP coverage for various periods of time.

Covered products are bought by federal agencies at different rates, based on the mission of each agency.[1] Note that there is a considerable amount of variation in the missions, and associated purchasing needs, of the fifteen executive departments, roughly seventy independent agencies and corporations, and numerous boards, commissions, quasi-official agencies, private regulatory corporations, and government enterprises that comprise the federal government. This variety complicates the facilitation, enforcement, and evaluation of FEMP compliance.

Other complicating factors include the size of the federal government and the ways it can control buildings. The federal sector controls approximately 889,000 buildings, which cover 3.35 billion square feet at an annual operating cost of approximately $30.8 billion (as of 2010, the most recent year for which data is available) (U.S. General Services Administration 2011). Federal government control of buildings can be further disaggregated in terms of three forms of legal interest in real property assets. Assets can be: owned by the government (79% of square footage, annual operating cost per square foot $5.30); leased by the government (17% of square footage, annual operating cost per square foot $15.00); or otherwise managed by the government (4% of square footage, operating cost data not available) (ibid.).[2]

Appendix D 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; the distribution of major building types across departments and agencies; an

[1] It is estimated that the government spends well over $200 billion annually on procurement (Thai 2001). This aggregate number is not differentiated between products and services.
[2] Otherwise managed buildings are typically owned by a state or foreign government, with rights to the federal government for use granted in a method other than a leasehold arrangement.

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. Note that the Department of Defense (DOD), which controls the largest number of federal buildings, also dwarfs the other agencies with respect to its share of federal sector building energy use (58%). The next closest agencies are: Veterans Affairs (VA, 8%) and the U.S. Postal Service (USPS, 8%); the Department of Energy (DOE, 6%); the Department of Justice (DOJ, 5%), and the General Services Administration (GSA, 4%). Note that the USPS is explicitly excluded from relevant statutory language regarding "agencies" and is thus excluded from this analysis (see Appendix A under 5 USC 7902(a)).

The legal authority undergirding the FEMP EEPP requires federal agencies to purchase FEMP covered products in 95% of new contract actions, task orders, and delivery orders, with the exclusion of products related to combat (see Executive Order 13514 entry in Appendix A). It requires federal agency heads to provide written notice that no ENERGY STAR or FEMP designated product that meets functional requirements is reasonably available or cost-effective (see Energy Policy Act (EPAct) of 2005 and Federal Acquisition Regulation (FAR) Part 23 entries in Appendix A). Finally, it requires that a standard clause be placed into contracts and solicitations which states that the scope of energy-efficient product procurement requirements extends to delivered products, products acquired by contractors at government controlled facilities, products furnished by contractors for government use, and products specified in the design, construction, renovation, or maintenance of buildings (see FAR Part 23 entry in Appendix A).

There are several reasons to believe that far fewer than 95% of federal purchases are meeting legal obligations for the purchase of energy efficient goods and services, however. First, studies of government compliance with the inclusion of the standard contracting clause show that in 2008, only 7% of the sample of federal contracts considered complied with the contract provision, while in 2010, only 24% of the sample of federal contracts complied (Capanna, Devranoglu et al. 2008; Siciliano 2010). Note that in 2010, Siciliano found that up to 46% of the sample of federal contracts could be considered *partially* compliant because these contracts included language related to energy efficiency and/or Executive Order 13514 (Siciliano 2010). Second, as shown in Appendix D, there are multiple pathways through which products enter into federal buildings. With the noted 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 2012). 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.).

3. Scenarios

As mentioned above, three key variables are required to estimate the reduction in wasted energy by federal buildings that can be achieved through the purchase of FEMP EEPP covered products: product savings, legal scope, and compliance rates. We bounded our estimated savings with the "Low Compliance" scenario that is conservative with respect to the legal scope and compliance rates associated with historical savings and the "Full Compliance" scenario that considers the potential if savings had always been occurring for all federal buildings at the 95% compliance rate called for in 2009's Executive Order 13514. A variation on the Full Compliance scenario ("Best Available – Full Compliance"), evaluates the additional potential for savings if all federal purchases of covered products not only meet the relevant energy efficiency requirements, but are the highest efficiency models available on the market.

Three additional scenarios are included to evaluate hypothetical federal procurement practices resulting in compliance rates between those used in the bounding scenarios. The "Low – Batch" scenario is a sensitivity analysis that assumes contracting officer involvement in a greater proportion of purchases by allowing for batch purchases of products. The "Full – Contracting Vehicle Products" scenario is a variation on the "Full" scenario. It models a situation in which efforts are focused on contracting officers, bringing the compliance rate of purchases involving a contracting officer to 95%; compliance of other purchases is assumed to remain at 0%. The "Transition" scenario is used to discuss federal agency progress toward EISA 2007 federal facility energy intensity goals; it models a transition from the Low Compliance scenario to the Full Compliance scenario in response to EISA 2007 energy targets. Details of these scenarios are presented below. For a graphical representation of these scenarios, see Appendix E. Note that the USPS is not included in any scenario, due to its legal status under 5 USC 7902(a). Additional intermediate scenarios are included in the technical companion report (Fujita and Taylor 2012).

Bounding Scenarios

Low Compliance: 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 (see Appendix B for a list of products that we expect will be affected by this de facto leasing exemption, which 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.

Full Compliance: 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.

Additional Scenarios

Low – Batch (Low – B): 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.

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.

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 fully compliant procurement triggered by EISA 2007.

Best Available – Full Compliance (BA – Full): 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.

4. Estimated Savings

This section presents the estimated savings associated with the scenarios presented above. In general, these savings are calculated based on applying the energy savings attributed to 62 FEMP covered products by government sources, as modified by the purchase in a given year of new, efficient products, plus the survivorship in that year of a portion of the existing stock of efficient products. For more detail on the methodology used to calculate these savings, see Appendix E. Note that the estimates presented in this section rely on assumptions regarding purchase volumes, the range of product efficiency on the market, the stringency of FEMP and ENERGY STAR requirements, leasing practices, and other related factors; unforeseen changes in any of these factors could reduce the accuracy of the following estimates. Appendix E includes more detailed discussion of assumptions and Section 5 discusses the limitations of this study.

Table 1 presents a snapshot of the savings achieved by the federal government in 2015 associated with the bounding scenarios at FEMP and ENERGY STAR required efficiency levels (Low and Full), according to product category. Table 1 also presents the highest possible energy savings that could be achieved if the best available technology with respect to efficiency was incorporated throughout the FEMP EEPP program, assuming compliance rates at 95% throughout the period each product was covered by FEMP and excluding the de facto leasing exemption (Best Available – Full). Scenarios are defined in detail in Section 3.

Table 1: Annual estimated savings by the federal government in each scenario as of 2015

	Low	Full	Best Available - Full
$Million	102	559	937
Tbtu/Yr	5.2	29.0	46.7
Million tons CO_2	0.69	3.7	6.3

Figure 1 presents the annual energy savings under the various scenarios detailed above, ordered from lowest to highest. Savings beyond 2015 are less certain, and are shaded to reflect this.

Figure 1: Energy savings over time by product category for select scenarios at existing efficiency levels (Low, Full – CVP, Full) and the highest possible efficiency levels (Best Available - Full)

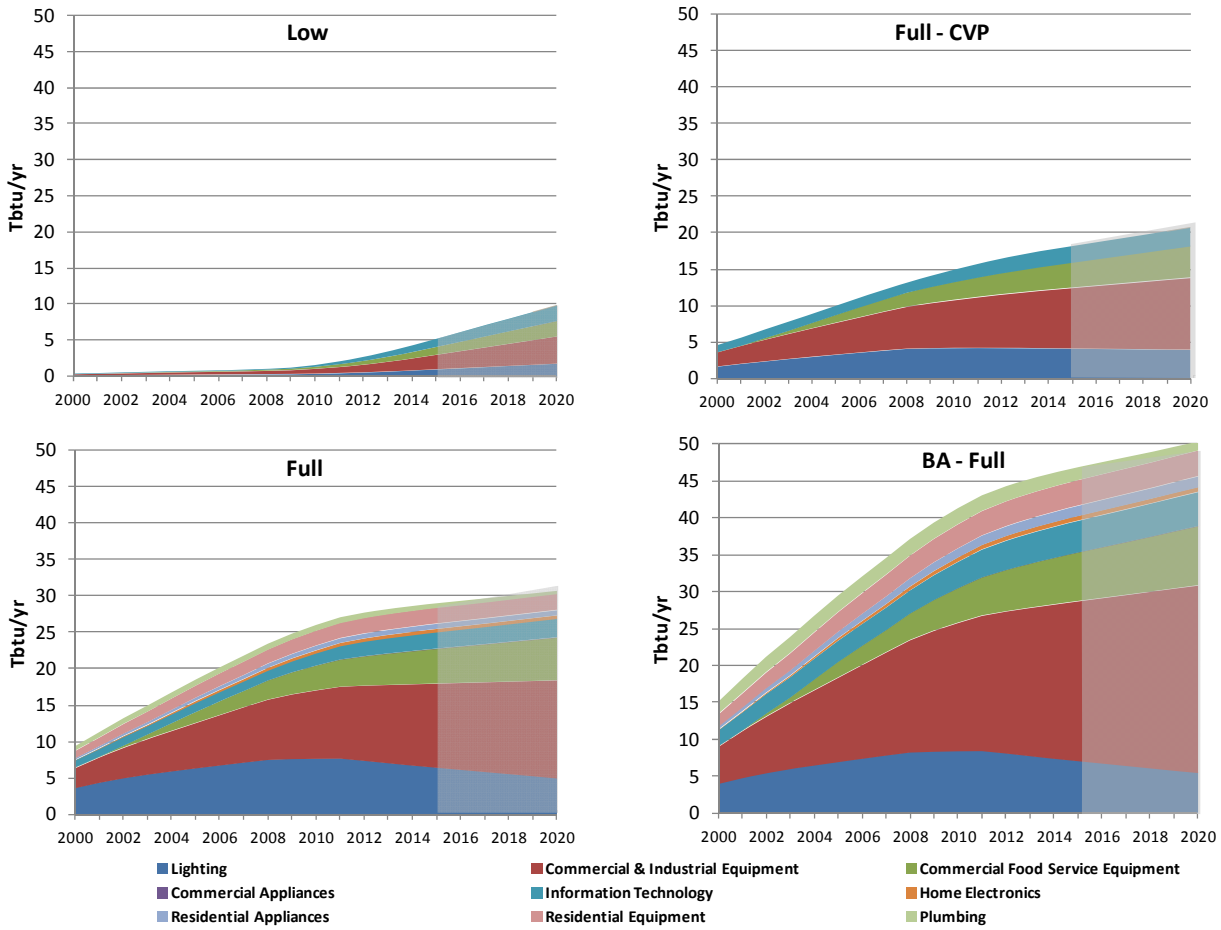


Table 2 displays the current difference between the energy use of the federal government as a whole, as well as the top five federal agencies according to building energy use (with the exception of the USPS, which is excluded for statutory reasons), and the EISA 2007 goals (30% reduction over the ten years ending in 2015) of these entities in 2011. 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.

Table 2: Estimated savings in the context of federal energy goals and energy expenditures

Government Entity	Gap between Energy Use and EISA Target[a], 2011 (TBtu)	Foregone Annual Energy Savings[b], 2011 (TBtu)	Foregone Annual Energy Cost Savings, 2011 ($ million)
Federal Government	20.6	9.4	209
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

[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 "negative" energy use gaps (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.

Figure 2 shows the energy savings to the federal sector of efficient product procurement under the Low compliance, Full compliance, and Best Available – Full compliance scenarios, broken down by the category of product purchased. The number of types of product in each category is included in the parentheses associated with the categories in Figure 2. The product category with the greatest savings is commercial and industrial equipment, followed by information technology, lighting, and commercial food service equipment.

Figure 2: Achieved and potential savings by product category

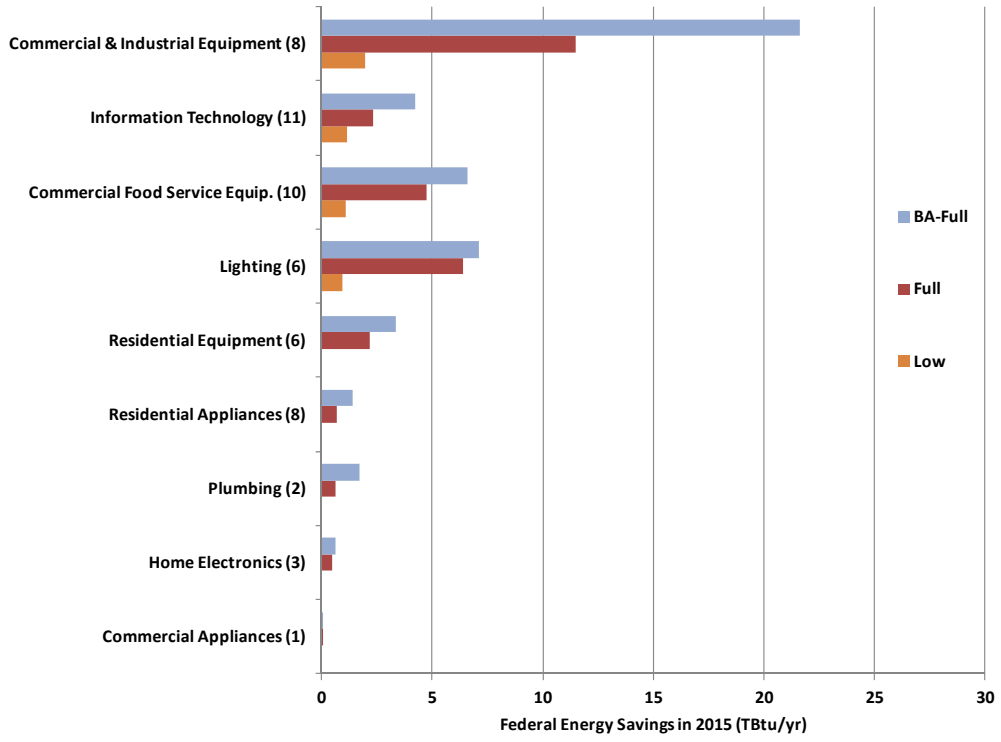
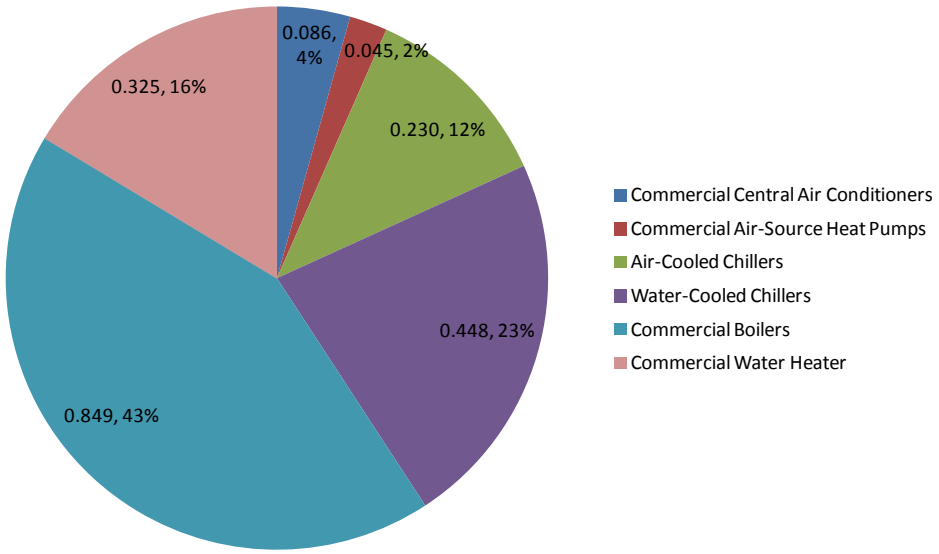


Figure 3 presents a product-level breakdown of the estimated energy savings for commercial and industrial equipment under the Low Compliance scenario. Energy savings (TBtu) and percent of category energy savings are included in Figure 3.

Figure 3: Low scenario savings for commercial & industrial equipment (TBtu/yr in 2015)



See Appendix F for additional results broken down at the level of individual products for a variety of scenarios. See Appendix G for several additional scenarios, including: cases in which an efficient product may go beyond substitution within an existing model class in order to "leap-frog" to a new technology; the unusual case of luminaires; and scenarios associated with recent trends towards the privatization of military housing.

5. Conclusion

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 (CO_2) emissions reductions (0.69 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 approximately $4.4 billion dollars, while wasting

217 TBtu of energy and emitting an additional 29 million tons of CO_2. 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 CO_2 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.

6. Limitations

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 C). 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.

Appendix A: 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 B: Background Material on Products Covered by FEMP and Included in Estimated Savings Calculated in this Report

Product	Efficiency Requirement	Energy Savings at Required Efficiency Level[e]	Energy Savings at Best Available Efficiency[e]	Product Classification[f]	Lifetime (Years)	Avg. Annual Purchases[g]	Covered by FEMP
Residential Appliances							
Clothes Washers [a]	EnergyStar	141 kWh/yr, or 24 kWh/yr and 6 therm/yr	237 kWh/yr, or 40 kWh/yr and 10 therm/yr	2B	13	20775	1997-2012
Dehumidifiers	EnergyStar	213 kWh/yr	290 kWh/yr	2	12	4079	2006-2012
Microwave Ovens	Low Standby Power	17 kWh/yr	30 kWh/yr	2	10	39970	2006-2012
Residential Dishwashers [a]	EnergyStar	74 kWh/yr, or 33 kWh/yr and 2 therm/yr	188 kWh/yr, or 84 kWh/yr and 5 therm/yr	2B	13	14521	1996-2012
Residential Freezers	EnergyStar	67 kWh/yr	387 kWh/yr	2B	22	5417	2004-2012
Residential Refrigerators – Full	EnergyStar	106 kWh/yr	222 kWh/yr	2B	17	139218	1996-2012
Room Air Cleaners	EnergyStar	525 kWh/yr	849 kWh/yr	2	9	5439	2006-2012
Room Air Conditioners	EnergyStar	125 kWh/yr	147 kWh/yr	2B	11	12950	1996-2012
Residential Equipment							
Gas Storage Water Heaters	EnergyStar	37 therm/yr	78 therm/yr	2B*	13	13201	1996-2012
Gas Furnaces	EnergyStar	73 therm/yr	113 therm/yr	2B*	24	6859	1996-2012
Air-Source Heat Pumps	EnergyStar	2888 kWh/yr	3071 kWh/yr	2B*	16	2120	1997-2012
Boilers	EnergyStar	43 therm/yr	50 therm/yr	2B*	25	844	2000-2012
Central Air Conditioners	EnergyStar	1024 kWh/yr	1500 kWh/yr	2B*	14	15042	1996-2012
Electric Heat Pump Water Heaters	EnergyStar	2526 kWh/yr	3156 kWh/yr	2B*	13	--	--
Electric Storage Water Heaters	FEMP	246 kWh/yr	371 kWh/yr	2B*	13	11074	1996-2012
Gas Condensing Water Heaters	EnergyStar	37 therm/yr	39 therm/yr	2B*	13	--	--
Whole-Home Tankless Water Heaters	EnergyStar	41 therm/yr	60 therm/yr	2B*	13	--	--
Commercial Appliances							
Family-Size (Commercial) Clothes Washers [a]	EnergyStar	342 kWh/yr, or 55 kWh/yr and 15 therm/yr	513 kWh/yr, or 83 kWh/yr and 23 therm/yr	2B*	11	3163	2006-2012
Commercial and Industrial Equipment							
Air-Cooled Chillers	FEMP	60000 kWh/yr	270000 kWh/yr	1*	23	411	1997-2012
Commercial Air-Source Heat Pumps	EnergyStar	3502 kWh/yr	8969 kWh/yr	1*	15	1525	1997-2012
Commercial Boilers	FEMP	4465 therm/yr	6083 therm/yr	1*	25	713	1998-2012
Commercial Central Air Conditioners	EnergyStar	712 kWh/yr	3507 kWh/yr	1*	15	14621	1998-2012
Commercial Gas Water Heaters	FEMP	310 therm/yr	400 therm/yr	1*	10	4166	1996-2012
Motors	FEMP	2546 kWh/yr	3377 kWh/yr	2B*	18	3966	1998-2009
Transformers	FEMP	25020 kWh/yr	25020 kWh/yr	2B*	32	8028	1998-2009
Water-Cooled Chillers	FEMP	160000 kWh/yr	117500 kWh/yr	1*	23	411	1997-2012
Lighting							
Ceiling Fans	EnergyStar	7 kWh/yr	36 kWh/yr	2*	10	71991	2000-2012
Compact Fluorescent Lamps (Light Bulbs) [c]	EnergyStar	67 kWh/yr	73 kWh/yr	2	5	676893	1997-2012
Compact Fluorescent Lamps (Light Bulbs) [d]	EnergyStar	52 kWh/yr	57 kWh/yr	2	5	--	1997-2012
Decorative Light Strings	EnergyStar	59 kWh/yr	65 kWh/yr	2	4	7588	1997-2012

Exit Signs	FEMP	262 kWh/yr	288 kWh/yr	1*	10	241377	1997-2008
Fluorescent (Tube) Lamps [c]	FEMP	11 kWh/yr	12 kWh/yr	2	7	8689982	1997-2011
Fluorescent (Tube) Lamps [d]	FEMP	3 kWh/yr	3 kWh/yr	2	7	--	1997-2011
Fluorescent Ballasts [c]	FEMP	50 kWh/yr	55 kWh/yr	1*	14	2204128	1997-2012
Fluorescent Ballasts [d]	FEMP	14 kWh/yr	15 kWh/yr	1*	14	--	1997-2012
Fluorescent Luminaires [c]	FEMP	30 kWh/yr	33 kWh/yr	1*	15	1580565	1998-2012
Fluorescent Luminaires [d]	FEMP	8 kWh/yr	9 kWh/yr	1*	15	--	1998-2012
Industrial/Commercial Luminaires	FEMP	134 kWh/yr	147 kWh/yr	1*	15	268721	2000-2012
Office Equipment							
(Computer) Printer	EnergyStar, Low Standby Power	67 kWh/yr	183 kWh/yr	1	5	247449	1997-2012
Computer Monitor	EnergyStar	15 kWh/yr	66 kWh/yr	1	4	670022	1997-2012
Copier	EnergyStar, Low Standby Power	129 kWh/yr	244 kWh/yr	1	6	24983	1997-2012
Desktop (Personal) Computer	EnergyStar, Low Standby Power	133 kWh/yr	247 kWh/yr	1	4	338201	1997-2012
Docking Stations	EnergyStar, Low Standby Power	6 kWh/yr	14 kWh/yr	1	4	63842	2000-2012
Enterprise (Computer) Servers	EnergyStar	570 kWh/yr	687 kWh/yr	1	5	53084	2009-2012
Fax Machine	EnergyStar, Low Standby Power	46 kWh/yr	47 kWh/yr	2	4	35782	1997-2012
Mailing Machine	EnergyStar	9 kWh/yr	21 kWh/yr	2	5	3067	2000-2012
Multifunction Devices	EnergyStar, Low Standby Power	46 kWh/yr	90 kWh/yr	1	6	182588	2000-2012
Notebook (Laptop) Computers - Tablet PCs	EnergyStar, Low Standby Power	40 kWh/yr	41 kWh/yr	1	4	299914	1997-2012
Scanners	EnergyStar	5 kWh/yr	19 kWh/yr	1	4	3834	2000-2012
Home Electronics							
DVD Players	EnergyStar, Low Standby Power	14 kWh/yr	20 kWh/yr	2	7	41548	2004-2012
Phones and Answering Machines	Low Standby Power	17 kWh/yr	26 kWh/yr	2	4	430728	2004-2012
Televisions	EnergyStar, Low Standby Power	258 kWh/yr	320 kWh/yr	2B	10	46909	2000-2012
Commercial Food Service Equipment							
Commercial (Air-Cooled) Ice Machines	EnergyStar	705 kWh/yr	1020 kWh/yr	1*	8	2276	1997-2012
Commercial Dishwashers [a]	EnergyStar	7948 kWh/yr, or 368 therm/yr	10000 kWh/yr, or 464 therm/yr	1*	15	4418	2004-2012
Commercial Fryers [b]	EnergyStar	888 kWh/yr, or 380 therm/yr	2012 kWh/yr, or 505 therm/yr	1*	12	3362	2002-2012
Commercial Griddles [b]	EnergyStar	1955 kWh/yr, or 112 therm/yr	2755 kWh/yr, or 204 therm/yr	1*	12	2210	2002-2012
Commercial Hot Food Holding Cabinets	EnergyStar	3988 kWh/yr	6850 kWh/yr	1*	12	839	2002-2012
Commercial Ovens [b]	EnergyStar	1416 kWh/yr, or 231 therm/yr	1557 kWh/yr, or 254 therm/yr	1*	12	7346	2002-2012
Commercial Refrigerators & Freezers	EnergyStar	616 kWh/yr	2418 kWh/yr	1*	12	2917	2002-2012
Commercial Steam Cookers [b]	EnergyStar	7364 kWh/yr, or 803 therm/yr	9085 kWh/yr, or 950 therm/yr	1*	12	1120	2002-2012
Pre-Rinse Spray Valves [a]	FEMP	1294 kWh/yr, or 60 therm/yr	3344 kWh/yr, or 155 therm/yr	2*	5	13253	2004-2005,2008-2012
Water-Cooled Ice Machines	FEMP	936 kWh/yr	1237 kWh/yr	1*	8	2276	1997-2012
Plumbing							
(Residential) Lavatory Faucets [a]	WaterSense	124 kWh/yr, or 6 therm/yr	433 kWh/yr, or 18 therm/yr	2*	7	88256	1997-2012
Showerheads [a]	WaterSense	285 kWh/yr, or 15 therm/yr	949 kWh/yr, or 52 therm/yr	2*	7	72662	1997-2012

[a] Savings depend on whether a gas or electric water heater is used with this product. The first savings value (kWh/yr) applies to use with an electric water heater. The second entry (therm/yr and kWh/yr) applies to use with a gas water heater; (therm/yr) represents savings from reduced use of heated water while (kWh/yr) represents electricity savings from appliance operation.

[b] Savings depend on whether the appliance runs on gas or electricity. The first savings value (kWh/yr) applies to models that run on electricity; the second savings value applies to models that run on gas.
[c] Savings assuming that the product is used in a commercial building. Average annual purchases for this product include both residential and commercial.
[d] Savings assuming that the product is used in housing. Average annual purchases for this product are included in the "commercial" row above.
[e] Generally, these savings values are taken from the cost-effectiveness examples or cost calculators provided on FEMP product overview webpages. Details on the source of energy use data or estimation methods are provided in the technical report (Fujita and Taylor 2012).
[f] These codes denote which products are included in which scenarios. 1: contracting officers are assumed to be involved in the purchase of single units of these products, either because of a blanket purchase agreement or the product price point; 2: contracting officers are likely not involved in the purchase of single units of these products because their average prices are below the $3000 micropurchase threshold; B: due to the product price point, contracting officers are assumed to be involved when these products are purchased in sets of 10 or more units; *: construction products, assumed to be under the control of the building owner (79% of federally occupied floor space is federally owned; 0% compliance assumed in other 21% of space assumed in baseline scenarios)
[g] Estimated average annual federal purchase volume (including FEMP EEPP compliant and non-compliant) for the years 2005 – 2010.

Appendix C: Covered Products Excluded from Estimated Savings Calculated in this Report

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*

Note that most of these products were excluded from analysis primarily because of lack of data. Federal purchases of these products must meet FEMP, ENERGY STAR, Water Sense, or Low Standby Power energy efficiency requirements.

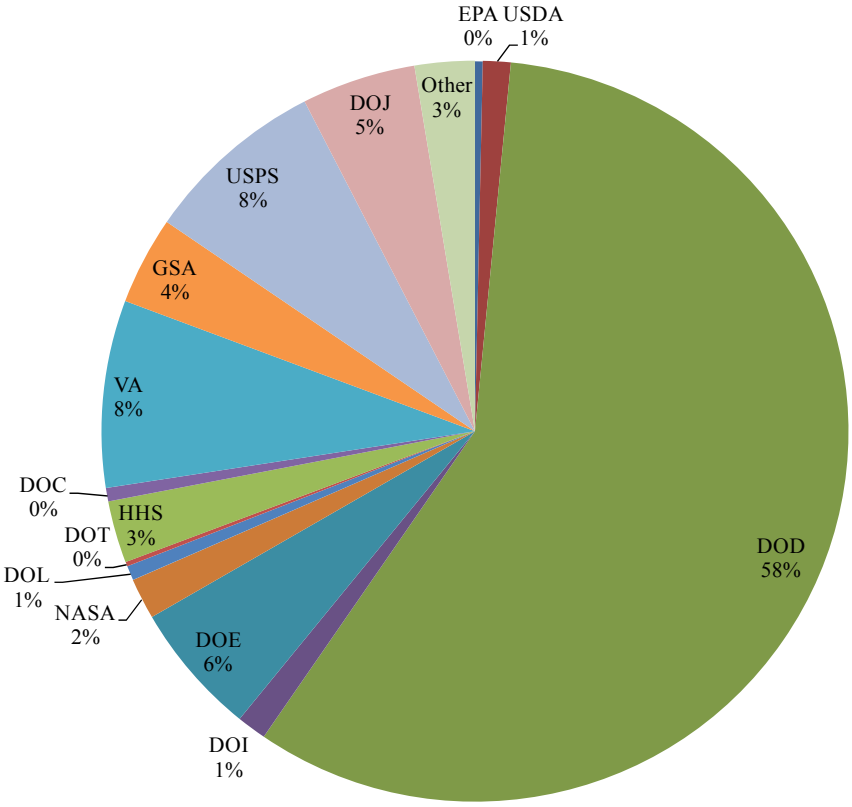
Those marked with a star (*) are excluded due to findings of the companion interview study (Taylor and Fujita 2012). Set-top and cable boxes are excluded because these products are generally bundled with a pay-TV package, not individually selected and purchased. Beverage vending machines are excluded 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 purchasing specification is based on ENERGY STAR bottled water coolers, rather than coolers for piped water.

Appendix D: Background on building energy use and procurement by 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 4); the distribution of major building types across departments and agencies (Figure 5); 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.

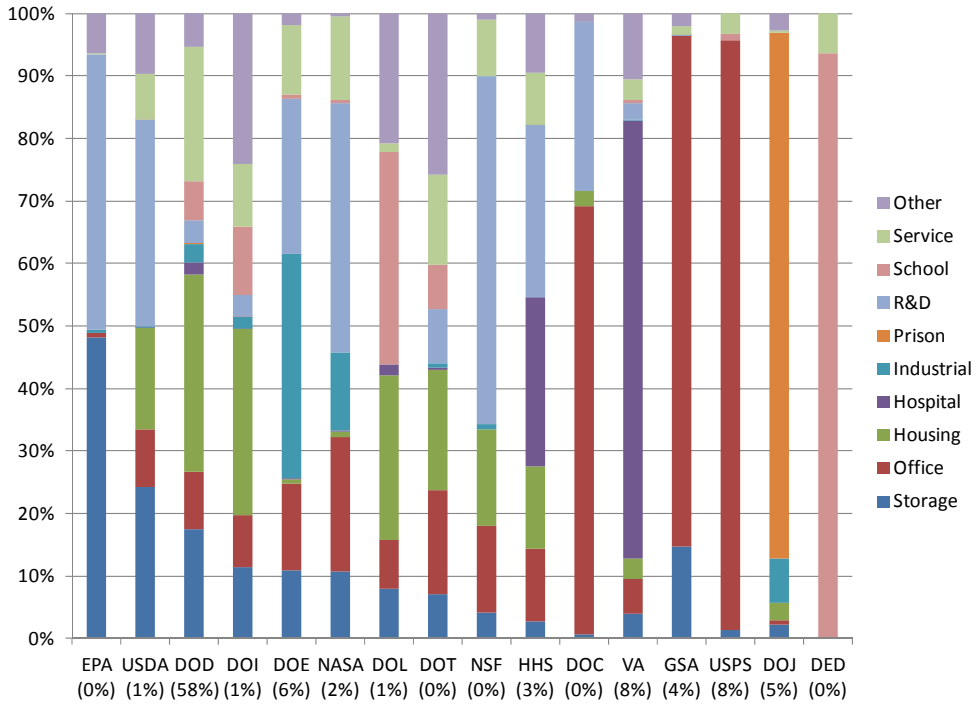
Federal Agency Energy Use and Building Types

Figure 4: 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 5: Major federal departments and independent agencies according to share of federal energy consumption and distribution of building types



Source: Author calculations based on data on federal energy usage by all buildings, as compiled by Pacific Northwest National Labs. 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 that this figure presents % of owned space; GSA leases space to other agencies. Percentages in parentheses below agency names are estimates of each agency's floor space as a percent of total federal floor space.

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 3. 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 3: 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.

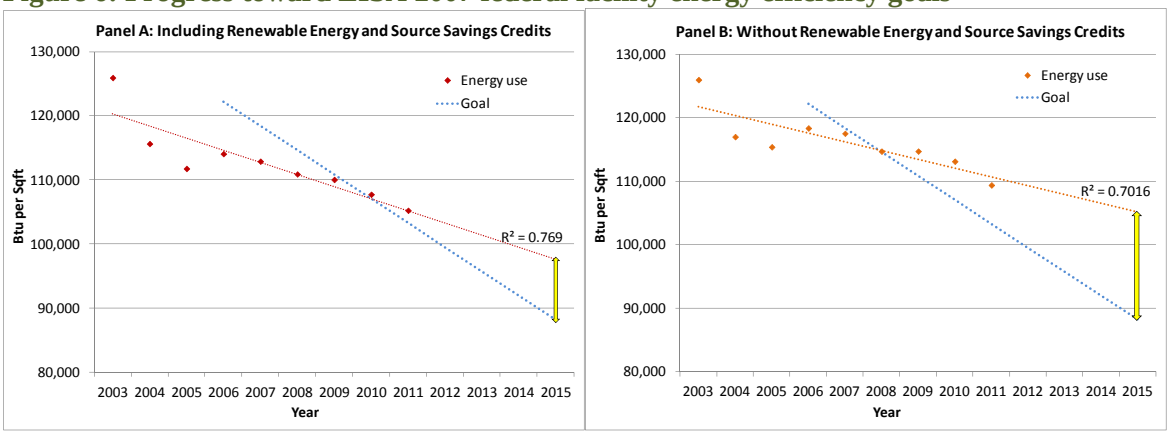
As shown in Figure 6, federal energy use in recent years was greater than the annual target set out in the EISA energy reduction goals. Given the current size of federal floor space, these energy intensities translate to substantial missed energy savings (2 TBtu/yr in 2010 and 6 TBtu/yr in 2011 applying the "with credits" metric; 18 TBtu/yr in 2010 and 21 TBtu/yr in 2011 applying the "without credits" metric). For comparison, Table 2 is based on the "without credits" metric.

Figure 6, 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 at least 9,423 Btu/sqft, which is equivalent to approximately 28.73 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 savings and considering only site energy savings through efficiency improvements and other conservation measures, achieving the goal appears much less likely (

Figure 6 Panel B), with annual energy use projected to exceed the goal by 51.78 TBtu/yr in 2015.

Figure 6: Progress toward EISA 2007 federal facility energy efficiency goals



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 foregone 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. See Section Four of the main body of this report for estimates of achieved and potential energy savings from energy efficient procurement, as well as the potential savings and energy reduction goals of individual federal agencies.

Federal Procurement Processes

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. Please see The Path to Savings: Understanding the Federal Purchase of Energy – Consuming Products (Taylor and Fujita 2012) for further discussion of federal procurement processes and their influence on the federal stock of energy-using products.

Appendix E: Methodology for calculating estimates of energy savings for FEMP covered products

This appendix provides a description of the methodology used to calculate energy, energy cost, and CO_2 savings. 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.

General Methodology

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

1) Annual federal product 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

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. 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. For detailed assumptions and calculation notes, see the technical companion report (Fujita and Taylor 2012).

Federal Stock Estimate

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 2010).[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

[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).

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

Source: (U.S. General Services Administration 2002-2010; U. S. Department of Defense 2010) USPS floor space has been excluded

Approximately 21% of buildings occupied by federal agencies are not owned by the specific agencies themselves (U.S. General Services Administration 2011). As federal agencies may not be able to influence the efficiency of installed products (i.e. HVAC, luminaires) in buildings that they occupy but do not own, our compliance scenarios draw a distinction between owned and otherwise occupied floor space, as described below.

In order to derive the approximate quantity of relevant products at use in the federal building stock, we estimated the product density of equipment and appliances covered by the FEMP EEPP requirements 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 2009 Residential Energy Consumption Survey (RECS) and the 2009 Commercial Buildings Energy Consumption Survey (CBECS), which are nationally representative surveys of energy-using equipment ownership and 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).[4] 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 2010). 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.

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). The GSA and DOD reports used by Harris and Johnson (2000) are no longer

[4] See the technical report for details of the data sources and assumptions for each product.

released by these agencies, or are released under different titles. 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. The Department of Defense expects to privatize roughly 190,000 to 195,000 housing units; we assume this shift toward privatization continues through 2025.[5] Depending on the form of product density data available, 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 must be 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 2010). Thus, we implicitly assume that federal purchases adhere to the general market ratio of desktops and laptops. A shipments modifier of 1 is used when CBECS categories do not need to be split to match FEMP categories.

Federal 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:

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

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.

Product Cohort Survivorship

Product cohort survivorship is used to estimate how many years each product remains in the federal stock, and thus how many years of savings can be attributed to a higher efficiency product. A Weibull distribution of lifetimes is applied to each year's cohort of purchases to

[5] Privatized military housing is considered in a separate scenario (Appendix G).

estimate how many remain in operation in later years. This is consistent with the methodology used in setting federal minimum efficiency standard: as stated in the home appliances Technical Support Document (TSD) "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"(U.S. Department of Energy 2010). Coefficients are taken from U.S. Department of Energy appliance energy efficiency standards TSDs 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

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 2010). 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.

Purchases are only likely to be compliant if there is a contracting officer involved in the transaction; products purchased directly by end users with p-cards are not expected to be compliant. 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 2012). 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.

The survivorship matrix is multiplied by five compliance vectors, each representing a different compliance scenario. This results in five 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:

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

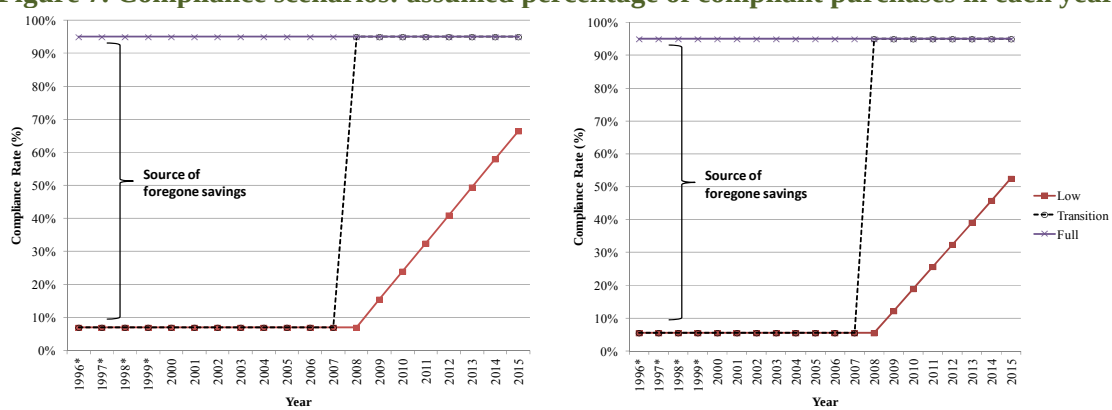
where y is the index of the year for which we are summing the stock and t is the index of cohort age.

Six scenarios are used in this analysis, bounding scenarios: Low Compliance and Full Compliance; additional scenarios: Low – Batch, Transition, Full – Contracting Vehicle Products Best Available – Full Compliance. These scenarios are described in detail in Section 3.

Compliance scenarios for an example product that is first covered by procurement requirements in 1996 and is purchased through contracting officers are presented below in

Figure 7. The left panel represents a product like a computer, which is not installed and is likely chosen by the federal agency, not the building owner. The right panel represents a product like a commercial air conditioner, which must be installed in a building.

Figure 7. Compliance scenarios: assumed percentage of compliant purchases in each year



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.

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 2010). For 2015 savings projections, we continue to assume current prices of energy.

To estimate per appliance savings, we rely primarily on FEMP and Energy Star cost savings examples, cost savings calculators, and qualified product lists. Per appliance annual energy and energy cost savings for each product and other product details are included in Appendix B.

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).

Example Calculation: 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 B: Background Material on Products Covered by FEMP and Included in Estimated Savings Calculated in this Report for 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.

Appendix F: Additional Results: Savings by Product

This appendix provides charts and tables of savings results for individual products. Table 5 summarizes estimated annual energy savings FEMP-designated products. Table 6 includes energy (TBtu/yr), energy cost ($/yr), and CO_2 (tons/yr) savings for all products and all scenarios. Finally, Figure 8 and Figure 9 rank the analyzed products from least to greatest savings for the Low and Best Available - Full scenarios, respectively. For additional results and details, see the companion technical report (Fujita and Taylor 2012).

Table 5. Energy Savings of FEMP-designated products in 2015 (TBtu/yr) under the Low scenario

Product Category	Product	Low: Energy Savings in 2015 (Tbtu/yr)	Full: Energy Savings in 2015 (Tbtu/yr)
Commercial & Industrial Equipment	Commercial Boilers	0.85	4.74
Commercial & Industrial Equipment	Air-Cooled Chillers	0.23	1.30
Commercial & Industrial Equipment	Water-Cooled Chillers	0.45	2.51
Commercial & Industrial Equipment	Commercial Water Heaters	0.32	1.37
Commercial & Industrial Equipment	Distribution Transformers	--	0.67
Commercial & Industrial Equipment	Motors	--	0.26
Lighting	Fluorescent Tube Lamps	--	0.49
Lighting	Fluorescent Ballasts	0.93	4.46
Lighting	Fluorescent Luminaires	0.40	1.93
Lighting	Commercial and Industrial Luminaires	0.30	1.40
Commercial Food Service Equipment	Water-Cooled Ice Machines	0.02	0.05
Commercial Food Service Equipment	Pre-Rinse Spray Valves	--	0.37
Residential Equipment	Electric Storage Water Heaters	--	0.07

Table 6: Low, Full, and Best Available – Full Scenario results by product: federal savings in 2015

Product[a]	$ Million / yr			Tbtu / yr			Million Ton CO_2 / yr		
	Low	Full	BA - Full	Low	Full	BA - Full	Low	Full	BA - Full
Compact Fluorescent Lamps	0.0	15.0	16.4	0.0	0.7	0.8	0	131	143
Fluorescent (Tube) Lamps	0.0	12.8	14.1	0.0	0.5	0.5	0	87	95
Fluorescent Ballasts	24.5	117.6	129.3	0.9	4.5	4.9	166	794	874
Exit Signs	1.1	18.8	20.6	0.0	0.7	0.8	7	127	139
Decorative Light Strings	0.0	0.2	0.2	0.0	0.0	0.0	0	1	1
Ceiling Fans	0.0	0.4	2.0	0.0	0.0	0.1	0	3	14
Com Central Air Conditioners	2.3	11.0	54.0	0.1	0.4	2.0	15	74	365
Com Air-Source Heat Pumps	1.2	5.8	14.8	0.0	0.2	0.6	8	39	100
Air-Cooled Chillers	6.1	34.3	154.2	0.2	1.3	5.8	41	232	1042
Water-Cooled Chillers	11.8	66.2	90.1	0.4	2.5	3.4	80	447	609
Com Boilers	7.9	44.1	64.6	0.8	4.7	6.9	52	289	424
Distribution Transformers	0.0	17.6	17.6	0.0	0.7	0.7	0	41	41
Motors	0.0	7.0	9.2	0.0	0.3	0.3	0	47	62
Com Water Heater	3.0	12.7	16.4	0.3	1.4	1.8	20	83	108
Com Dishwashers	4.0	16.3	20.6	0.4	1.5	1.9	26	108	136
Com Fryers	2.3	9.3	13.5	0.2	0.9	1.3	15	61	89
Com Griddles	0.8	3.1	4.8	0.0	0.2	0.2	5	20	32
Com Hot Food Cabinets	0.7	2.8	4.9	0.0	0.1	0.2	5	19	33
Com (Air-Cooled) Ice Machines	0.3	1.1	1.6	0.0	0.0	0.1	2	7	11
Com Ovens	3.2	12.7	14.0	0.3	1.1	1.2	21	84	93
Com Refrigerators & Freezers	0.4	1.5	5.9	0.0	0.1	0.2	2	10	40
Com Steam Cookers	1.8	7.5	8.6	0.1	0.5	0.6	12	50	61
Water-Cooled Ice Machines	0.4	1.4	1.9	0.0	0.1	0.1	3	10	13
Pre-Rinse Spray Valves	0.0	3.4	8.9	0.0	0.4	1.0	0	23	58
Commercial Clothes Washers	0.0	0.5	0.7	0.0	0.0	0.1	0	3	5
Desktop Computer	8.5	16.5	30.7	0.3	0.6	1.2	58	112	208
Computer Monitor	1.9	3.7	16.2	0.1	0.1	0.6	13	25	110
Enterprise Servers	11.5	22.2	26.7	0.4	0.8	1.0	78	150	180
Notebook Computers	2.3	4.4	4.5	0.1	0.2	0.2	15	30	30

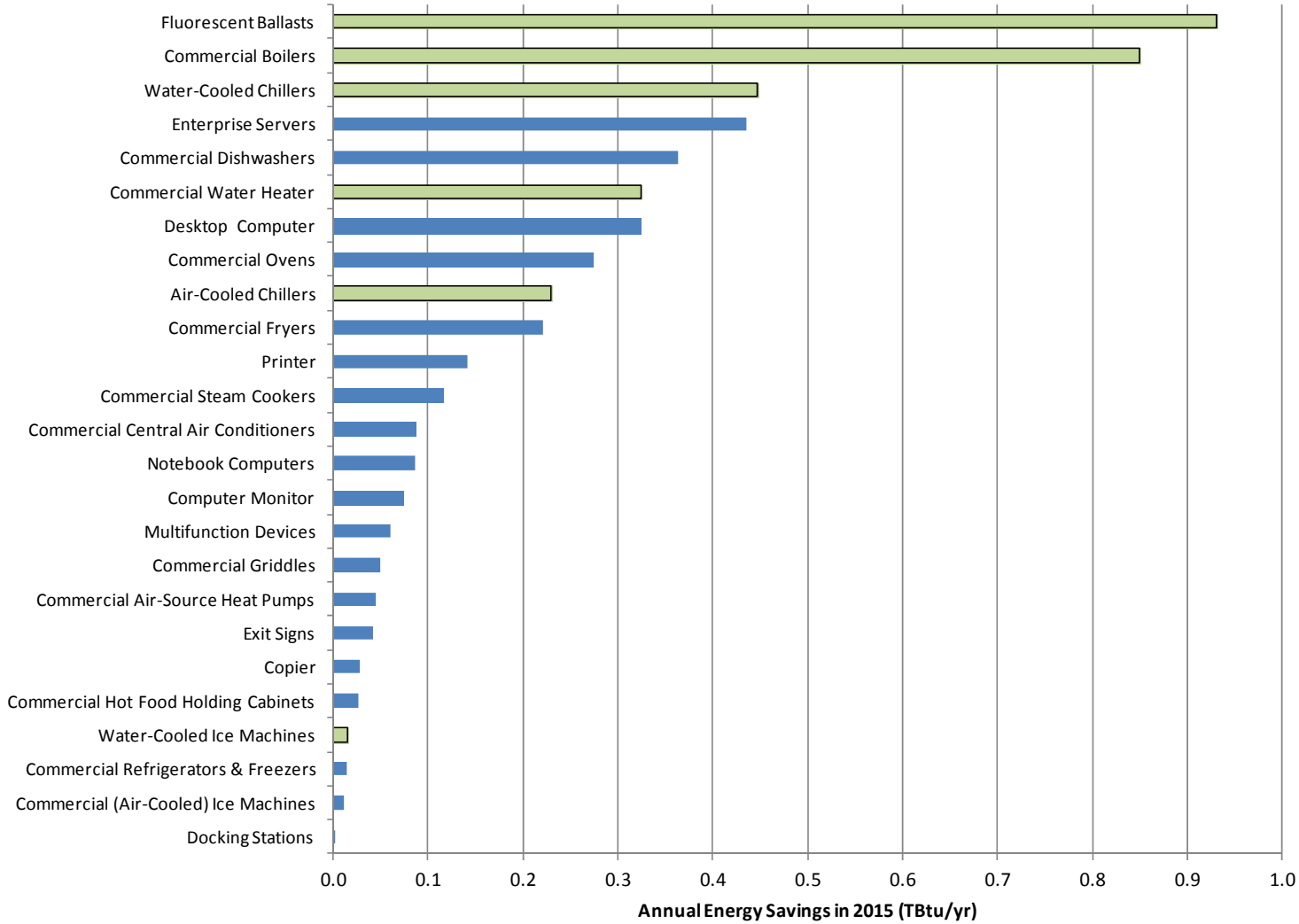
[a] Green highlight denotes products that were considered "FEMP-designated" for most or all of the analysis period

Table 6 continued: Low, Full, and Best Available – Full Scenario results by product: federal savings in 2015

Product	$ Million / yr			Tbtu / yr			Million Ton CO_2 / yr		
	Low	Full	BA - Full	Low	Full	BA - Full	Low	Full	BA - Full
Docking Stations	0.1	0.1	0.3	0.0	0.0	0.0	0	1	2
Printer	3.7	8.8	23.9	0.1	0.3	0.9	25	59	161
Fax Machine	0.0	0.6	0.6	0.0	0.0	0.0	0	4	4
Copier	0.7	1.7	3.2	0.0	0.1	0.1	5	12	22
Scanners	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Multifunction Devices	1.6	3.1	6.0	0.1	0.1	0.2	11	21	41
Mailing Machines	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Televisions	0.0	9.6	11.9	0.0	0.4	0.5	0	65	81
DVD Players	0.0	0.3	0.5	0.0	0.0	0.0	0	2	3
Phones	0.0	2.7	4.1	0.0	0.1	0.2	0	18	28
Residential Refrigerators	0.0	9.0	20.9	0.0	0.3	0.8	0	60	142
Residential Freezers	0.0	0.3	2.0	0.0	0.0	0.1	0	2	13
Residential Dishwashers	0.0	0.9	2.0	0.0	0.0	0.1	0	6	16
Clothes Washers	0.0	2.3	3.8	0.0	0.1	0.2	0	15	25
Room Air Conditioners	0.0	0.9	1.1	0.0	0.0	0.0	0	6	8
Dehumidifiers	0.0	0.6	0.8	0.0	0.0	0.0	0	4	6
Room Air Cleaners	0.0	1.6	2.5	0.0	0.1	0.1	0	11	17
Microwave Ovens	0.0	0.4	0.8	0.0	0.0	0.0	0	3	5
(Res) Central Air Conditioners	0.0	16.6	24.3	0.0	0.6	0.9	0	112	164
(Res) Air-Source Heat Pumps	0.0	7.0	7.4	0.0	0.3	0.3	0	47	50
(Res Gas) Furnaces	0	7.8	12.1	0	0.8	1.3	0	51	80
(Res) Boilers	0	0.4	0.5	0	0.0	0.1	0	3	3
Electric Storage Water Heaters	0	1.8	2.7	0	0.1	0.1	0	12	18
Gas Storage Water Heaters	0	3.2	6.7	0	0.3	0.7	0	21	44
(Res) Lavatory Faucets	0	3.2	10.5	0	0.2	0.7	0	21	70
Showerheads	0	6.3	21.3	0	0.4	1.0	0	42	142

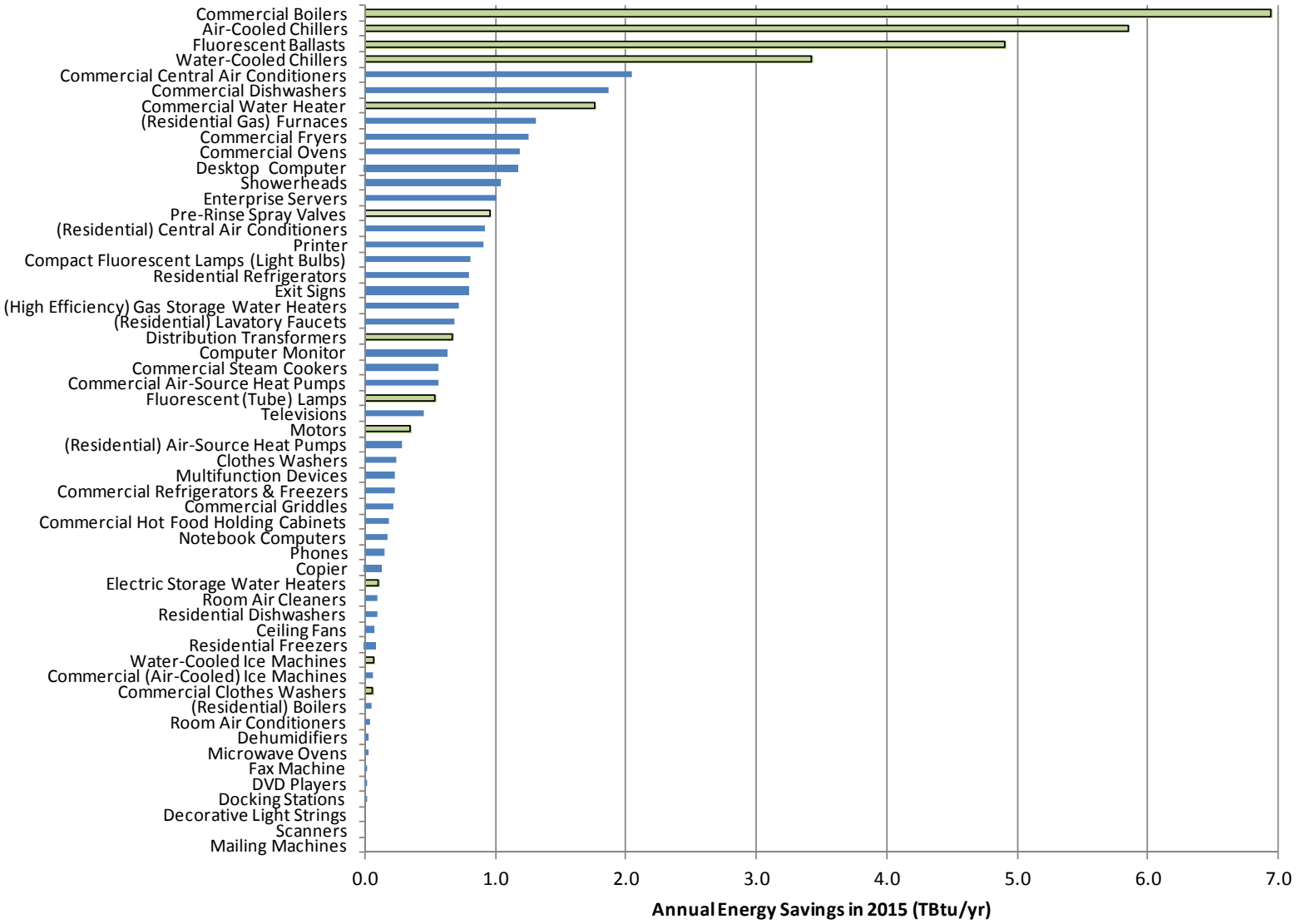
[a] Green highlight denotes products that were considered "FEMP-designated" for most or all of the analysis period

Figure 8: 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 9: Products ranked by annual savings in 2015 under the Best Available - Full scenario (TBtu/yr)



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

Appendix G: Additional Scenario Results

In this section we explore two 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.[6] 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.

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 more efficient technologies (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 increase in market share from 2.6% and 0% in 2006, respectively, to 5% each 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 7.

[6] 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.

Table 7: 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 in practice. 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. Estimated savings account only for savings achieved through lower density of lighting products (see

Table 8). 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 8: 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; military housing privatization was initiated by the Military Housing Privatization Initiative of 1996. This trend is currently expected to continue until approximately 195,000 housing units are privatized by around 2020 (which represents approximately 75% of the military housing stock from the early 2000s) (Office of the Deputy Under Secretary of Defense 2012). The primary analysis considers only the remaining federally administrated housing because housing managed by private companies is not currently subject to FEMP EEPP requirements. We assume that privatized housing units receive baseline efficiency products because higher efficiency is not mandated.[7]

In this section, we explore a hypothetical situation in which all military housing (both federally owned and privatized) is subject to EEPP requirements. 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 effects of the Military 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.[8] 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 Appendix E (Methodology), using this estimate of privatized military housing units.

Table 9 presents summary results for the privatized military housing scenario. Low, Full, and Best Available - Full compliance scenarios are defined as in Appendix E. The privatized housing scenario assumes that all military housing floor space will become subject to procurement requirements.

[7] 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.
[8] We recognize that there are other factors that cause the stock of military housing to change over time, but data availability necessitates this simplification.

Table 9: 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

References

Alliance to Save Energy (2012). Understanding Federal Compliance with Energy Efficiency Procurement Requirements: Procurement Forecast Review.

Capanna, S., S. Devranoglu, et al. (2008). A Review of Federal Agency Compliance with Energy-Efficient Procurement Laws. Washington, D.C., Alliance to Save Energy.

Fujita, K. S. and M. Taylor (2012). Achieved and Potential Energy Savings through Energy Efficient Procurement, Lawrence Berkeley National Laboratory. **LBNL-5737E**.

Gupta, M. and R. J. Palmer (2008). "A Brief History and Review of Purchasing Card Use by the U.S. Government: 1990-2005." Journal of Public Procurement **8**(2): 174-199.

Harris, J. and F. Johnson (2000). Potential Energy, Cost, and CO2 Savings from Energy-Efficient Government Purchasing. ACEEE Summer Study on Energy Efficiency in Buildings, Commercial Buildings: Program Design, Implementation, and Evaluation.

Norris, J. K. (2010). Tapping the Energy Efficiency Market within Federal Building Lease Renewals, CleanTechnica.com.

Office of the Deputy Under Secretary of Defense. (2012). "Military Housing Privatization." Retrieved March, 2012, from http://www.acq.osd.mil/housing/index.htm.

Pacific Gas and Electric Company. (2012). "Carbon Footprint Calculator Assumptions." Retrieved February, 2012, from http://www.pge.com/about/environment/calculator/assumptions.shtml.

Siciliano, G. (2010). 2010 Review of Federal Agency Compliance with Energy-Efficient Procurement Laws. Washington, D.C., Alliance to Save Energy.

Taylor, M. and K. S. Fujita (2012). The Path to Savings: Mapping Federal Energy-Consuming Product Procurement Processes, Prepared for the Federal Energy Management Program.

U. S. Department of Defense (2010). Base Structure Report Fiscal Year 2010 Baseline: A Summary of DoD's Real Property Inventory. Office of the Deputy Under Secretary of Defense.

U.S. Department of Energy (2010). 2010 Building Energy Data Book. Energy Efficiency & Renewable Energy Building Technologies Program.

U.S. Department of Energy (2010). Annual Report to Congress on Federal Government Energy Management and Conservation Programs: Fiscal Year 2007. Energy Efficiency & Renewable Energy Federal Energy Management Program.

U.S. Department of Energy (2010). Energy Conservation Standards for Certain Consumer Products (Dishwashers, Dehumidifiers, Microwave Ovens, and Electric and Gas Kitchen Ranges and Ovens) and for Certain Commercial and Industrial Equipment (Commercial Clothes Washers): Final Rule. Energy Efficiency & Renewable Energy Building Technologies Program.

U.S. Energy Information Agency (2003). Commercial Buildings Energy Consumption Survey.

U.S. Energy Information Agency (2009). Residential Energy Consumption Survey.

U.S. Environmental Protection Agency and U.S. Environmental Protection Agency (2000). Carbon Dioxide Emissions from the Generation of Electric Power in the United States.

U.S. General Services Administration (2002-2010). The Federal Real Property Council's Federal Real Property Report: An Overview of the U.S. Federal Government's Real Property Assets.

U.S. General Services Administration (2011). FY 2010 Federal Real Property Report: An Overview of the U.S. Federal Government's Real Property Assets. Federal Real Property Council.