Energy Efficiency Standards for Residential and Commercial Equipment: Additional Opportunities

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1. Introduction

Energy efficiency standards set minimum levels of energy efficiency that must be met by new products. Depending on the dynamics of the market and the level of the standard, the effect on the market for a given product may be small, moderate, or large.

Energy efficiency standards address a number of market failures that exist in the buildings sector. Decisions about efficiency levels often are made by people who will not be responsible for the energy bill, such as landlords or developers of commercial buildings. Many buildings are occupied for their entire lives by very temporary owners or renters, each unwilling to make long-term investments that would mostly reward subsequent users. And sometimes what looks like apathy about efficiency merely reflects inadequate information or time invested to evaluate it. In addition to these sector-specific market failures, energy efficiency standards address the endemic failure of energy prices to incorporate externalities.

In the U.S., energy efficiency standards for consumer products were first implemented in California in 1977. National standards became effective starting in 1988. By the end of 2001, national standards were in effect for over a dozen residential appliances, as well as for a number of commercial sector products. Updated standards will take effect in the next few years for several products. Outside the U.S., over 30 countries have adopted minimum energy performance standards.[1]

Technologies and markets are dynamic, and additional opportunities to improve energy efficiency exist. There are two main avenues for extending energy efficiency standards. One is upgrading standards that already exist for specific products. The other is adopting standards for products that are not covered by existing standards.

In the absence of new and upgraded energy efficiency standards, it is likely that many new products will enter the stock with lower levels of energy efficiency than would otherwise be the case. Once in the stock, it is either impossible or more costly to improve the energy efficiency. Therefore, by not expanding or upgrading energy efficiency standards, opportunities for saving energy would be lost.

In the past two decades, standards have significantly raised the level of energy efficiency for new products.[2] How much more might be gained by making standards more stringent on products already subject to them, or by extending standards to products not yet covered?

The main goal of this study is to estimate key national impacts of new and upgraded energy efficiency standards for residential and commercial equipment. These impacts approximate the opportunity for national benefits that may be lost if standards are not upgraded and expanded from current levels. This study also identifies the end uses where the largest opportunities exist.

This analysis was prepared for the National Commission on Energy Policy (NCEP). It uses an analytical approach that is similar in concept to that used by the U.S. Department of Energy (DOE) to set standard levels. It relies on much less data and uses more simplified assumptions than the detailed and complex formulations used in DOE's standard-setting process. The results of this analysis should thus be viewed as a first approximation of the impacts that would actually be achieved by new standards.

Note: All monetary values in this report are in 2002 dollars.

2. Products Considered

Within each of the key end uses, we considered equipment standards for specific products, as shown in Table 1. For some of the products listed, we determined that additional standards would not be cost-effective on a national-average basis. These products are listed later.

Products that we did not consider include those listed below. The reasons for not considering them were one or more of the following: (1) a more stringent standard is probably not cost-effective (e.g., clothes dryers); (2) the impact of a new standard would probably be low because the market for the product is small and shrinking (e.g., boilers); and (3) lack of adequate data. We also did not consider plumbing fixtures that can reduce hot water consumption in the residential and commercial sectors.

Residential Equipment:
Freezer
Clothes dryer
Oil furnace
Boiler
Furnace fan
Cooking equipment
Television

Commercial Equipment:
Electric heat pump
Gas unit heaters
Gas cooking equipment
Commercial clothes washers
Distribution transformers
Miscellaneous -- such as service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, emergency electricity generators.

Table 1: End Uses and Products Considered for Efficiency Standards

End Use	Products Considered
Residential	
Space heating	Gas furnace Heat pump
Air conditioning	Room air conditioners Central air conditioner and heat pump
Refrigeration	Refrigerator
Water heating	Electric and gas water heater
Clothes washing	Clothes washer
Dishwashing	Dishwasher
Lighting	Torchiere
Electric motors	Ceiling fan, pool pump, well pump, miscellaneous small motors
Household electronics	Various products
Commercial	
Space heating	Gas furnace and boiler
Air conditioning	Air-source and water-source air conditioner and heat pump
Ventilation	Various products
Lighting	Fluorescent lamp HID lamp
Water heating	Gas-fired storage water heater Gas-fired instantaneous water heater
Refrigeration	Various products
Office equipment	PC and Other Equipment

3. Technology Cost-Efficiency Analysis

For each considered product, we estimated the incremental consumer cost of technologies providing higher energy efficiency relative to a specific baseline technology, as well as the associated reduction in annual energy use. Key data sources include the technical analyses published by the Department of Energy (DOE) for its equipment standards rulemakings[3] and data from the analysis done by the Interlaboratory Working Group for the "Scenarios for a Clean Energy Future" study.[4]

Box 1 provides an example of the key data inputs, sources and results for a product. In this and other cases, we selected the most common type of product to serve as a proxy for the product category. Appendix 1 provides a description of the cost-efficiency analysis for each considered product, as well as the sources of data.

Box 1: Example of Technology Cost-Efficiency Analysis

Sector: Residential
End Use: Air conditioning
Product: Room air conditioner
Lifetime (years): 12.5

Baseline Technology: 8,000-13,999 Btu/hr, with louvered sides, without reversing valve, 9.85 EER

	Technology for 2010 Standard	Technology for 2020 Standard
Description	10.11 EER	Same as 2010
Increase in consumer first cost* ($)	$8	$7
Annual energy savings* (kWh)	17	17
CCE (¢/kWh)	5.2	4.5
Decrease in LCC* ($)	$4	$5

* Relative to baseline technology with first cost of $482 in 2010, annual energy use of 657 kWh, and LCC in 2010 of $930.

Source(s): U.S. Department of Energy (DOE)-Office of Codes and Standards. 1997. "Technical Support Document for Energy Conservation Standards for Room Air Conditioners, Volume 2 – Detailed Analysis of Efficiency Levels " Washington, DC.

Our estimates of technology costs in 2010 and 2020 assume that a decline occurs from current costs due to a "learning curve" effect. The central idea is that manufacturers develop efficiencies of production as the industry as a whole matures. Accordingly, an empirical learning curve typically uses cumulative production of the product in question as a measure of experience accumulated. The key impact of this learning is the reduction of input use per product – and thus the cost.

To estimate a "learning parameter" for this study, we relied on an empirical analysis that developed a product-characteristics model of energy-using consumer durables.[5] As described in Appendix 2, one result of this analysis is estimates of a "learning parameter" for three appliances. Based on the results for the three appliances, we applied a decrease of 1.5% per year to the current estimates of incremental cost for each product. We also address how the results might change if no learning effect was incorporated.

For each higher-efficiency technology, we calculated cost-of-conserved-energy (CCE) values that spread the initial incremental cost over the lifetime of the equipment. The CCE in terms of dollars per kWh or MMBtu (gas) is an expression of the extra first cost incurred to save a unit of energy. Calculation of CCE requires application of a Present Worth Factor (PWF) to spread the initial incremental cost over the lifetime of the equipment. The PWF uses a discount rate to effectively amortize costs over time. We derived average discount rates for consumer costs as shown in Table 2. Appendix 3 provides a discussion of the derivation of these discount rates. The rates reflect adjustment for inflation and for tax impacts (such as deduction of mortgage interest).

Table 2: Discount Rates for Types of Costs

Type of Cost	Discount Rate (%)	Basis for Rate
Residential equipment standards	5.6	Opportunity cost for households of investment in energy efficiency
Commercial equipment standards	6.1	Weighted cost of capital for typical commercial sector enterprises

4. Consumer Impacts Analysis

To estimate the impacts of new and upgraded standards on residential and commercial consumers, we used life-cycle cost (LCC) analysis. The LCC for an appliance includes the initial capital cost and the operating costs over an assumed lifetime, with the operating costs discounted to a present value. Using the data from the technology cost-efficiency analysis, and the discount rates shown above, we calculated the LCC for each technology considered for each product.

For some considered products, technologies that are more energy-efficient than the baseline technology have a higher LCC than the baseline. For these products, we do not include a new or upgraded standard.

Ideally, a consumer impacts analysis should use marginal energy prices to calculate the reduction in energy costs associated with standards. Marginal energy prices are the prices consumers pay for the last unit of energy used in a given billing period. Since marginal prices reflect a change in a consumer's bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with efficiency standards.

For commercial sector electric end uses, we estimated end-use-specific marginal electricity prices for air conditioning, lighting, and refrigeration. We made use of past analysis by DOE/LBNL on estimating marginal electricity prices for commercial unitary air conditioners in this study.[6] That analysis looked at actual commercial sector tariffs for utilities across the U.S. to derive the marginal prices faced by consumers. As we did not have similar analysis for commercial sector natural gas prices, we used average prices.

For residential consumers, we did not have data on marginal energy prices, so we used average electricity and natural gas prices. Given the structure of residential tariffs, one would expect that the difference between marginal and average prices is less in the residential sector than in the commercial sector.

For residential end uses and commercial natural gas end uses, the life-cycle energy costs utilize projections of average sectoral natural gas and electricity prices from the DOE-Energy Information Administration's (DOE-EIA) *Annual Energy Outlook 2004 (AEO 2004).*[7] (The *AEO* projections go through 2025. We extrapolated the projected trends in 2015-2025 to estimate prices for later years.) For commercial sector electric end uses, we applied the trend in the EIA projections to the estimated marginal prices in 2002. Figures 1 and 2 show the price projections used.

We also consider changes in maintenance costs where the standards have a significant impact.
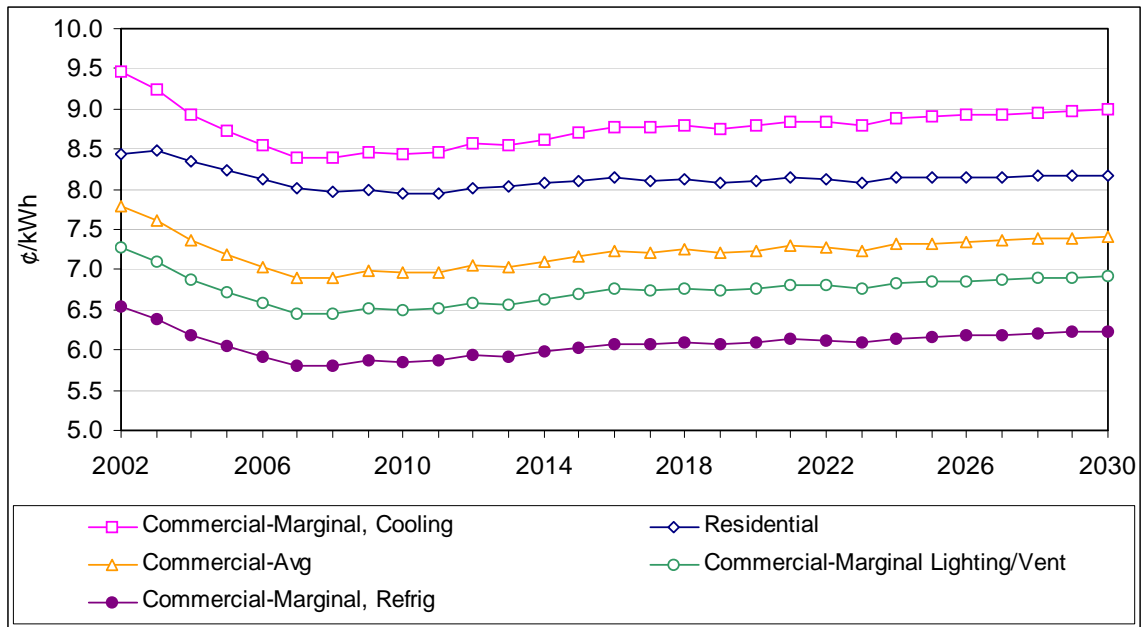
Figure 1: Projected Electricity Prices
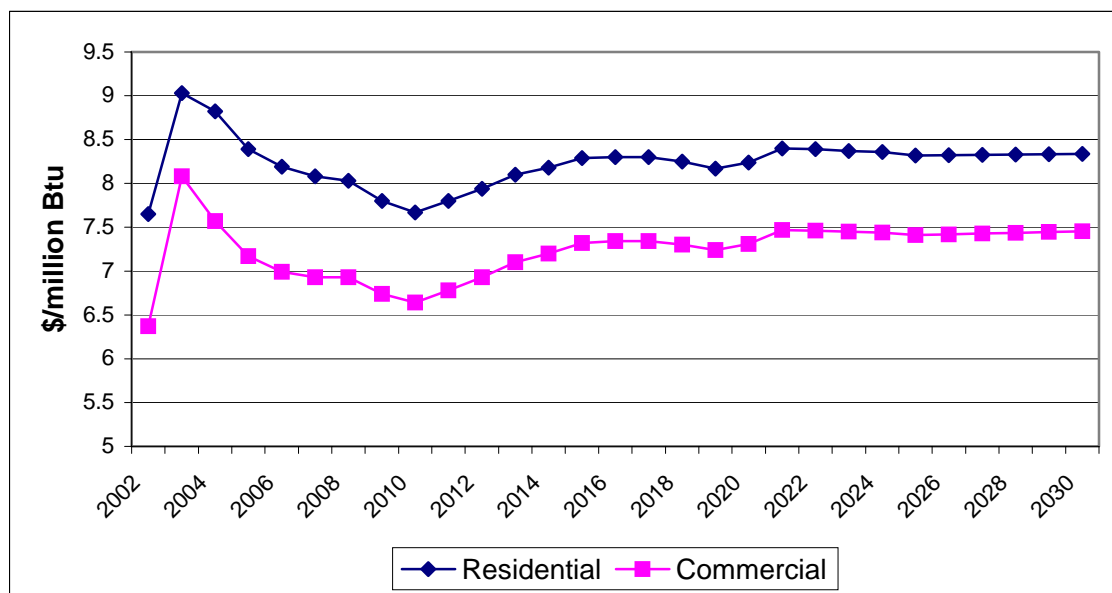
Figure 2: Projected Natural Gas Prices

5. Selection of Efficiency Levels for Upgraded Standards

For each product, we selected the technology with the lowest LCC in 2010 and 2020 for the 2010 and 2020 standards. As mentioned above, new or upgraded standards were not cost-effective relative to the baseline technology for a few of the considered products. Table 3 illustrates the results for the case of residential refrigerators.

Table 3: LCC Example - Residential Refrigerator*

Technology Option	LCC in 2010	LCC in 2020
484 kWh/yr (baseline)	$1,046	$964
473 kWh/yr	$1,041	$958
444 kWh/yr	$1,030	$945
437 kWh/yr (2010 std)	$1,029	$943
426 kWh/yr	$1,031	$943

* Top-mount freezer with auto-defrost

Tables 4 and 5 show the technologies selected for 2010 and 2020 standard levels and their cost of conserved energy for the residential and commercial sectors, respectively. For many products, an upgrade of the 2010 standard in 2020 is not cost-effective, so the 2020 standard is the same as the 2010 standard. Note that even if the standard is the same, the CCE is lower in 2020 due to the assumed decrease in equipment costs over time. Table 6 shows the relevant energy prices to which the CCEs may be compared.

Product standards that were considered but judged not cost-effective on a national-average basis are those for central air conditioners, electric heat pumps, gas water heaters, and clothes washers. In each case, new DOE standards either took effect in 2004 or will take effect in 2006-07. Improvement beyond those standards is not cost-effective given the costs and energy prices currently envisioned.

Table 4: Technologies Selected for Upgraded Standards – Residential Sector

End Use/Product	Baseline Technology	Technology for 2010 Standard	CCE for 2010 Standard	Technology for 2020 Standard	CCE for 2020 Standard
Space heating					
Gas furnace	80% AFUE	81% AFUE using 2-stage modulation	$6.20/MMBtu	Same as 2010	$5.40/MMBtu
Air conditioning					
Room air conditioner	9.85 EER	10.11 EER	5.2¢/kWh	Same as 2010	4.5¢/kWh
Refrigeration	484 kWh/yr	426 kWh/yr	4.9¢/kWh	Same as 2010	4.2¢/kWh
Lighting					
Torchiere	Incandescent	Fluorescent	6.8¢/kWh	Same as 2010	5.9¢/kWh
Water heating					
Electric	92 EF	92 EF	n/a	Heat pump	3.9¢/kWh
Dishwashing*	2.14 kWh/cycle	1.96 kWh/cycle	4.2¢/kWh	Same as 2010	3.6¢/kWh
Motors					
Ceiling fans	Current practice	Higher efficiency	3.4¢/kWh	Same as 2010	2.9¢/kWh
Pool pumps	Single-Speed	Two-Speed	4.6¢/kWh	Same as 2010	4.0¢/kWh
Electronics**					
Audio	Current practice	1 watt standby	1.2¢/kWh	Same as 2010	1.0¢/kWh
Settop box	Current practice	7 watt standby	0.3¢/kWh	Same as 2010	0.2¢/kWh
Telephony	Current practice	1 watt standby	4.0¢/kWh	Same as 2010	3.5¢/kWh
Microwave oven	Current practice	1 watt standby	0.3¢/kWh	Same as 2010	0.2¢/kWh
Misc. electronics	Current practice	1 watt standby	1.5¢/kwh	Same as 2010	1.3¢/kwh

* The values include the energy savings from reduced water heating associated with a higher-efficiency dishwasher.
** This category does not include TVs or computers and associated equipment.

Table 5: Technologies Selected for Upgraded Standards -- Commercial Sector

End Use/Product	Baseline Technology	Technology for 2010 Standard	CCE for 2010 Standard	Technology for 2020 Standard	CCE for 2020 Standard
Space Heating	Thermal Effc'y	Thermal Effc'y	$/MMBtu	Thermal Effc'y	$/MMBtu
Packaged Boilers, Gas-Fired, HW (400 kBtu/hr)	75%	79%	1.00	same as 2010	0.90
Packaged Boilers, Gas-Fired, HW (800 kBtu/hr)	75%	78%	3.30	88%	5.00
Packaged Boilers, Gas-Fired, HW (1500 kBtu/hr)	75%	88%	2.70	same as 2010	2.30
Packaged Boilers, Gas-Fired, HW (3000 kBtu/hr)	75%	88%	1.60	same as 2010	1.40
Packaged Boilers, Gas-Fired, Steam (400 kBtu/hr)	72%	76%	3.30	same as 2010	2.80
Packaged Boilers, Gas-Fired, Steam (800 kBtu/hr)	72%	76%	2.90	same as 2010	2.50
Packaged Boilers, Gas-Fired, Steam (1500 kBtu/hr)	72%	79%	3.30	same as 2010	2.80
Packaged Boilers, Gas-Fired, Steam (3000 kBtu/hr)	72%	80%	1.90	same as 2010	1.70
Warm-Air Furnaces, Gas-Fired (250 kBtu/hr)	78%	80%	6.50	same as 2010	5.60
Warm-Air Furnaces, Gas-Fired (400 kBtu/hr)	78%	80%	5.10	same as 2010	4.40
Air conditioning	EER	EER	¢/kWh	EER	¢/kWh
3-Phase, Single-Package, Air-Source AC (<65 kBtu/h)	9.7	12	4.2	same as 2010	3.6
3-Phase, Split-System, Air-Source AC (<65 kBtu/h)	10	12	6	same as 2010	5.2
3-Phase, Single-Package, Air-Source HP (<65 kBtu/h)	9.7	12	4.6	same as 2010	3.9
3-Phase, Split-System, Air-Source HP (<65 kBtu/h)	10	13	5.2	same as 2010	4.5
Central, Air-Source AC (>65 kBtu/h and <135 kBtu/h)	10.1	11.5	3.2	12	4.5
Central, Air-Source HP (>65 kBtu/h and <135 kBtu/h)	10.1	11.5	3.2	12	4.5
Central, Water-Source HP (>65 kBtu/h and <135 kBtu/h)	12	12.5	7.2	13	7.4
Central, Water-Cooled AC (>65 kBtu/h and <135 kBtu/h)	11.5	12.4	5.9	14	6.9
Central, Air-Source AC (>135 kBtu/h and <240 kBtu/h)	9.5	11.5	2.7	12	3.6
Central, Air-Source HP (>135 kBtu/h and <240 kBtu/h)	9.5	11.5	2.7	12	3.6
Central, Water-Cooled AC (>135 kBtu/h and <240 kBtu/h)	11	11.5	2.9	same as 2010	2.5
Central, Water-Cooled AC (<65 kBtu/h)	12.1	12.1	0	12.5	7.5
Central, Water-Source HP (<17 kBtu/h)	11.2	11.2	0	12.5	7.8
Central, Water-Source HP (>17 kBtu/h and <65 kBtu/h)	12	13.1	7.1	same as 2010	6.1
Packaged Terminal Air Conditioners (PTACs) (< 7kBtu/h)	9.4	11	5.8	same as 2010	5.0
Packaged Terminal Air Conditioners (PTACs) (7-10 kBtu/h)	9	10.8	3.8	same as 2010	3.3
Packaged Terminal Air Conditioners (PTACs) (10-13 kBtu/h)	8.3	10.5	4.1	same as 2010	3.6
Packaged Terminal Air Conditioners (PTACs) (>13 kBtu/h)	7.9	10	1.9	same as 2010	1.7
Packaged Terminal Heat Pumps (PTHPs) (< 7kBtu/h)	9.3	10.8	5.8	same as 2010	5.0
Packaged Terminal Heat Pumps (PTHPs) (7-10 kBtu/h)	8.9	10.6	3.4	11.4	4.5
Packaged Terminal Heat Pumps (PTHPs) (10-13 kBtu/h)	8.2	9.7	2.8	same as 2010	2.4
Packaged Terminal Heat Pumps (PTHPs) (>13 kBtu/h)	7.8	10	4.7	same as 2010	4.0
Ventilation	Efficiency	Efficiency	¢/kWh	Efficiency	¢/kWh
Air Distribution					
Large Unitary (10 HP)	85%	92%	0.5	same as 2010	0.4
Exhaust Fan (0.5 HP)	60%	80%	0.2	same as 2010	0.2
Room Fan Coil (0.17 HP)	50%	75%	0.9	same as 2010	0.7
Central Station Air Handling Unit (10 HP)	87%	93%	0.6	same as 2010	0.5
Hydronic Hot and Chilled Water Circulation					
Centrifugal Chiller (25 HP)	90%	95%	0.5	same as 2010	0.5
Screw Chiller (10 HP)	90%	94%	1.4	same as 2010	1.2

| End Use/Product	Baseline Technology	Technology for 2010 Standard	CCE for 2010 Standard	Technology for 2020 Standard	CCE for 2020 Standard
Reciprocating Chiller (10 HP)	88%	93%	1.5	same as 2010	1.3
Absorption Chiller (25 HP)	90%	95%	0.5	same as 2010	0.4
Hydronic heating (10 HP)	90%	94%	0.8	same as 2010	0.7
Cooling Water Circulation					
Centrifugal Chiller (25 HP)	90%	95%	0.5	same as 2010	0.4
Screw Chiller (10 HP)	90%	94%	1.0	same as 2010	0.9
Reciprocating Chiller (10 HP)	88%	93%	1.9	same as 2010	1.6
Lithium Bromide Water Absorption Chiller (25 HP)	90%	95%	0.5	same as 2010	0.4
Heat Rejection					
Large Unitary (5 HP)	85%	90%	1.4	same as 2010	1.2
Air Cooled Screw Chillers (2 HP)	85%	92%	0.1	same as 2010	0.1
Air Cooled Reciprocating Chillers (2 HP)	85%	92%	0.1	same as 2010	0.1
Cooling Tower (10 HP)	85%	92%	1.4	same as 2010	1.2
Water Heating	Thermal Effc'y	Thermal Effc'y	$/MMBtu	Thermal Effc'y	$/MMBtu
Storage Water Heater, Gas-Fired (120 kBtu/hr)	80%	82%	4.00	same as 2010	3.50
Storage Water Heater, Gas-Fired (199 kBtu/hr)	80%	82%	4.10	same as 2010	3.50
Storage Water Heater, Gas-Fired (360 kBtu/hr)	80%	82%	4.30	same as 2010	3.70
Instantaneous Water Heater, Gas-Fired (1000 kBtu/hr)	80%	83%	4.80	same as 2010	4.10
Instantaneous Tank Water Heater, Gas-Fired (500 kBtu/hr)	80%	82%	4.30	same as 2010	3.70
Lighting*	Technology	Technology	¢/kWh	Technology	¢/kWh
Fluorescent Lamp/ballast	Current Practice	Hi-perf T8 w/elec and hi-perf ballast	1.9	Hi-perf T8 w/ hi-perf ballast	1.1
HID -- Lo Bay	MV 20%, MH 55%, HPS 25%	PMH 75% & HPS 25%	3.0	PMH/SSB 75% & HPS 25%	2.9
HID -- Hi Bay	MV 20%, MH 55%, HPS 25%	PMH 75% & HPS 25%	1.0	PMH/SSB 75% & HPS 25%	1.0
Refrigeration	Technology	Effc'y Improvement	¢/kWh	Effc'y Improvement	¢/kWh
Supermarket Units	Current technology	16%	1.2	same as 2010	1.1
Beverage Merchandiser Units	Current technology	61%	2.1	same as 2010	1.8
Reach-in Freezers	Current technology	52%	2.5	same as 2010	2.3
Reach-in Refrigerators	Current technology	38%	1.9	same as 2010	1.6
Ice Machines	Current technology	23%	2.8	same as 2010	2.4
Refrigerated Vending Machines	Current technology	51%	2.9	same as 2010	2.5
Walk-in Coolers	Current technology	46%	1.2	same as 2010	1.0
Walk-in Freezers	Current technology	48%	3.0	same as 2010	2.6
Office equipment					
Personal Computers & Monitors	Current technology	Low standby	1.0	Not applicable	0.1
Other	Current technology	Low standby	1.0	Not applicable	0.2

* MV = mercury vapor; MH = metal halide; HPS = high-pressure sodium; PMH = pulse metal halide; SSB = solid-state ballast

Table 6: Energy Prices for CCE Comparison

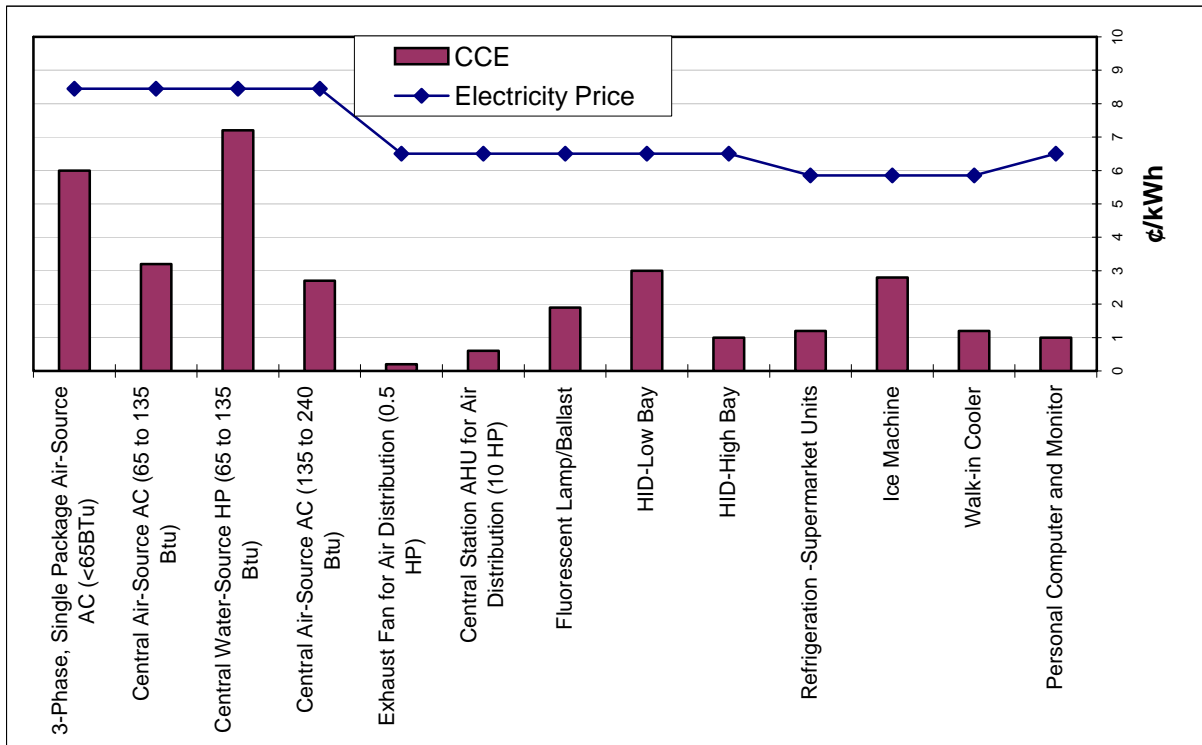|	Residential Sector	Commercial Sector
Electricity (¢/kWh)		
Price in 2010-20 period	8.5-9.0	7.0-7.2*
Price in 2020-30 period	8.8-9.0	7.2-7.4*
Natural gas ($/MMBtu)		
Price in 2010-20 period	7.7-8.3	6.7-7.3
Price in 2020-30 period	8.4	7.4

* These are average prices. Prices are 8.5-9.0 ¢/kWh for air conditioning, 6.5-6.9 ¢/kWh for lighting and ventilation, and 5.8-6.1 ¢/kWh for refrigeration. See Figure 1.

As Figures 3 and 4 illustrate, the CCE for the 2010 standards is well below the relevant energy price for most products. This result indicates that most of the standards would be cost-effective even if we did not assume that manufacturing costs decline over time due to a learning effect.
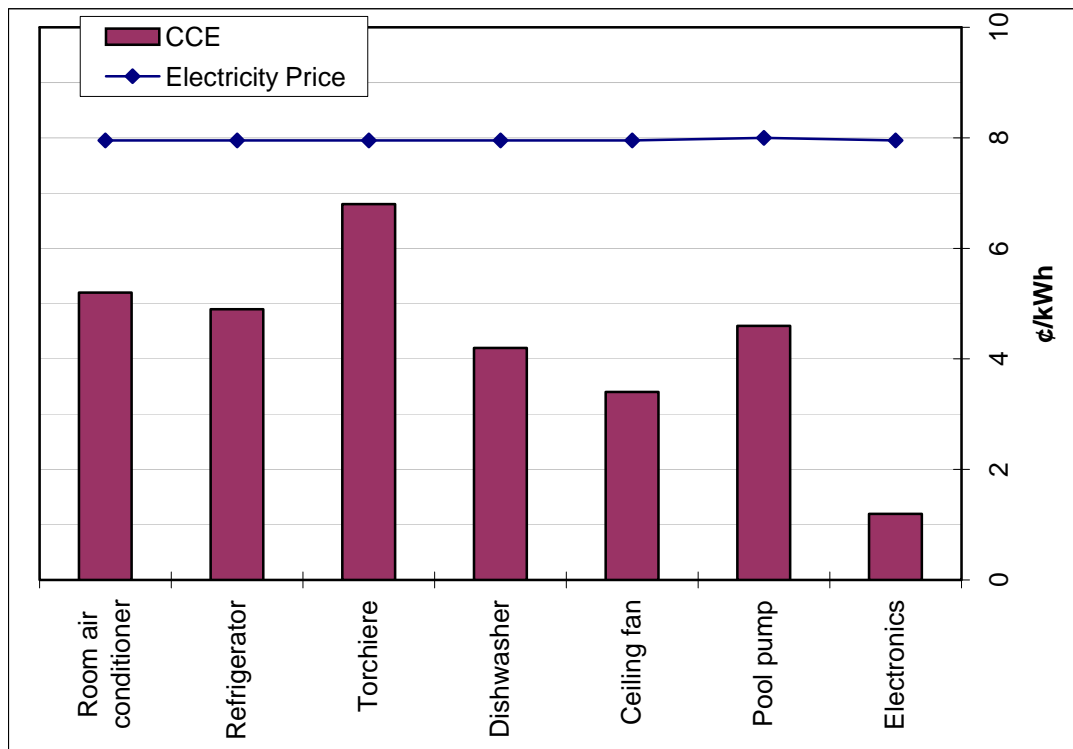
Figure 3. Comparison of Cost of Conserved Energy for 2010 Standards to Projected Electricity Price in the Residential Sector

Figure 4: Comparison of Cost of Conserved Energy for Representative 2010 Standards to Marginal Electricity Price in the Commercial Sector

Our analysis considers the consumer perspective. Another perspective of interest is how the CCEs compare to the avoided costs of providing a unit of electricity and natural gas to consumers. In the short run, energy conservation mainly affects a utility's energy costs. In the long run, energy conservation may affect decisions about expanding generating and transmission and distribution capacity.[8] The impact of energy efficiency standards on decisions about expanding generating and load distribution capacity varies across the U.S. On average, however, the impact of such standards is sufficiently large to have an impact on capacity expansion. This situation supports the use of long run avoided costs to measure the impacts of energy efficiency standards.

Determining the appropriate avoided costs at a national level for a future time period is not a simple exercise. One would expect the long run avoided costs of electricity and natural gas to be somewhat less than the retail prices we have used in this analysis. Given that the CCE for most of the considered standards is well below the forecast retail price, however, it is likely that most of the standards would be cost-effective compared to the long run avoided cost.

6. Estimation of National Impacts

The Base Case (Business-as-usual) provides a reference against which we measure the potential impacts of upgraded standards. Our Base Case uses the reference energy consumption projections in *AEO2004* through 2025 and extrapolated values thereafter. It includes all standards that have already been promulgated by DOE as of 2004.[a] It implicitly assumes that new buildings meet recent State building codes. As a result of these and other factors, the Base Case shows ongoing efficiency improvement in each end-use.

The Upgraded Standards Case assumes upgraded and new standards take effect in 2010, and more stringent standards take effect in 2020 if they are cost-effective. The standards affect products installed from the effective date through 2030. We consider the impacts of standards over the lifetime of all products installed in the 2010-2030 period.

To estimate impacts of upgraded standards for each product, we first estimate the fraction of current energy consumption in each end use that is accounted for by the considered product. We assume this fraction remains constant over time.[b] We then use a stock model to estimate what share of the stock of each product in each future year consists of units installed after the standard effective date. Such products include replacements for retired products as well as products installed in new buildings. The stock model makes use of the estimated current stock, the mean lifetime of each product, a retirement function, and projected installations due to new construction of residential and commercial buildings. Projections of new construction are based on *AEO 2004.*

Appliances installed after the standard effective date represents those products potentially affected by standards. For the residential sector, we had data that allowed estimation of the share of the products in the Base Case that are more efficient than the upgraded standard, and thus would not be impacted by new or upgraded standards. We estimated these shares based on market statistics for high-efficiency products with an "Energy Star" designation. As similar data were not available for the commercial sector products, we assumed that all of the products installed after the standard effective date would potentially be affected by standards. In the Base Case, we assume that the "eligible" products utilize the baseline technology considered in the technology cost-efficiency analysis. Since some commercial sector products installed after 2010 are likely to have a higher efficiency than the baseline technology even without standards, our method leads to some over-estimation of energy savings from standards.

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[a] The base case includes standards with effective dates in the future, such as the revised standard for clothes washers that will take effect in 2007. It does not include standards that are still under consideration by DOE.

[b] Ideally, one would model potential change in the share. Such analysis was not possible for this study.

In the Upgraded Standards Case, we apply the percentage reduction in average annual energy consumption associated with the standard (relative to the baseline technology) to the share of Base Case energy consumption that is accounted for by products installed after the standard effective date. The result is the aggregate energy savings attributable to the standard.

For example, the 2010 standard for refrigerators results in 10% reduction in the average annual energy consumption compared to the baseline technology. We estimated that 25% of the total new units purchased after 2010 would be at least as efficient as the upgraded 2010 standard. Thus, 75% of the total new units purchased after 2010 would be affected by the standard. We assume that these units are the baseline technology. We calculate total annual energy savings by multiplying: (1) the 10% reduction in average annual energy consumption by (2) the average annual energy consumption of the baseline technology by (3) the number of eligible products installed in each year.

Appendix 4 provides further discussion of the accounting framework used to estimate national-level impacts. The approach used is obviously a simplification of a complex reality, and many of the assumptions are subject to uncertainty.

We express the annual electricity and natural gas savings from upgraded standards in total primary energy using annual primary-to-site energy factors based on *AEO 2004.*[c]

7. Value of Energy Savings

One way to measure the value of the energy savings due to standards is to consider the costs avoided by energy suppliers. In the short run, energy conservation mainly affects a utility's energy costs (though there may also be short-run avoided capacity costs). In the long run, energy conservation may affect decisions about expanding generating and transmission and distribution capacity.

The view that the long-run avoided utility cost is the appropriate measure for energy efficiency was actively discussed in the context of utility energy conservation programs, and various approaches for estimating it were debated for many years. *Least-Cost Utility Planning,* a handbook for public utility commissioners published by the National association of Regulatory Utility Commissioners, discusses several methods for measuring long-run avoided costs of conservation programs.[8]

The impact of energy efficiency standards on decisions about expanding generating and load distribution capacity varies across the U.S. On average, however, the impact of such standards is sufficiently large to have an impact on capacity expansion, which suggests that long run avoided utility costs are a more appropriate measure of the avoided cost associated with energy efficiency standards. Estimating such costs on a national level is difficult, however. For this report, we calculated the value of the energy savings

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[c] The *AEO 2004* projections go through 2025. We extrapolated the past trends to estimate prices for later years.

from new and upgraded standards by using the same energy prices as in the consumer impacts analysis. This value reflects the consumer perspective.

We calculated the Net Present Value (NPV) to consumers as the difference between the national operating cost savings due to the equipment standards and the increased national equipment costs associated with the standards. We expressed future costs and benefits in present (2004) value terms by using alternative national-level discount rates.

The 7% discount rate is based on guidance issued by the Office of Management and Budget (OMB) in Circular No. A-94 (Revised), which states (section 8): "In general, public investments and regulations displace both private investment and consumption. … Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years."[d] OMB's guidance reflects the view that – from a national perspective – the opportunity cost of capital invested to improve appliance efficiency is best approximated by using the return on an average investment in the private sector. In DOE's analyses of the national economic impacts of equipment energy efficiency standards, it relies on the OMB guidance.

The OMB guidance notes that regulations may displace both private investment and consumption. Most estimates of the rate of return on consumption are on the order of 3 or 4 percent.[9] In 2003 the OMB advised Federal agencies to use a 3% discount rate to express the "social rate of time preference" when regulation primarily affects private consumption (e.g., through higher consumer prices for goods).[e] Thus, we also apply a "consumption discount rate"of 3%.

8. Results

Figures 5 and 6 show the cumulative primary energy savings and cumulative net present value due to new and upgraded efficiency standards by end use for the residential and commercial sectors. The values reflect the lifetime impacts from products installed in the 2010-2030 period. The largest energy savings are associated with standards for residential electronics products, but the estimate for this group of products is subject to a high degree of uncertainty. The next largest savings in the residential sector come from standards for electric water heaters and torchieres. Apart from electronics, the greatest savings come from standards for commercial refrigeration, followed by lighting and air conditioning.

The largest net present value comes from residential electronics products, but the caveat mentioned above applies here. Apart from residential electronics products, standards in the commercial sector yield more NPV than do those in the residential sector.
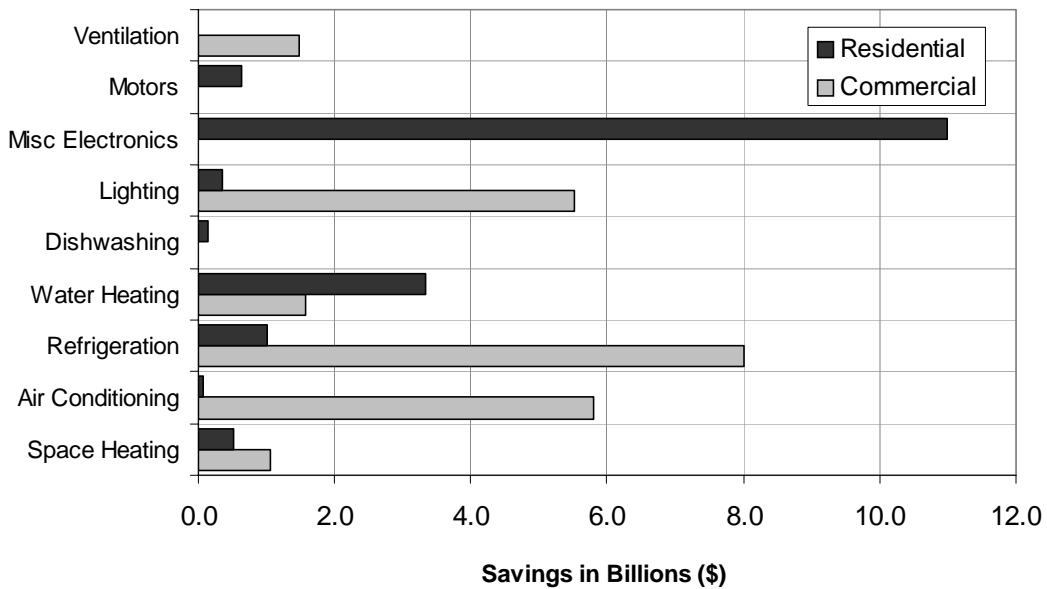
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[d] See http://www.whitehouse.gov/omb/circulars/a094/a094.html#9.

[e] OMB, Circular A-4, Sept. 17, 2003, p. 33.

Figure 5. Cumulative primary energy savings from upgraded standards for
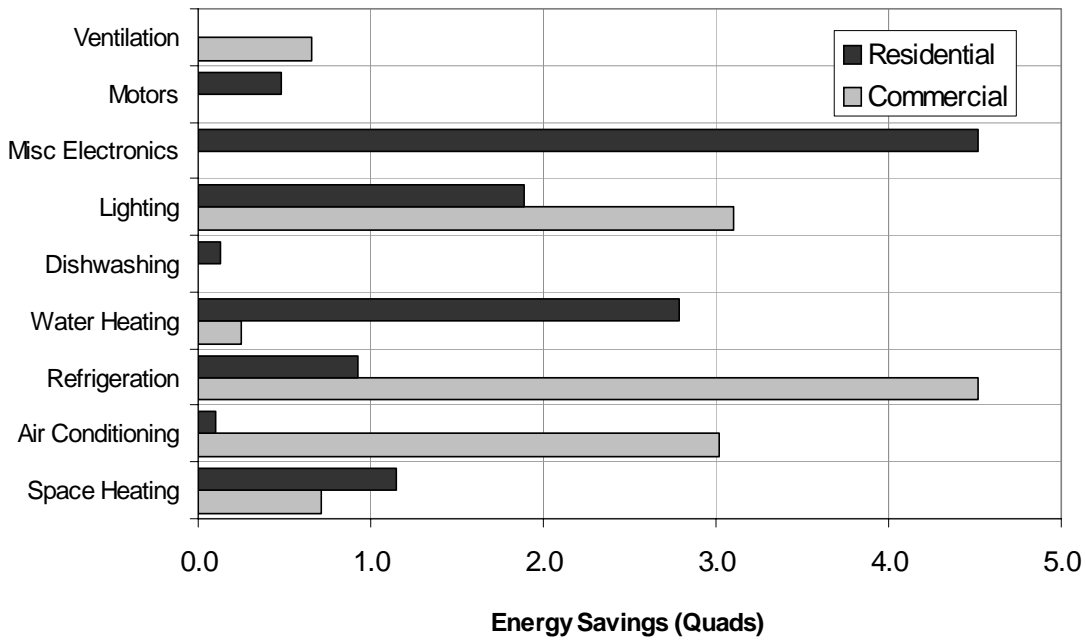
products installed in 2010-2030 period

Figure 6. Net present value of consumer benefit from upgraded standards for products installed in 2010-2030 period (7% discount rate)

In tabular form, Tables 7 and 8 show the cumulative primary energy savings and cumulative net present value due to upgraded equipment standards by end use for the residential and commercial sectors, respectively. The total cumulative energy savings

amount to just under 26 quads. The total NPV is $42 billion using a 7% discount rate, but $104 billion using 3%. The commercial sector accounts for a greater share of the total energy savings and NPV than the residential sector.

Table 7: Residential Sector Energy Savings and Consumer Benefit for Products Installed in 2010-2030 Period

End Use/Product	Cumulative Primary Energy Savings (quads)	NPV of Consumer Benefit (billion $)	
		7% discount rate	3% discount rate
Space Heating			
Gas furnace	1.1	0.5	3.1
Air Conditioning			
Room air conditioner	0.10	0.08	0.30
Refrigeration			
Refrigerator	0.92	1.0	3.6
Lighting			
Torchiere	1.9	0.36	1.5
Water heating			
Electric	2.8	3.3	11.8
Dishwashing*	0.13	0.13	0.35
Motors	0.48	0.62	1.5
Electronics	4.5	11.0	22.9
TOTAL	**12.0**	**17.0**	**45.1**

* Includes water heating savings derive from the higher-efficiency dishwasher, which uses less hot water.

Table 8: Commercial Sector Energy Savings and Consumer Benefit for Products Installed in 2010-2030 Period

End Use/Products	Cumulative Primary Energy Savings (quads)	NPV of Consumer Benefit (billion $)	
		7% discount rate	3% discount rate
Space Heating			
Various	0.71	1.1	2.7
Air Conditioning			
Various	3.0	5.8	14.0
Ventilation			
Various	0.66	1.5	3.2
Water Heating			
Various	0.25	1.6	3.2
Lighting			
Various	3.1	5.5	12.8
Refrigeration			
Various	4.5	8.0	16.6
Office Equipment	1.6	3.7	6.0
TOTAL COMMERCIAL	**13.8**	**27.2**	**58.6**

9. Conclusion

This study estimated key national impacts of potential upgrades in energy efficiency standards for residential and commercial equipment. These impacts approximate the opportunity for national benefits that may be lost if energy efficiency standards for residential and commercial equipment are not upgraded and expanded from current levels.

The study used an analytical approach that is similar to the one used by the U.S. Department of Energy to set standard levels. Since it relies on much less data and uses simplified assumptions rather than the detailed formulations used in DOE's standard-setting process, the results of this analysis should be viewed as a first approximation of the impacts that would actually be achieved by new standards.

Our estimate of total cumulative energy savings from new and upgraded standards that would be effective in 2010-2030 amounts to just under 26 quads. The annual savings amount to one quad in 2015 and two quads in 2025. The largest energy savings are associated with standards for residential electronics products, but this estimate is subject to a high degree of uncertainty. Apart from electronics, the greatest savings come from standards for commercial refrigeration, followed by lighting and air conditioning. The

next largest savings in the residential sector come from standards for electric water heaters and torchieres.

The total NPV is $42 billion using a 7% discount rate, but $104 billion using 3%. The largest net present value comes from residential electronics products, but the caveat mentioned above applies here. Apart from residential electronics products, standards in the commercial sector yield much more NPV than do those in the residential sector.

In assessing the results, the limitations of this study should be borne in mind. As mentioned in the introduction, this study relied on much less data and more simplified assumptions than does DOE's standard-setting process. Despite this caveat, our results suggest that national benefits from new and upgraded standards may be substantial. They also indicate that standards for currently-unregulated products would yield more benefits than upgrading minimum efficiency standards for products that already have them. The majority of those currently-unregulated products are in the commercial sector.

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Appendix 1

Methods and Sources Used for the
Appliance Cost-Efficiency Analysis

General Approach

For each considered product, we estimated the incremental consumer cost of technologies providing higher energy efficiency relative to a specific baseline technology, as well as the associated reduction in annual energy use. This appendix describes the key inputs and results, and presents the sources for the input data.

For some of the products, we used the most common type as a proxy for the entire class. For example, for refrigerator-freezers, we used a top-mount auto-defrost refrigerator-freezer with 21.4 cu.ft. adjusted volume as a proxy for the class.

The tables in this appendix present data for the technologies that were selected for the 2010 and 2020 standards. One summary statistic for each technology is the cost of conserved energy (CCE), which spreads the initial incremental cost over the lifetime of the equipment. Cost of conserved energy (non-discounted) for each product is given by:

$$CCE = \frac{\Delta EC}{\sum_{1}^{L} \Delta OC}$$

where

|		
CCE	=	Cost of Conserved Energy
ΔEC	=	Incremental Consumer Equipment Cost
ΔOC	=	Annual Consumer Operating Cost Savings
L	=	Equipment Lifetime

Calculation of a discounted CCE values requires application of a Present Worth Factor (PWF) to spread the initial incremental cost over the lifetime of the equipment. The PWF uses a discount rate to effectively amortize costs over time. We derived separate discount rates for residential and commercial consumers, as discussed in Appendix 3.

Another summary statistic is the life-cycle cost (LCC). The LCC for a piece of equipment includes the initial capital cost and the operating costs over an assumed lifetime, with the operating costs discounted to a present value. We calculated the LCC for each technology using the same discount rates as for the CCE calculation.

The tables include installed costs, annual energy consumption and LCC for the baseline model of each technology, where available. For some technologies, only incremental costs and consumption were available; baseline data are not listed for these technologies.

For each considered product, we actually analyzed a number of technologies. Figures 1-4 provide examples of the range of technologies considered, and show how the consumer price and the LCC change with efficiency.

Figures 1 and 2. Price and Life-Cycle Cost Change vs. Efficiency for Commercial Central Air Conditioner, Water-Source HP >65 kBtu/h and <135 kBtu/h
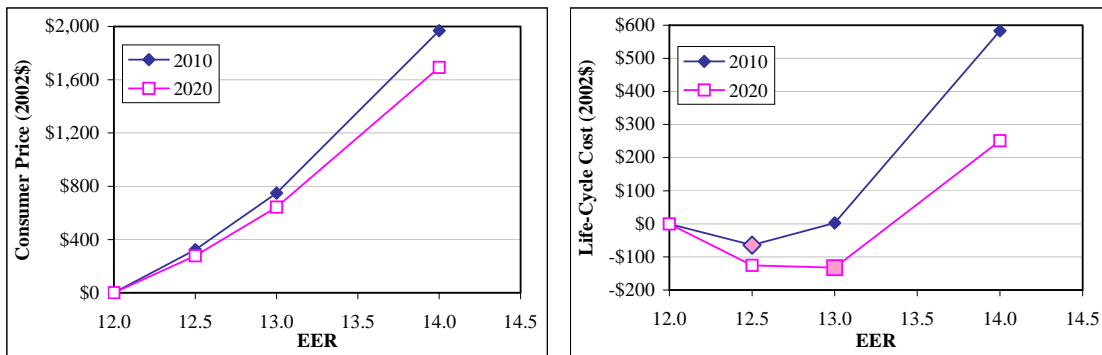
Figures 3 and 4. Price and Life-Cycle Cost Change vs. Efficiency for Top-Mount Auto Defrost Refrigerator-Freezer

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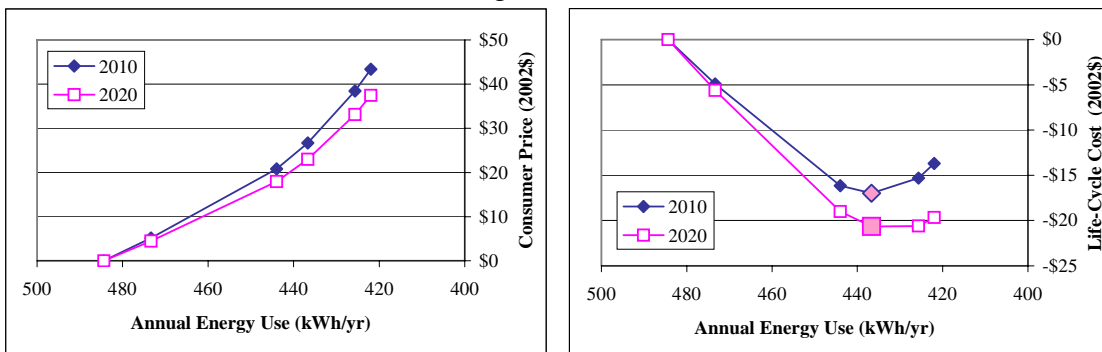
Residential Sector Products

Sector: Residential
End Use: Natural Gas and LPG Space Heating
Product: Gas Furnace
Lifetime (years): 20
Baseline Technology: 80% Annual Fuel Utilization Efficiency (AFUE)
Baseline Installed Cost in 2010: $1,792
Baseline Annual Energy Consumption: 64.9 MMBtu
Baseline Life Cycle Cost in 2010: $8,214

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	81% AFUE using two-stage modulation	Same as 2010
Increase in installed cost* ($)	$155	$136
Annual energy savings* (MMBtu)	2.1	2.1
CCE ($/MMBtu)	$6.20	$5.40
Decrease in LCC* ($)	$41	$75

* Relative to baseline technology.

Notes:

Incremental costs for LPG equipment are assumed equivalent to those for natural gas furnaces, since most manufacturers market an LPG furnace of nearly identical design to their natural gas models. The annual savings, CCE, and LCC change given are specific to natural gas furnaces.

81% 2-stage modulation furnace uses Category I venting system.

Source(s):
House Heating load – RECS97.

Other inputs – DOE Residential Furnaces and Boilers Proposed Rulemaking, Preliminary Engineering Analysis - September 22, 2002

http://www.eere.energy.gov/buildings/appliance_standards/residential/furnaces_boilers.html

Sector: Residential

End Use: Air conditioning

Product: Room air conditioner

Lifetime (years): 12.5

Baseline Technology: 8,000-13,999 Btu/hr, with louvered sides, without reversing valve, 9.85 EER
Baseline Installed Cost in 2010: $482
Baseline Annual Energy Consumption: 657 kWh
Baseline Life Cycle Cost in 2010: $930

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	10.11 EER	Same as 2010
Increase in installed cost* ($)	$8	$7
Annual energy savings* (kWh)	17	17
CCE (¢/kWh)	5.2	4.5
Decrease in LCC* ($)	$4	$5

* Relative to baseline technology.
Source(s): U.S. Department of Energy (DOE)-Office of Codes and Standards. 1997. "Technical Support Document for Energy Conservation Standards for Room Air Conditioners, Volume 2 – Detailed Analysis of Efficiency Levels (Docket Numbers EE-RM-90-201 & EM-RM-93-801-RAC)." Washington, DC. September, 1997.

Sector: Residential
End Use: Refrigeration
Product: Refrigerator-freezer
Lifetime (years): 19

Baseline Technology: Top-mount auto-defrost refrigerator-freezer, 21.4 cu.ft. adjusted volume, using 484 kWh/year
Baseline Installed Cost in 2010: $603
Baseline Annual Energy Consumption: 484 kWh
Baseline Life Cycle Cost in 2010: $1,046

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	437 kWh/yr	Same as 2010
Increase in installed cost* ($)	$27	$23
Annual energy savings* (kWh)	48	48
CCE (¢/kWh)	4.9	4.2
Decrease in LCC* ($)	$17	$21

* Relative to baseline technology.

Notes:

Source(s): U.S. Department of Energy (DOE)-Office of Codes and Standards. 1995. "Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, & Freezers." Washington, DC. DOE/EE-0064. July, 1995.

Sector: Residential
End Use: Water heating
Product: Electric water heater
Lifetime (years): 14

Baseline Technology: 90 Energy Factor (EF), 50 gallon nominal
Baseline Installed Cost in 2010: $491
Baseline Annual Energy Consumption: 3275 kWh
Baseline Life Cycle Cost in 2020: $1,046

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	None	Heat pump
Increase in installed cost* ($)	N/A	$753
Annual energy savings* (kWh)	N/A	2097
CCE (¢/kWh)	N/A	3.9
Decrease in LCC* ($)	N/A	$865

* Relative to baseline technology.

Notes:
Heat pump water heater price - D & R International - ENERGY STAR Labeling Potential for Water Heaters - DOE April 4, 2003.

Source(s): U.S. Department of Energy (DOE)-Office of Codes and Standards. 2001. "Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Water Heaters." Washington, DC. January, 2001.

Sector: Residential
End Use: Dishwashing
Product: Dishwasher
Lifetime (years): 12.6

Baseline Technology: 2.14 kWh/cycle
Baseline Equipment Cost in 2010: $332
Baseline Annual Energy Consumption: 535 kWh
Baseline Life Cycle Cost in 2010: $620

	Technology for 2010 Standard	Technology for 2020 Standard
Description	1.96 kWh/cycle	Same as 2010
Increase in consumer first cost* ($)	$17	$15
Annual energy savings* (kWh)	52	52
CCE (¢/kWh)	3.6	3.1
Decrease in LCC* ($)	$8	$10

 * Relative to baseline technology.

Notes:
Annual energy consumption and savings includes associated water heater energy use assuming gas water heater efficiency of 75% and market share of 55%. Although we present the energy in kWh, the values include gas and electricity use. The CCE includes the energy savings from reduced water heating.

Source: Biermayer, P. Energy and Water Saving Potential of Dishwashers and Clothes Washers: An Update. 1996 ACEEE Summer Study on Building Energy Efficiency.

Sector: Residential
End Use: Lighting
Product: Torchiere
Lifetime (years): 4.5

Baseline Technology: Incandescent lamp
Baseline Equipment Cost in 2010: $17
Baseline Annual Energy Consumption: 209 kWh
Baseline Life Cycle Cost in 2010: $81

	Technology for 2010 Standard	Technology for 2020 Standard
Description	Fluorescent lamp	Same as 2010
Increase in consumer first cost* ($)	$30	$26
Annual energy savings* (kWh)	123	123
CCE (¢/kWh)	6.8	5.9
Decrease in LCC* ($)	$6	$10

 * Relative to baseline technology.

Notes:
Base case assumes that halogen lamps are phased out by 2010. Incremental cost includes purchase of a replacement CFL and replacement of incandescent lamps during the lifetime of the torchiere.

Source(s): Unpublished analysis done by LNBL in 2003. Data inputs were from industry sources.

Sector: Residential
End Use: Other Electricity - Electronics
Product: Audio
Lifetime (years): 7

Baseline Technology: 3 W Standby Rack/Component System and 10 W Standby Compact System
Baseline Annual Energy Consumption**:** 121 kWh

	Technology for 2010 Standard	Technology for 2020 Standard
Description	1 W Standby	Same as 2010
Increase in consumer first cost* ($)	$2	$2
Annual energy savings* (kWh)	30	30
CCE (¢/kWh)	1.2	1.0
Decrease in LCC* ($)	$12	$12

* Relative to baseline technology.

Notes:
The values given are stock-weighted averages for rack/component and compact audio systems. Incremental equipment cost of $2 is from Clean Energy Futures report – assumes that most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.

Audio products included account for an estimated 7% of energy use in Other Electricity category.

Source(s): Usage, power, equipment lifetime and shipments from Rosen and Meier – "Energy Use of Home Audio Products in the U.S.", LBNL-43468. Stock quantities are from DOE FY 2005 Preliminary Priority-Setting Summary Report, Appendix A: FY 2005 Technical Support Document.

Sector: Residential
End Use: Other Electricity - Electronics
Product: Settop Boxes
Lifetime (years): 10
Baseline Technology: Current Practice Standby Power
Baseline Annual Energy Consumption: 184 kWh

	Technology for 2010 Standard	Technology for 2020 Standard
Description	7W Standby	Same as 2010
Increase in consumer first cost* ($)	$2	$2
Annual energy savings* (kWh)	95	95
CCE (¢/kWh)	0.3	0.2
Decrease in LCC* ($)	$55	$55

* Relative to baseline technology.
Notes:

The values given are shipment-weighted averages over digital and wireless settop boxes. Analog settop boxes are assumed to be phased out before 2010. Incremental equipment cost of $2 is from Clean Energy Futures report – assumes that most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.

Product accounts for estimated 8% of energy use in Other Electricity category.

Source(s): Usage, power, equipment lifetime and shipments from Rosen et al (2001), "Energy Use of Set-top boxes and Telephone Products in the U.S.," LBNL-45305. Stock quantities are from DOE FY 2005 Preliminary Priority-Setting Summary Report, Appendix A: FY 2005 Technical Support Document.

Sector: Residential
End Use: Other Electricity - Electronics
Product: Telephony
Lifetime (years): 8

Baseline Technology: 3W Standby Power
Baseline Annual Energy Consumption: 31 kWh

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	1W Standby Power	Same as 2010
Increase in consumer first cost* ($)	$2	$2
Annual energy savings* (kWh)	8	8
CCE (¢/kWh)	4.0	3.5
Decrease in LCC* ($)	$2	$2

* Relative to baseline technology.

Notes:
The values given are averages over answering machines and cordless phones. Incremental equipment cost of $2 from the Clean Energy Futures report – assumes that most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.
Product accounts for estimated 3.1% of energy use in Other Electricity category.

Sources: Energy consumption from Sanchez et al (1998), "Miscellaneous Electricity Use in U.S. Homes", LBNL-40295. Equipment lifetime is from *Appliance,* September 1998 (average of answering machine and cordless phone)

Sector: Residential
End Use: Other Electricity - Electronics
Product: Microwave Oven
Lifetime (years): 12

Baseline Technology: 3W Standby Power
Baseline Annual Energy Consumption: 120 kWh

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	1W Standby Power	Same as 2010
Increase in consumer first cost* ($)	$2	$2
Annual energy savings* (kWh)	81	81
CCE (¢/kWh)	0.3	0.2
Decrease in LCC* ($)	$53	$54

* Relative to baseline technology.

Notes:
Incremental equipment cost of $2 is from Clean Energy Futures report – assumes that most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.
Product accounts for estimated 1.9% of energy use in Other Electricity category.

Sources: Energy consumption is from Sanchez et al. (1998), "Miscellaneous Electricity Use in U.S. Homes", LBNL-40295. Equipment lifetime is from *Appliance,* September 1998.

Sector: Residential
End Use: Other Electricity - Electronics
Product: Miscellaneous Electronics
Lifetime (years): 7

Baseline Technology: Current Practice Standby Power
Baseline Annual Energy Consumption: 42 kWh

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	1W Standby Power	Same as 2010
Increase in consumer first cost* ($)	$2	$2
Annual energy savings* (kWh)	24	24
CCE (¢/kWh)	1.5	1.3
Decrease in LCC* ($)	$9	$9

* Relative to baseline technology.

Notes:

The values given are weighted averages over battery chargers, shavers, electric toothbrushes, hand-held rechargeables, garage door openers, doorbells, security systems, modems, power strips and timers. Weighting is by estimated total national electricity consumption of each product. Incremental equipment cost of $2 is from the Clean Energy Futures report – assumes that most savings come from circuit redesign during the normal design phase (at negligible cost) plus an improved power supply.
Products account for estimated 6.1% of energy use in Other Electricity category.

Sources: Energy consumption is from Sanchez et al (1998), "Miscellaneous Electricity Use in U.S. Homes", LBNL-40295. Equipment lifetime is average over included appliances from *Appliance,* September 1998.

Sector: Residential
End Use: Other Electricity - Motors
Product: Ceiling Fan
Lifetime (years): 15

Baseline Technology: Typical new fan motor efficiency
Baseline Annual Energy Consumption: 164 kWh

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Energy Star Fan	Same as 2010
Increase in consumer first cost* ($)	$10	$9
Annual energy savings* (kWh)	30	30
CCE (¢/kWh)	3.4	2.9
Decrease in LCC* ($)	$14	$15

* Relative to baseline technology.

Notes:

Energy savings are from higher motor efficiency only.

Product accounts for estimated 4.6% of energy use in Other Electricity category.

Source(s): DOE FY 2005 Preliminary Priority-Setting Summary Report, Appendix A: FY 2005 Technical Support Document. Incremental cost is from Clean Energy Futures report. Equipment lifetime is from *Appliance,* September 1998.

Sector: Residential
End Use: Other Electricity - Motors
Product: Pool Pump
Lifetime (years): 10

Baseline Technology: Single-speed pump motor
Baseline Annual Energy Consumption: 725 kWh

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Dual-speed motor	Same as 2010
Increase in consumer first cost* ($)	$100	$86
Annual energy savings* (kWh)	363	363
CCE (¢/kWh)	3.7	3.2
Decrease in LCC* ($)	$116	$130

* Relative to baseline technology.

Product accounts for estimated 4.3% of energy use in Other Electricity category.

Source(s): Baseline energy consumption is from Department of Energy, Office of Building Research and Standards – *2002 Priority Setting for New Products*, October 2001. Equipment lifetime, standards energy savings, and incremental cost are from Pacific Gas and Electric Company – *Analysis of Standards Options for Residential Pool Pumps, Motors and Controls*, May 2004.

Commercial Sector Products

Note: All data given for commercial floor space are from EIA's 1999 Commercial Building Energy Consumption Survey.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Hot Water (400 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 75% thermal efficiency
Baseline Installed Cost in 2010: $4,886
Baseline Annual Energy Consumption: 408 MMBtu
Baseline Life Cycle Cost in 2010: $41,867

	Technology for 2010 Standard	Technology for 2020 Standard
Description	79% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$291	$250
Annual energy savings* (MMBtu)	25.7	25.7
CCE ($/MMBtu)	$1.03	$0.89
Decrease in LCC* ($)	$1581	$1811

* Relative to baseline technology.

Notes: This product accounts for about 7% of the furnaces and boiler market for commercial space heating and covers about 11% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Hot Water (800 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 75% thermal efficiency
Baseline Installed Cost in 2010: $6,926
Baseline Annual Energy Consumption: 1016 MMBtu
Baseline Life Cycle Cost in 2010: $80,885

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	78% thermal efficiency	88% thermal efficiency
Increase in installed cost* ($)	$1405	$8175
Annual energy savings* (MMBtu)	39.1	150.0
CCE ($/MMBtu)	$3.28	$4.97
Decrease in LCC* ($)	$1439	$3853

* Relative to baseline technology.

Notes: This product accounts for about 7% of the furnaces and boiler market for commercial space heating and covers about 12% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Hot Water (1500 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 75% thermal efficiency
Baseline Installed Cost in 2010: $10,458
Baseline Annual Energy Consumption: 1904 MMBtu
Baseline Life Cycle Cost in 2010: $149,133

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	88% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$8354	$7182
Annual energy savings* (MMBtu)	281.3	281.3
CCE ($/MMBtu)	$2.71	$2.33
Decrease in LCC* ($)	$12,132	$15,371

* Relative to baseline technology.

Notes: This product accounts for about 1% of the furnaces and boiler market for commercial space heating and covers about 2% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boilers, Gas-Fired, Hot Water (3000 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 75% thermal efficiency
Baseline Installed Cost in 2010: $16,894
Baseline Annual Energy Consumption: 3809 kBtu
Baseline Life Cycle Cost in 2010: $294,243

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	88% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$10,136	$8714
Annual energy savings* (MMBtu)	562.7	562.7
CCE ($/MMBtu)	$1.64	$1.41
Decrease in LCC* ($)	$30,836	$36,392

* Relative to baseline technology.

Notes: This product accounts for about 0.4% of the furnaces and boiler market for commercial space heating and covers about 0.7% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Steam (400 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 72% thermal efficiency
Baseline Installed Cost in 2010: $6,715
Baseline Annual Energy Consumption: 529 MMBtu
Baseline Life Cycle Cost in 2010: $45,237

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	76% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$1008	$866
Annual energy savings* (MMBtu)	27.8	27.8
CCE ($/MMBtu)	$3.30	$2.84
Decrease in LCC* ($)	$1020	$1366

* Relative to baseline technology.

Notes: This product accounts for about 3% of the furnaces and boiler market for commercial space heating and covers about 5% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Steam (800 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 72% thermal efficiency
Baseline Installed Cost in 2010: $8,916
Baseline Annual Energy Consumption: 1058 MMBtu
Baseline Life Cycle Cost in 2010: $85,957

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	76% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$1783	$1533
Annual energy savings* (MMBtu)	55.9	55.9
CCE ($/MMBtu)	$2.92	$2.51
Decrease in LCC* ($)	$2272	$2931

 * Relative to baseline technology.

Notes: This product accounts for about 4% of the furnaces and boiler market for commercial space heating and covers about 7% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Steam (1500 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 72% thermal efficiency
Baseline Installed Cost in 2010: $15,476
Baseline Annual Energy Consumption: 1983 MMBtu
Baseline Life Cycle Cost in 2010: $159,929

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	79% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$6302	$5418
Annual energy savings* (MMBtu)	175.8	175.8
CCE ($/MMBtu)	$3.27	$2.81
Decrease in LCC* ($)	$6498	$8673

 * Relative to baseline technology.

Notes: This product accounts for about 1% of the furnaces and boiler market for commercial space heating and covers about 1.6% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Packaged Boiler, Gas-Fired, Steam (3000 kBtu/hr)
Lifetime (years): 30

Baseline Technology: 72% thermal efficiency
Baseline Installed Cost in 2010: $22,173
Baseline Annual Energy Consumption: 3967 MMBtu
Baseline Life Cycle Cost in 2010: $311,079

	Technology for 2010 Standard	Technology for 2020 Standard
Description	80% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$8425	$7244
Annual energy savings* (MMBtu)	396.8	396.8
CCE ($/MMBtu)	$1.94	$1.66
Decrease in LCC* ($)	$20,465	$24,562

* Relative to baseline technology.

Notes: This product accounts for about 0.3% of the furnaces and boiler market for commercial space heating and covers about 0.5% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Warm-Air Furnace, Gas-Fired (250 kBtu/hr)
Lifetime (years): 15

Baseline Technology: 78% thermal efficiency
Baseline Installed Cost in 2010: $7,835
Baseline Annual Energy Consumption: 224 MMBtu
Baseline Life Cycle Cost in 2010: $24,179

	Technology for 2010 Standard	Technology for 2020 Standard
Description	80% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$403	$347
Annual energy savings* (MMBtu)	5.6	5.6
CCE ($/MMBtu)	$6.52	$5.60
Decrease in LCC* ($)	$8	$106

* Relative to baseline technology.

Notes: This product accounts for about 46% of the furnaces and boiler market for commercial space heating and covers about 19% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Space Heating
Product: Warm-Air Furnace, Gas-Fired (400 kBtu/hr)
Lifetime (years): 15

Baseline Technology: 78% thermal efficiency
Baseline Installed Cost in 2010: $11,712
Baseline Annual Energy Consumption: 359 MMBtu
Baseline Life Cycle Cost in 2010: $37,863

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	80% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$510	$438
Annual energy savings* (MMBtu)	9.0	9.0
CCE ($/MMBtu)	$5.14	$4.42
Decrease in LCC* ($)	$148	$286

* Relative to baseline technology.

Notes: This product accounts for about 30% of the furnaces and boiler market for commercial space heating and covers about 12% of the commercial floor space heating.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: 3-Phase, Single-Package, Air-Source AC (<65 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.7 SEER
Baseline Installed Cost in 2010: $2,618
Baseline Annual Energy Consumption: 10,036 kWh
Baseline Life Cycle Cost in 2010: $11,062

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	12 SEER	Same as 2010
Increase in installed cost* ($)	$785	$675
Annual energy savings* (kWh)	1924	1924
CCE (¢/kWh)	4.2	3.6
Decrease in LCC* ($)	$833	$1008

* Relative to baseline technology.

Notes: This product accounts for about 7% of the air-conditioning market for commercial space cooling and covers about 9% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: 3-Phase, Split-System, Air-Source AC (<65 kBtu/h)
Lifetime (years): 15

Baseline Technology: 10 SEER
Baseline Installed Cost in 2010: $2,666
Baseline Annual Energy Consumption: 9735 kWh
Baseline Life Cycle Cost in 2010: $10,857

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	12 SEER	Same as 2010
Increase in installed cost* ($)	$960	$826
Annual energy savings* (kWh)	1623	1623
CCE (¢/kWh)	6.0	5.2
Decrease in LCC* ($)	$405	$594

* Relative to baseline technology.

Notes: This product accounts for about 12% of the air-conditioning market for commercial space cooling and covers about 16% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: 3-Phase, Single-Package, Air-Source Heat Pump (<65 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.7 SEER
Baseline Installed Cost in 2010: $3,092
Baseline Annual Energy Consumption: 10,036 kWh
Baseline Life Cycle Cost in 2010: $11,536

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	12 SEER	Same as 2010
Increase in installed cost* ($)	$865	$744
Annual energy savings* (kWh)	1924	1924
CCE (¢/kWh)	4.6	3.9
Decrease in LCC* ($)	$753	$940

* Relative to baseline technology.

Notes: This product accounts for about 1.3% of the air-conditioning market for commercial space cooling and covers about 2% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: 3-Phase, Split-System, Air-Source Heat Pump (<65 kBtu/h)
Lifetime (years): 15

Baseline Technology: 10 SEER
Baseline Installed Cost in 2010: $2,612
Baseline Annual Energy Consumption: 9,735 kWh
Baseline Life Cycle Cost in 2010: $10,803

	Technology for 2010 Standard	Technology for 2020 Standard
Description	13 SEER	Same as 2010
Increase in installed cost* ($)	$1149	$988
Annual energy savings* (kWh)	2247	2247
CCE (¢/kWh)	5.2	4.5
Decrease in LCC* ($)	$741	$978

* Relative to baseline technology.

Notes: This product accounts for about 6% of the air-conditioning market for commercial space cooling and covers about 7.5% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Air-Source AC (>65 and <135 kBtu/h)
Lifetime (years): 15

Baseline Technology: 10.1 EER
Baseline Installed Cost in 2010: $6,732
Baseline Annual Energy Consumption: 16,079 kWh
Baseline Life Cycle Cost in 2010: $19,677

	Technology for 2010 Standard	Technology for 2020 Standard
Description	11.5 EER	12.0 EER
Increase in installed cost* ($)	$555	$982
Annual energy savings* (kWh)	1769	2251
CCE (¢/kWh)	3.2	4.5
Decrease in LCC* ($)	$887	$1001

* Relative to baseline technology.

Notes: This product accounts for about 11% of the air-conditioning market for commercial space cooling and covers about 15% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2004. "Commercial Unitary Air Conditioners and Heat Pumps, Energy Conservation Standards Rulemaking, Life Cycle Cost Analysis Spreadsheet Model (Tariff-Based Electricity Prices)." Washington, DC. Product Class: 7.5 tons. <http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html>

Sector: Commercial
End Use: Air Conditioning
Product: Central, Air-Source Heat Pump (>65 and <135 kBtu/h)
Lifetime (years): 15

Baseline Technology: 10.1 EER
Baseline Installed Cost in 2010: $6,732
Baseline Annual Energy Consumption: 16,079 kWh
Baseline Life Cycle Cost in 2010: $19,677

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	11.5 EER	12.0 EER
Increase in installed cost* ($)	$555	$982
Annual energy savings* (kWh)	1769	2251
CCE (¢/kWh)	3.2	4.5
Decrease in LCC* ($)	$887	$1001

* Relative to baseline technology.

Notes: This product accounts for about 1% of the air-conditioning market for commercial space cooling and covers about 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2004. "Commercial Unitary Air Conditioners and Heat Pumps, Energy Conservation Standards Rulemaking, Life Cycle Cost Analysis Spreadsheet Model (Tariff-Based Electricity Prices)." Washington, DC. Product Class: 7.5 tons. <http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html>

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Source Heat Pump (>65 and <135 kBtu/h)
Lifetime (years): 19

Baseline Technology: 12 EER
Baseline Installed Cost in 2010: $3,984
Baseline Annual Energy Consumption: 11,528 kWh
Baseline Life Cycle Cost in 2010: $13,684

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	12.5 EER	13.0 EER
Increase in installed cost* ($)	$324	$644
Annual energy savings* (kWh)	461	887
CCE (¢/kWh)	7.2	7.4
Decrease in LCC* ($)	$64	$132

* Relative to baseline technology.

Notes: This product accounts for about 9% of the air-conditioning market for commercial space cooling and covers about 11% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Cooled AC (>65 and <135 kBtu/h)
Lifetime (years): 19

Baseline Technology: 11.5 EER
Baseline Installed Cost in 2010: $4,118
Baseline Annual Energy Consumption: 12,029 kWh
Baseline Life Cycle Cost in 2010: $14,240

	Technology for 2010 Standard	Technology for 2020 Standard
Description	12.4 EER	14.0 EER
Increase in installed cost* ($)	$508	$1445
Annual energy savings* (kWh)	873	2148
CCE (¢/kWh)	5.9	6.9
Decrease in LCC* ($)	$227	$435

* Relative to baseline technology.

Notes: This product accounts for less than 1% of the air-conditioning market for commercial space cooling and covers less than 1% of the commercial cooled floor space.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Air-Source AC (>135 and <240 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.5 EER
Baseline Installed Cost in 2010: $11,812
Baseline Annual Energy Consumption: 33,953 kWh
Baseline Life Cycle Cost in 2010: $39,356

	Technology for 2010 Standard	Technology for 2020 Standard
Description	11.5 EER	12.0 EER
Increase in installed cost* ($)	$1357	$2173
Annual energy savings* (kWh)	5220	6239
CCE (¢/kWh)	2.7	3.6
Decrease in LCC* ($)	$2879	$3213

* Relative to baseline technology.

Notes: This product accounts for about 8% of the air-conditioning market for commercial space cooling and covers about 11% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2004. "Commercial Unitary Air Conditioners and Heat Pumps, Energy Conservation Standards Rulemaking, Life Cycle Cost Analysis Spreadsheet Model (Tariff-Based Electricity Prices)." Washington, DC. Product Class: 7.5 tons. <http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html>

Sector: Commercial
End Use: Air Conditioning
Product: Central, Air-Source Heat Pump (>135 and <240 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.5 EER
Baseline Installed Cost in 2010: $11,812
Baseline Annual Energy Consumption: 33,953 kWh
Baseline Life Cycle Cost in 2010: $39,356

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	11.5 EER	12.0 EER
Increase in installed cost* ($)	$1357	$2173
Annual energy savings* (kWh)	5220	6239
CCE (¢/kWh)	2.7	3.6
Decrease in LCC* ($)	$2879	$3213

* Relative to baseline technology.

Notes: This product accounts for less than 1% of the air-conditioning market for commercial space cooling and covers less than 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2004. "Commercial Unitary Air Conditioners and Heat Pumps, Energy Conservation Standards Rulemaking, Life Cycle Cost Analysis Spreadsheet Model (Tariff-Based Electricity Prices)." Washington, DC. Product Class: 7.5 tons. <http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html>

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Cooled AC (>135 and <240 kBtu/h)
Lifetime (years): 19

Baseline Technology: 11 EER
Baseline Installed Cost in 2010: $9,632
Baseline Annual Energy Consumption: 25,152 kWh
Baseline Life Cycle Cost in 2010: $30,795

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	11.5 EER	Same as 2010
Increase in installed cost* ($)	$309	$266
Annual energy savings* (kWh)	1094	1094
CCE (¢/kWh)	2.9	2.5
Decrease in LCC* ($)	$611	$691

* Relative to baseline technology.

Notes: This product accounts for less than 1% of the air-conditioning market for commercial space cooling and covers less than 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Cooled AC (<65 kBtu/h)
Lifetime (years): 19

Baseline Technology: 12.1 EER
Baseline Installed Cost in 2010: $4,396
Baseline Annual Energy Consumption: 8,045 kWh
Baseline Life Cycle Cost in 2010: $11,165

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	12.1 EER	12.5 EER
Increase in installed cost* ($)	N/A	$190
Annual energy savings* (kWh)	N/A	257
CCE (¢/kWh)	N/A	7.5
Decrease in LCC* ($)	N/A	$36

  * Relative to baseline technology.

Notes: This product accounts for less than 1% of the air-conditioning market for commercial space cooling and covers less than 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Source Heat Pump (<17 kBtu/h)
Lifetime (years): 19

Baseline Technology: 11.2 EER
Baseline Installed Cost in 2010: $876
Baseline Annual Energy Consumption: 1,738 kWh
Baseline Life Cycle Cost in 2010: $2,338

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	11.2 EER	12.5 EER
Increase in installed cost* ($)	N/A	$139
Annual energy savings* (kWh)	N/A	181
CCE (¢/kWh)	N/A	7.8
Decrease in LCC* ($)	N/A	$19

  * Relative to baseline technology.

Notes: This product accounts for about 1% of the air-conditioning market for commercial space cooling and covers about 1% of the commercial cooled floor space.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Central, Water-Source Heat Pump (>17 and <65 kBtu/h)
Lifetime (years): 19

Baseline Technology: 12 EER
Baseline Installed Cost in 2010: $1,346
Baseline Annual Energy Consumption: 4,867 kWh
Baseline Life Cycle Cost in 2010: $5,442

	Technology for 2010 Standard	Technology for 2020 Standard
Description	13.1 EER	Same as 2010
Increase in installed cost* ($)	$286	$246
Annual energy savings* (kWh)	409	409
CCE (¢/kWh)	7.1	6.1
Decrease in LCC* ($)	$58	$112

* Relative to baseline technology.

Notes: This product accounts for about 1% of the air-conditioning market for commercial space cooling and covers about 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Air Conditioner (PTAC) (<7 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.4 EER
Baseline Installed Cost in 2010: $734
Baseline Annual Energy Consumption: 1331 kWh
Baseline Life Cycle Cost in 2010: $1,854

	Technology for 2010 Standard	Technology for 2020 Standard
Description	11 EER	Same as 2010
Increase in installed cost* ($)	$110	$95
Annual energy savings* (kWh)	194	194
CCE (¢/kWh)	5.8	5.0
Decrease in LCC* ($)	$53	$75

* Relative to baseline technology.

Notes: This product accounts for about 4% of the packaged terminal air-conditioning market and covers less than 1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Air Conditioner (PTAC) (7-10 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9 EER
Baseline Installed Cost in 2010: $807
Baseline Annual Energy Consumption: 1688 kWh
Baseline Life Cycle Cost in 2010: $2,227

	Technology for 2010 Standard	Technology for 2020 Standard
Description	10.8 EER	Same as 2010
Increase in installed cost* ($)	$105	$91
Annual energy savings* (kWh)	281	281
CCE (¢/kWh)	3.8	3.3
Decrease in LCC* ($)	$131	$156

 * Relative to baseline technology.

Notes: This product accounts for about 20% of the packaged terminal air-conditioning market and covers 1.4% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Air Conditioner (PTAC) (10-13 kBtu/h)
Lifetime (years): 15

Baseline Technology: 8.3 EER
Baseline Installed Cost in 2010: $716
Baseline Annual Energy Consumption: 2476 kWh
Baseline Life Cycle Cost in 2010: $2,800

	Technology for 2010 Standard	Technology for 2020 Standard
Description	10.5 EER	Same as 2010
Increase in installed cost* ($)	$211	$181
Annual energy savings* (kWh)	519	519
CCE (¢/kWh)	4.1	3.6
Decrease in LCC* ($)	$226	$273

 * Relative to baseline technology.

Notes: This product accounts for about 21% of the packaged terminal air-conditioning market and covers 1.5% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Air Conditioner (PTAC) (>13 kBtu/h)
Lifetime (years): 15

Baseline Technology: 7.9 EER
Baseline Installed Cost in 2010: $887
Baseline Annual Energy Consumption: 3168 kWh
Baseline Life Cycle Cost in 2010: $3,552

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	10 EER	Same as 2010
Increase in installed cost* ($)	$126	$108
Annual energy savings* (kWh)	665	665
CCE (¢/kWh)	1.9	1.7
Decrease in LCC* ($)	$434	$474

* Relative to baseline technology.

Notes: This product accounts for about 9% of the packaged terminal air-conditioning market and covers 0.7% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Heat Pump (PTHP) (<7 kBtu/h)
Lifetime (years): 15

Baseline Technology: 9.3 EER
Baseline Installed Cost in 2010: $810
Baseline Annual Energy Consumption: 1345 kWh
Baseline Life Cycle Cost in 2010: $1,942

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	10.8 EER	Same as 2010
Increase in installed cost* ($)	$107	$92
Annual energy savings* (kWh)	187	187
CCE (¢/kWh)	5.8	5.0
Decrease in LCC* ($)	$50	$71

* Relative to baseline technology.

Notes: This product accounts for about 3% of the packaged terminal air-conditioning market and covers 0.2% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Heat Pump (PTHP) (7-10 kBtu/h)
Lifetime (years): 15

Baseline Technology: 8.9 EER
Baseline Installed Cost in 2010: $895
Baseline Annual Energy Consumption: 1707 kWh
Baseline Life Cycle Cost in 2010: $2,331

	Technology for 2010 Standard	Technology for 2020 Standard
Description	10.6 EER	11.4 EER
Increase in installed cost* ($)	$93	$164
Annual energy savings* (kWh)	274	374
CCE (¢/kWh)	3.4	4.5
Decrease in LCC* ($)	$138	$164

 * Relative to baseline technology.

Notes: This product accounts for about 19% of the packaged terminal air-conditioning market and covers 1.4% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Heat Pump (PTHP) (10-13 kBtu/h)
Lifetime (years): 15

Baseline Technology: 8.2 EER
Baseline Installed Cost in 2010: $777
Baseline Annual Energy Consumption: 2507 kWh
Baseline Life Cycle Cost in 2010: $2,887

	Technology for 2010 Standard	Technology for 2020 Standard
Description	9.7 EER	Same as 2010
Increase in installed cost* ($)	$108	$93
Annual energy savings* (kWh)	388	388
CCE (¢/kWh)	2.8	2.4
Decrease in LCC* ($)	$218	$246

 * Relative to baseline technology.

Notes: This product accounts for about 16% of the packaged terminal air-conditioning market and covers 1.1% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Air Conditioning
Product: Packaged Terminal Heat Pump (PTHP) (>13 kBtu/h)
Lifetime (years): 15

Baseline Technology: 7.8 EER
Baseline Installed Cost in 2010: $944
Baseline Annual Energy Consumption: 3208 kWh
Baseline Life Cycle Cost in 2010: $3,643

	Technology for 2010 Standard	Technology for 2020 Standard
Description	10 EER	Same as 2010
Increase in installed cost* ($)	$326	$280
Annual energy savings* (kWh)	706	706
CCE (¢/kWh)	4.7	4.0
Decrease in LCC* ($)	$268	$338

* Relative to baseline technology.

Notes: This product accounts for about 8% of the packaged terminal air-conditioning market and covers 0.6% of the commercial floor space cooling.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Ventilation
Product: Air Distribution, Large Unitary (10 HP)
Lifetime (years): 15

Baseline Technology: 85% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	Technology for 2020 Standard
Description	92%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	1795	1795
CCE (¢/kWh)	0.5	0.4
Decrease in LCC* ($)	$1042	$1081

* Relative to baseline technology.

Notes: This product accounts for about 4% of the energy consumption by Air Distribution units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-3 and 4-4.

Sector: Commercial
End Use: Ventilation
Product: Air Distribution, Exhaust Fan (0.5 HP)
Lifetime (years): 15

Baseline Technology: 60% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	80%	Same as 2010
Increase in installed cost* ($)	$13	$12
Annual energy savings* (kWh)	710	710
CCE (¢/kWh)	0.2	0.2
Decrease in LCC* ($)	$432	$444

* Relative to baseline technology.

Notes: This product accounts for about 38% of the energy consumption by Air Distribution units

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-3 and 4-4.

Sector: Commercial
End Use: Ventilation
Product: Air Distribution, Room Fan Coil (0.17 HP)
Lifetime (years): 15

Baseline Technology: 50% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	75%	Same as 2010
Increase in installed cost* ($)	$12	$10
Annual energy savings* (kWh)	142	142
CCE (¢/kWh)	0.9	0.7
Decrease in LCC* ($)	$77	$81

* Relative to baseline technology.

Notes: This product accounts for about 2% of the energy consumption by Air Distribution units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-3 and 4-4.

Sector: Commercial
End Use: Ventilation
Product: Air Distribution, Central Station Air Handling Unit (10 HP)
Lifetime (years): 15

Baseline Technology: 87% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	93%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	1516	1516
CCE (¢/kWh)	0.6	0.5
Decrease in LCC* ($)	$868	$902

* Relative to baseline technology.

Notes: This product accounts for about 40% of the energy consumption by Air Distribution units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-3 and 4-4.

Sector: Commercial
End Use: Ventilation
Product: Hydronic Hot and Chilled Water Circulation, Centrifugal Chiller (25 HP)
Lifetime (years): 23

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	95%	Same as 2010
Increase in end user cost* ($)	$73	$63
Annual energy savings* (kWh)	1111	1111
CCE (¢/kWh)	0.5	0.5
Decrease in LCC* ($)	$789	$820

* Relative to baseline technology.

Notes: This product accounts for about 14% of the energy consumption by Hydronic Hot and Chilled Water Circulation units.

Source(s): Arthur D. Little.1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-5 and 4-6.

Sector: Commercial
End Use: Ventilation
Product: Hydronic Hot and Chilled Water Circulation, Screw Chiller (10 HP)
Lifetime (years): 20

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	Technology for 2020 Standard
Description	94%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	500	500
CCE (¢/kWh)	1.4	1.2
Decrease in LCC* ($)	$304	$335

* Relative to baseline technology.

Notes: This product accounts for about 1% of the energy consumption by Hydronic Hot and Chilled Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-5 and 4-6.

Sector: Commercial
End Use: Ventilation
Product: Hydronic Hot and Chilled Water Circulation, Reciprocating Chiller (10 HP)
Lifetime (years): 20

Baseline Technology: 88% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	Technology for 2020 Standard
Description	93%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	476	476
CCE (¢/kWh)	1.5	1.3
Decrease in LCC* ($)	$286	$306

* Relative to baseline technology.

Notes: This product accounts for about 13% of the energy consumption by Hydronic Hot and Chilled Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-5 and 4-6.

Sector: Commercial
End Use: Ventilation
Product: Hydronic Hot and Chilled Water Circulation, Absorption Chiller (25 HP)
Lifetime (years): 23

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	95%	Same as 2010
Increase in installed cost* ($)	$73	$63
Annual energy savings* (kWh)	1250	1250
CCE (¢/kWh)	0.5	0.4
Decrease in LCC* ($)	$897	$930

* Relative to baseline technology.

Notes: This product accounts for about 1% of the energy consumption by Hydronic Hot and Chilled Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-5 and 4-6.

Sector: Commercial
End Use: Ventilation
Product: Hydronic Hot and Chilled Water Circulation, Hydronic Heating (10 HP)
Lifetime (years): 23

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	94%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	857	857
CCE (¢/kWh)	0.8	0.7
Decrease in LCC* ($)	$581	$609

* Relative to baseline technology.

Notes: This product accounts for about 70% of the energy consumption by Hydronic Hot and Chilled Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-5 and 4-6.

Sector: Commercial
End Use: Ventilation
Product: Cooling Water Circulation, Centrifugal Chiller (25 HP)
Lifetime (years): 23

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	95%	Same as 2010
Increase in installed cost* ($)	$73	$63
Annual energy savings* (kWh)	1235	1235
CCE (¢/kWh)	0.5	0.4
Decrease in LCC* ($)	$870	$902

* Relative to baseline technology.

Notes: This product accounts for about 58% of the energy consumption by Cooling Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-7 and 4-8.

Sector: Commercial
End Use: Ventilation
Product: Cooling Water Circulation, Screw Chiller (10 HP)
Lifetime (years): 20

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	94%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	714	714
CCE (¢/kWh)	1.0	0.9
Decrease in LCC* ($)	$462	$486

* Relative to baseline technology.

Notes: This product accounts for about 4% of the energy consumption by Cooling Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-7 and 4-8.

Sector: Commercial
End Use: Ventilation
Product: Cooling Water Circulation, Reciprocating Chiller (10 HP)
Lifetime (years): 20

Baseline Technology: 88% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	93%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	381	381
CCE (¢/kWh)	1.9	1.6
Decrease in LCC* ($)	$207	$226

* Relative to baseline technology.

Notes: This product accounts for about 29% of the energy consumption by Cooling Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-7 and 4-8.

Sector: Commercial
End Use: Ventilation
Product: Cooling Water Circulation, Li-Br Water Absorption Chiller (25 HP)
Lifetime (years): 23

Baseline Technology: 90% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	95%	Same as 2010
Increase in installed cost* ($)	$73	$63
Annual energy savings* (kWh)	1250	1250
CCE (¢/kWh)	0.5	0.4
Decrease in LCC* ($)	$881	$914

* Relative to baseline technology.

Notes: This product accounts for about 8% of the energy consumption by Cooling Water Circulation units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-7 and 4-8.

Sector: Commercial
End Use: Ventilation
Product: Heat Rejection, Large Unitary (5 HP)
Lifetime (years): 15

Baseline Technology: 85% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	90%	Same as 2010
Increase in installed cost* ($)	$46	$39
Annual energy savings* (kWh)	299	299
CCE (¢/kWh)	1.4	1.2
Decrease in LCC* ($)	$164	$176

* Relative to baseline technology.

Notes: This product accounts for about 14% of the energy consumption by Heat Rejection units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-9 and 4-10.

Sector: Commercial
End Use: Ventilation
Product: Heat Rejection, Air Cooled Screw Chillers (2 HP)
Lifetime (years): 20

Baseline Technology: 85% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	92%	Same as 2010
Increase in installed cost* ($)	$14	$12
Annual energy savings* (kWh)	1667	1667
CCE (¢/kWh)	0.1	0.1
Decrease in LCC* ($)	$1156	$1186

* Relative to baseline technology.

Notes: This product accounts for about 1% of the energy consumption by Heat Rejection units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-9 and 4-10.

Sector: Commercial
End Use: Ventilation
Product: Heat Rejection, Air Cooled Reciprocating Chillers (2 HP)
Lifetime (years): 20

Baseline Technology: 85% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	92%	Same as 2010
Increase in installed cost* ($)	$14	$12
Annual energy savings* (kWh)	952	952
CCE (¢/kWh)	0.1	0.1
Decrease in LCC* ($)	$654	$672

* Relative to baseline technology.

Notes: This product accounts for about 9% of the energy consumption by Heat Rejection units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-9 and 4-10.

Sector: Commercial
End Use: Ventilation
Product: Heat Rejection, Cooling Tower (10 HP)
Lifetime (years): 20

Baseline Technology: 85% efficiency
Baseline Installed Cost in 2010: not available
Baseline Annual Energy Consumption: not available
Baseline Life Cycle Cost in 2010: not available

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	92%	Same as 2010
Increase in installed cost* ($)	$84	$72
Annual energy savings* (kWh)	559	559
CCE (¢/kWh)	1.4	1.2
Decrease in LCC* ($)	$309	$330

* Relative to baseline technology.

Notes: This product accounts for about 5% of the energy consumption by Heat Rejection units.

Source(s): Arthur D. Little. 1999. "Opportunities for Energy Savings in the Residential and Commercial Sectors with High Efficiency Electric Motors." Cambridge, MA. December, 1999. Tables 4-9 and 4-10.

Sector: Commercial
End Use: Water Heating
Product: Storage Water Heater, Gas-Fired (120 gallon)
Lifetime (years): 7

Baseline Technology: 78% thermal efficiency
Baseline Installed Cost in 2010: $2,184
Baseline Annual Energy Consumption: 101 MMBtu
Baseline Life Cycle Cost in 2010: $6,181

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	82% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$116	$100
Annual energy savings* (MMBtu)	4.9	4.9
CCE ($/MMBtu)	$4.01	$3.45
Decrease in LCC* ($)	$79	$115

 * Relative to baseline technology.

Notes: This product accounts for about 11% of the gas-fired water heater market.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Water Heating
Product: Storage Water Heater, Gas-Fired (199 gallon)
Lifetime (years): 7

Baseline Technology: 78% thermal efficiency
Baseline Installed Cost in 2010: $2,722
Baseline Annual Energy Consumption: 165 MMBtu
Baseline Life Cycle Cost in 2010: $9,260

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	82% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$193	$166
Annual energy savings* (MMBtu)	8.1	8.1
CCE ($/MMBtu)	$4.07	$3.50
Decrease in LCC* ($)	$126	$185

 * Relative to baseline technology.

Notes: This product accounts for about 23% of the gas-fired water heater market.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Water Heating
Product: Storage Water Heater, Gas-Fired (360 gallon)
Lifetime (years): 7

Baseline Technology: 80% thermal efficiency
Baseline Installed Cost in 2010: $4,828
Baseline Annual Energy Consumption: 284 MMBtu
Baseline Life Cycle Cost in 2010: $16,066

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	82% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$175	$151
Annual energy savings* (MMBtu)	6.9	6.9
CCE ($/MMBtu)	$4.30	$3.70
Decrease in LCC* ($)	$99	$151

 * Relative to baseline technology.

Notes: This product accounts for about 23% of the gas-fired water heater market.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Water Heating
Product: Instantaneous Water Heater, Gas-Fired (1000 kBtu/hr)
Lifetime (years): 15

Baseline Technology: 80% thermal efficiency
Baseline Installed Cost in 2010: $5,282
Baseline Annual Energy Consumption: 760 MMBtu
Baseline Life Cycle Cost in 2010: $35,392

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	83% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$770	$662
Annual energy savings* (MMBtu)	27.5	27.5
CCE ($/MMBtu)	$4.76	$4.09
Decrease in LCC* ($)	$319	$537

 * Relative to baseline technology.

Notes: This product accounts for about 6% of the gas-fired water heater market.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Water Heating
Product: Instantaneous Tank Water Heater, Gas-Fired (500 kBtu/hr)
Lifetime (years): 15

Baseline Technology: 80% thermal efficiency
Baseline Installed Cost in 2010: $7,069
Baseline Annual Energy Consumption: 382 MMBtu
Baseline Life Cycle Cost in 2010: $22,176

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	82% thermal efficiency	Same as 2010
Increase in installed cost* ($)	$344	$296
Annual energy savings* (MMBtu)	9.3	9.3
CCE ($/MMBtu)	$4.25	$3.65
Decrease in LCC* ($)	$24	$110

* Relative to baseline technology.

Notes: This product accounts for about 1% of the gas-fired water heater market.

Source(s): U.S. Department of Energy (DOE)-Office of Energy Efficiency and Renewable Energy. 2000. "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment, Volume 1 - Main Report and Volume 2 - Appendix Material." Washington, DC. April, 2000. Table 2.4, Table 2.5, Table 3.8, Appendix D3-D80.

Sector: Commercial
End Use: Lighting
Product: Fluorescent Lamp/Ballast
Lifetime (years): 14
Baseline Technology: F40T12/ES lamp with magnetic ballast (15% market share); F32T8RE7 lamp with electronic ballast (85% share)
Baseline Installed Cost in 2010: $22.6
Baseline Annual Energy Consumption: 324 kWh
Baseline Life Cycle Cost in 2010: $219

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	High-performance T8 lamps with electronic ballasts and with high-performance electronic ballasts	High-performance T8 lamps with high-performance electronic ballasts
Increase in installed cost* ($)	3.5	2.5
Annual energy savings* (kWh)	27	37
CCE (¢/kWh)	2	1
Decrease in LCC* ($)	12	20

* Relative to baseline technology.

Notes: Technology mix for 2010 standard assumes a market share of 40% of high-performance T8 Lamp with electronic ballast and 60% of high-performance T8 Lamp with high-performance electronic ballast.
Installed costs are aggregated for the technology mix.
To calculate efficiency improvement, Lighting Power Densities for the 2010 and 2020 standards were used in combination with the above market share assumptions; LPDs were calculated by LBNL using adapted ASHRAE/IESNA 90.1 lighting application models.

Source(s): Equipment prices are from www.goodmart.com. Last accessed March 11, 2004.

Sector: Commercial
End Use: Lighting
Product: High Intensity Discharge Lamp (HID), Low Bay
Lifetime (years): 13.5
Baseline Technology: Mercury Vapor (MV) 20%; Metal Halide (MH) 55%; High Pressure Sodium (HPS) 25%
Baseline Installed Cost in 2010: $60
Baseline Annual Energy Consumption: 1140 kWh
Baseline Life Cycle Cost in 2010: $769

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Pulse MH 75%; HPS 25%	Pulse MH/SSB 75%; HPS 25%
Increase in installed cost* ($)	24	32
Annual energy savings* (kWh)	159	196
CCE (¢/kWh)	3.0	2.9
Decrease in LCC* ($)	52	71

* Relative to baseline technology.

Notes: SSB = solid state electronic ballast; installed costs are aggregated for the technology mix.
To calculate efficiency improvement, Lighting Power Densities for the 2010 and 2020 standards were used in combination with the above market share assumptions; LPDs were calculated by LBNL using adapted ASHRAE/IESNA 90.1 lighting application models.

Source(s): Equipment prices are from www.goodmart.com. Last accessed March 11, 2004.

Sector: Commercial
End Use: Lighting
Product: High Intensity Discharge Lamp (HID), High Bay
Lifetime (years): 13.5

Baseline Technology: Mercury Vapor (MV) 20%; Metal Halide (MH) 55%; High Pressure Sodium (HPS) 25%
Baseline Installed Cost in 2010: $70
Baseline Annual Energy Consumption: 1915 kWh
Baseline Life Cycle Cost in 2010: $1249

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Pulse MH 75%; HPS 25%	Pulse MH/SSB 75%; HPS 25%
Increase in installed cost* ($)	16.3	24.6
Annual energy savings* (kWh)	373	435
CCE (¢/kWh)	1.0	1.0
Decrease in LCC* ($)	193	236

* Relative to baseline technology.

Notes: SSB = solid state electronic ballast; Installed costs are aggregated for the technology mix.

Source(s): Equipment prices are from www.goodmart.com. Last accessed March 11, 2004.
Lighting Power Densities for the 2010 and 2020 standards were based on the above assumptions, as calculated by LBNL using adapted ASHRAE/IESNA 90.1 lighting application models.

Sector: Commercial
End Use: Refrigeration
Product: Supermarket Units
Lifetime (years): 10

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	16% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$21,490	$18,475
Annual energy savings* (kWh)	248,946	248,946
CCE (¢/kWh)	1.2	1.1
Decrease in LCC* ($)	$6918	$7937

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-10.

Sector: Commercial
End Use: Refrigeration
Product: Beverage Merchandizer
Lifetime (years): 8.5

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	61% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$344	$295
Annual energy savings* (kWh)	2375	2375
CCE (¢/kWh)	2.1	1.8
Decrease in LCC* ($)	$3	$11

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-17.

Sector: Commercial
End Use: Refrigeration
Product: Reach-In Freezers
Lifetime (years): 9

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	52% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$465	$424
Annual energy savings* (kWh)	2687	2687
CCE (¢/kWh)	2.5	2.3
Decrease in LCC* ($)	$12	$23

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-18.

Sector: Commercial
End Use: Refrigeration
Product: Reach-In Refrigerators
Lifetime (years): 9

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	38% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$212	$183
Annual energy savings* (kWh)	1631	1631
CCE (¢/kWh)	1.9	1.6
Decrease in LCC* ($)	$162	$191

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-19.

Sector: Commercial
End Use: Refrigeration
Product: Ice Machines
Lifetime (years): 8.5

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	Technology for 2020 Standard
Description	23% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$221	$190
Annual energy savings* (kWh)	1141	1141
CCE (¢/kWh)	2.8	2.4
Decrease in LCC* ($)	$15	$30

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-20.

Sector: Commercial
End Use: Refrigeration
Product: Refrigerated Vending Machines
Lifetime (years): 8.5

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	Technology for 2020 Standard
Description	51% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$308	$265
Annual energy savings* (kWh)	1540	1540
CCE (¢/kWh)	2.9	2.5
Decrease in LCC* ($)	-$1	$4

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-21.

Sector: Commercial
End Use: Refrigeration
Product: Walk-In Coolers
Lifetime (years): 10

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	46% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$1611	$1385
Annual energy savings* (kWh)	19,370	19,370
CCE (¢/kWh)	1.2	1.0
Decrease in LCC* ($)	$13	$85

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-23.

Sector: Commercial
End Use: Refrigeration
Product: Walk-In Freezers
Lifetime (years): 10

Baseline Technology: Current Technology (characteristics uncertain)

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	48% efficiency improvement*	Same as 2010
Increase in installed cost* ($)	$1572	$1351
Annual energy savings* (kWh)	7517	7517
CCE (¢/kWh)	3.0	2.6
Decrease in LCC* ($)	-$44	$69

* Relative to baseline technology.

Notes:

Source(s): Arthur D. Little. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Cambridge, MA. June, 1996. Table 5-24.

Sector: Commercial
End Use: Office Equipment
Product: Personal Computers
Lifetime (years): 5

Baseline Technology: Current standby power

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Standby power at FEMP Phase 2 level	Not applicable
Increase in user first cost* ($)	0.5	
Annual energy savings* (kWh)	15	
CCE (¢/kWh)	0.8	
Decrease in LCC* ($)	3.5	

* Relative to baseline technology.

Notes: Products include monitors and laptops used in offices. Values given are averages weighted by current levels of shipments.

FEMP Phase 2 level refers to target levels for Federal Energy Management Program.

We did not consider a 2020 standard due to the expected rapid evolution of technology in this area.

Source(s): Unpublished LBNL analysis done in 2003; data inputs based on industry sources and LBNL estimates. See also: Bertoldi, Paolo, Bernard Aebischer, Charles Edlington, Craig Hershberg, Benoit Lebot, Jiang Lin, Tony Marker, Alan Meier, Hidetoshi Nakagami, Yoshiaki Shibata, Hans Paul Siderius, and Carrie Webber. "Standby power use: How big is the problem? What policies and technical solutions can address it?". In *2002 ACEEE Summer Study on Energy Efficiency in Buildings; Pacific Grove, CA; August 18-23 2002*. ACEEE, 2002. LBNL-50567

Sector: Commercial
End Use: Office Equipment
Product: Other than Personal Computers
Lifetime (years): 5

Baseline Technology: Current standby power

	Technology for 2010 Standard	**Technology for 2020 Standard**
Description	Standby power at FEMP Phase 2 level	Not applicable
Increase in user first cost* ($)	0.5	
Annual energy savings* (kWh)	12	
CCE (¢/kWh)	0.9	
Decrease in LCC* ($)	2.9	

* Relative to baseline technology.

Notes: Products include printers, copiers, scanners and fax machines. Values given are averages weighted by current levels of shipments.

FEMP Phase 2 level refers to target levels for Federal Energy Management Program.

We did not consider a 2020 standard due to the expected rapid evolution of technology in this area.

Source(s): Unpublished LBNL analysis done in 2003; data inputs based on industry sources and LBNL estimates. See also: Bertoldi, Paolo, Bernard Aebischer, Charles Edlington, Craig Hershberg, Benoit Lebot, Jiang Lin, Tony Marker, Alan Meier, Hidetoshi Nakagami, Yoshiaki Shibata, Hans Paul Siderius, and Carrie Webber. "Standby power use: How big is the problem? What policies and technical solutions can address it?". In *2002 ACEEE Summer Study on Energy Efficiency in Buildings; Pacific Grove, CA; August 18-23 2002*. ACEEE, 2002. LBNL-50567

Appendix 2
Calculation of Learning Rate Parameter

In this study we employ a parameter to estimate the change in manufacturing costs over time for various products that could be subject to standards. We rely on research by economist Richard Newell that he did for DOE to provide a "sound theoretical and empirical basis" for modeling technological advancement for EIA's National Energy Modeling System (NEMS) forecasts. The premise of this research is the common notion of learning by experience. The central idea is that manufacturers will develop efficiencies of production as the industry as a whole matures. This trend scales with the total historical production of the product in question. Accordingly, an empirical learning curve typically uses cumulative production of the product in question as a measure of experience accumulated. The key impact of the learning is a reduction in input use per product – and thus the price.

Mathematically, the learning relationship is expressed with price varying as a power law in total production:

$$c = aQ^{-b} \text{ ,}$$

where c is the cost (or input quantity) required to produce the Qth unit of output, a is the cost of the first unit produced, Q is cumulative production, and b is the learning parameter.

For the purposes of this analysis, we are interested in the rate at which cost can be expected to decline in the future as total production grows. Since a is constant, the annual percentage change in cost is dependent on Q, b and the annual change in cumulative production, ΔQ:

$$\frac{\Delta c}{c} = \left(\frac{\Delta Q}{Q} \right)^{-b}$$

The annual change in production in one year equals the shipments for that year. Thus, the rate of change in cost can be determined with total production, shipments and the learning parameter b.

Newell concentrated on three products for which historical data were available: room air conditioners, central air conditioners and gas water heaters. The learning parameter b is in principle product-specific. Table 1 summarizes the parameters and results of the learning rate calculation. The learning parameter b was found to be close to 0.4 for each of the products studied, with only a slight variation. Annual shipments from 2002 (the most recent year available) are taken to represent ΔQ, and for the purposes of this calculation, annual shipments are assumed constant. Inserting the appropriate values for Q, ΔQ and b for each product yields an annual price decrease rate of 1.3%, 1.8% and 1.3% for room air conditioners, central air

conditioners and gas water heaters, respectively. For simplicity, and because *b* is not determined for all end uses, we use the shipments-weighted average value of 1.5% for all products.

Table 1. Learning Rate Derivation

	Room Air Conditioner	Central Air Conditioner	Gas Water Heater
Production through 2002, Q (million)	171	122	157
Annual shipments ΔQ in 2002 (million)	6.15	5.26	4.99
Learning parameter b	0.38	0.43	0.41
Annual Percentage Increase in Production $\Delta Q/Q$	3.6%	4.3%	3.2%
Implied Cost Growth Factor $(1+\Delta Q/Q)^{-b}$	0.987	0.982	0.987
Implied Annual Rate of Decline in Cost $1-(1+\Delta Q/Q)^{-b}$	1.3%	1.8%	1.3%

Source: Census Data (quoted in Newell) and *Appliance* Magazine
Beginning production dates are first date for which data are available.

Reference

Newell, Richard G. *DRAFT, Incorporation of Technological Learning into NEMS Buildings Modules.* Prepared for Energy Information Administration, Department of Energy, Washington, D.C., September 2000.

Appendix 3
Derivation of Discount Rates

The discount rate is the rate at which future monetary values are discounted to establish their present value. In this study, we applied discount rates in two parts of the analysis. In the estimation of consumer impacts, we used discount rates that are appropriate for average residential and commercial consumers. In the estimation of the net economic impacts from the national perspective, we applied alternative discount rates of 7% and 3.5%.

Discount Rates Used in Consumer Impacts Analysis

Residential sector

For the residential sector, we derived discount rates using an approach similar to that used in DOE's recent analysis of residential central air conditioners.[1]

One way of estimating discount rates involves defining the share of various finance methods that are used for purchasing an appliance and then determining the associated interest rates for each of the finance methods. This method focuses on establishing the type of financing utilized for the purchase. For equipment financed through the purchase of a new home, this approach is reasonable.

Replacement equipment for existing homes is usually purchased using cash or some form of credit. One approach is to identify the types of credit used to purchase a given type of equipment, the associated interest rates, and the shares of each credit type in total replacement purchases. Such information is difficult to come by, and there are reasons to favor an alternative approach.

When a household makes a major appliance purchase, the short-term effect may be an increase in debt if the purchase is financed with a dealer loan or credit card, or a decrease in cash if the product is purchased with cash. However, financial theory suggests that in the medium-term, households should tend to rebalance their overall equity/debt portfolio to maintain approximately the same relative shares of different equity/debt classes. According t   o this line of reasoning, the appropriate opportunity cost for purchase of long-lived equipment should reflect a household's overall equity/debt portfolio, and not simply the financial or opportunity cost of the debt or equity used to purchase the equipment.

For example, even though the purchase might be financed through a dealer loan or some other short-term financing vehicle, the more probable effect of the purchase is to either cause the consumer to incur additional credit card debt or forego investment in some type of savings-related asset. Cash that was once available to either pay for household expenses or to invest in an asset like the stock market or a savings account now must be earmarked to pay off the equipment purchase, thus causing the consumer to incur additional credit card debt or to lose the opportunity to earn income from assets.

We estimated the discount rate for new-house equipment based on mortgage interest rate data provided in the Federal Reserve Board's *Survey of Consumer Finances* (SCF).[2] This survey indicates that mortgage rates carried by homeowners in 1998 averaged 7.9%. After adjusting for inflation and interest tax deduction (assuming a 28% marginal income tax rate), real after-tax interest rates on mortgages averaged 4.2%.

Equipment installed in new homes is financed as part of the mortgage. The Federal Reserve Board's *Survey of Consumer Finances* (SCF) indicates that mortgage rates carried by homeowners in 1998 averaged 7.9%. Since these mortgages were initiated over a period of many years, we assume that this rate is a reasonable long-term average. Since mortgage interest is tax-deductible, the effective mortgage rate for the average household with a 28% marginal income tax rate is 5.7%. Adjustment for inflation brings the rate to 4.2%.

For equipment purchased to replace old or failed equipment, we estimated the opportunity cost by assuming that households will eventually rebalance their equity/debt portfolio after purchase to maintain approximately the same shares as existed prior to the purchase. Regardless of which type of debt or equity the household actually uses to purchase the appliance, the final opportunity cost is equal to the average rate of return on equity or interest on debt, weighted by the percentage shares of each debt/equity type in the household's total financial portfolio.

We estimated the average household equity and debt portfolio from the 1995 and 1998 *Survey of Consumer Finances*. In considering the household financial portfolio, we exclude highly illiquid types of equity (retirement accounts, life insurance, and other managed assets) and debt on a primary mortgage. We assume that these types of equity are not included in the rebalancing.

We estimated interest or return rates associated with each type of household equity and debt holding from a variety of sources. Rates for second mortgages and credit cards are from 1998 SCF data. We estimated interest rates associated with certificates of deposit (CDs), treasury bills (T-bills), and corporate bonds as an average of the Federal Reserve Board time-series data covering 1977–2001. Based on relative returns to less-liquid assets, we assumed that the interest rate on transactions (checking) accounts averages 2% real. We estimated annual return associated with household stock holdings as an average of data published by the Stern Business School covering the 1977–2001 period.[3] We estimated mutual fund rates as an average of the Standard and Poor's (S&P) 500 stock rate (67% weight) and the T-bill rate (33% weight).

Table 1 summarizes the shares of household equity and debt based on the above sources and the real, after-tax interest rates associated with each type of equity or debt. We assumed a marginal tax rate of 28% and CPI inflation to derive real from nominal values. The weighted-average real, after-tax interest rate across all types of household debt and equity is 6.7%.

Table 6. After-Tax Real Interest or Return Rates for Household Debt and Equity Types

Type	Average Share of Household Debt plus Equity (%)*	Mean Rate (%)
Second mortgage	3.0	5.9
Credit card and installment loans	9.1	12.0
Transaction (checking) accounts	20.0	2.0
CD (6-month)	7.9	2.8
Savings bonds (Treasury)	1.6	3.7
Bonds (Corporate AAA)	8.3	4.4
Stocks (S&P500)	30.2	9.6
Mutual funds	19.8	7.6
Total/Weighted-average discount rate	100	6.7

* 1998 data

In this study, we were not able to separately track equipment purchased with new homes and equipment purchased for replacement. Thus, we derived a weighted-average total discount rate based on the 4.2% rate for new-home equipment and the 6.7% rate for replacement equipment. The weighted-average of 5.6% assumes that two-thirds of total equipment shipments are for replacement equipment. For the analysis of building codes for new homes, however, we used the new-home rate of 4.2%.

Commercial sector

For the commercial sector, we used the discount rates derived for DOE's recent analysis of commercial air conditioners. DOE/LBNL derived the discount rates for this analysis from estimates of the cost of capital of companies that purchase commercial air-conditioning equipment. Most companies use both debt and equity capital to fund investments, so the typical cost of capital is the weighted average of the cost to the firm of equity and debt financing.[4]

The cost of equity financing was estimated using the capital asset pricing model (CAPM). The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportionate to the amount of systematic risk associated with a firm. The cost of equity financing tends to be high when a firm faces a large degree of systematic risk and the cost tends to be low when the firm faces a small degree of systematic risk.

The degree of systematic risk facing a firm is determined by several variables, including the risk coefficient of a firm, the expected return on "risk free" assets (R_f), and the additional return expected on assets facing average market risk (which is known as the equity risk premium or *ERP*). The variable used to measure firm risk is termed the risk coefficient or "beta." Beta indicates the degree of risk associated with a given firm relative to the level of risk (or price variability) in the overall stock market. Betas usually vary between 0.5 and 2.0. A firm with a

beta of 0.5 faces half the risk of other stocks in the market; a firm with a beta of 2.0 faces twice the overall stock market risk.

Following this approach, the cost of equity financing for a particular company is given by the equation:

$$k_e = R_f + (\beta * ERP)$$

where:
k_e =	cost of equity for a company,
R_f =	expected return of the risk free asset,
β =	beta of the company stock, and
ERP =	expected equity risk premium.

The cost of debt financing is the yield or interest rate paid on money borrowed by a company (for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk (the risk that a firm will go bankrupt) and excludes deductions for taxes.

We estimated the cost of debt for companies by adding a risk adjustment factor to the current yield on long-term corporate bonds (the risk free rate). This procedure was used to estimate company costs to obtain debt financing. The adjustment factor was based on indicators of company risk, such as credit rating or variability of stock returns.

The discount rate of a company is the weighted average cost of debt and equity financing or the weighted average cost of capital (WACC). It was estimated from the equation:

$$k = k_e \cdot w_e + k_d \cdot w_d$$

Where,
k =	(nominal) cost of capital,
k_e =	expected rate of return on equity,
k_d =	expected rate of return on debt,
w_e =	proportion of equity financing in total annual firm financing, and
w_d =	proportion of debt financing in total annual firm financing.

The cost of capital is a nominal rate, because it includes anticipated future inflation in the expected returns from stocks and bonds. The real discount rate or WACC deducts expected inflation from the nominal rate. We calculated expected inflation (2.3 percent) from the average of the last five quarters' change in gross domestic product (GDP) prices.

We defined the expected return on "risk free" assets, or risk free rate (5.5 percent), by the yield (December 2001) on long-term government bonds.[5] The equity risk premium (*ERP*) represents the difference between the expected (average) stock market return and the risk free rate. The 5.5 percent estimate for the ERP was taken from the Damodaran Online site.[6]

A sample of companies used to represent commercial air conditioner purchasers was pulled from a database of 7,319 U.S. companies included in the Damodaran Online site.[3] This firm database includes most of the publicly traded companies in the United States economy. This database of companies was divided into the categories shown in Table 3 according to their standard industrial code (SIC) code. Financial information was sought for all the retail, property owner, medical service, hotel, and food service firms as well as all of the public for profit and not for profit firms included in the full sample. Financial information was sought for only 10 percent of the industrial and office/service sector firms in the full sample in order keep the data base manageable. The 10 percent sub-sample was chosen by listing the companies alphabetically and drawing every tenth firm on the list. In cases where one or more of the variables needed to estimate the discount rate was missing or could not be obtained, the firm was discarded from the analysis. Overall, about 80 percent of the firms in the full database were discarded for this reason.

Ultimately, a sample of 973 companies was used to represent commercial air conditioner purchasers. For each company, the cost of debt, percent debt financing, and systematic firm risk were drawn from information provided at the Damodaran Online site[6] (Leonard N. Stern School of Business, New York University), Bloomberg Professional,[7] and Federal Regulator Energy Commission (FERC) Form 1 filings.[8*] The cost of debt financing was estimated from the long-term government bond rate (5.5 percent) and the standard deviation of the stock price. Average values for the cost of debt, percent debt financing, and systematic firm risk for companies that purchase commercial air conditioners are shown in Table 2. For the public not-for-profit subsector, we based the cost of capital on average interest rates for Treasury, state, and municipal bonds.

Table 2. Average Values for Variables Used to Estimate Company Discount Rates

Variable	Average	Source
Risk free asset return (R_f)	5.5%	Bloomberg Financial. December 2001
Equity risk premium (ERP)	5.5%	Stern Business School, Damodaran Online
Expected inflation (r)	2.3%	Bureau of Economic Analysis
Cost of debt (after tax) (k_d)	5.9%	Stern Business School, Damodaran Online
Percent debt financing (w_d)	44%	Stern Business School, Damodaran Online
Systematic firm risk (β)	0.93	Stern Business School, Damodaran Online

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[*] Percent debt for firms in the property-owning category was estimated using data from Bloomberg Professional. Cost of debt for publicly owned utilities was taken from FERC Form 1 filings.

We determined the share of each category in total commercial building square footage with package air conditioning from EIA's 1999 Commercial Building Energy Consumption Survey (CBECS).[9] From these data, we estimated the shares of total commercial sector purchases of commercial air conditioners (Table 3).[**]

Table 3. Estimated Shares of Total Purchases of Commercial Air Conditioners

Category	Percent
Property owners and managers	21.2
Retail firms	16.5
Medical services	6.7
Industrial	4.9
Hotels	4.0
Food service	5.3
Office/Service sector	19.4
Public for profit	11.0
Public not for profit	11.0
Total	100.0

Table 4 shows estimates of the real discount rate by category. The weighted average discount rate across all companies is 6.1 percent.

[**] The share of total square footage occupied by property owners is around 40%. However, in some of these buildings the tenants purchase commercial air conditioners. We assumed that this is the case for half of the square footage occupied by property owners. We then allocated the remaining quantity among the other subsectors in proportion to their shares of total square footage.

Table 4. Real Discount Rates by Category for Purchasers of Commercial Air Conditioners

Category	SIC Code	Estimated share of purchases	Mean real discount rate (WACC)	Standard deviation	Number of observations
Retail stores	53, 54, 56	16.5%	7.1%	2.1%	218
Property owners & managers	6720	21.2%	5.2%	0.7%	11
Medical services	8000	6.7%	7.0%	1.7%	115
Industrial	1000-4000	4.9%	6.9%	3.2%	253
Hotels	7000	4.0%	5.6%	1.5%	51
Food service	5400, 5812	5.3%	6.1%	1.4%	88
Office/services	5910-9913	19.4%	6.9%	2.1%	128
Public for profit	7950, 8299	11.0%	7.3%	1.8%	68
Public not for profit	N.A.	11.0%	3.0%	0.7%	41
Weighted Average		N.A.	**6.1%**	1.6%	N.A.
Sources: CBECS, Damodaron Online and LBNL calculations					

Discount Rates in Estimation of National Economic Impacts

In its analyses of the national economic impacts of equipment energy efficiency standards, DOE relies on guidance issued in 1992 by the Office of Management and Budget (OMB) in Circular No. A-94 (Revised), which states (section 8): "In general, public investments and regulations displace both private investment and consumption. … Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years."[f] We apply this "investment discount rate" in this study.

As the OMB guidance notes, regulations such as energy efficiency standards displace both private investment and consumption. Economist Kenneth Arrow notes that "Since consumption is much larger than investment [in the economy], it is reasonable to assume that the appropriate hurdle rate should be closer to the consumption rate… Most estimates of the rate of return on consumption are on the order of 3 or 4 percent."[10] Based on this line of reasoning, we apply a "consumption discount rate" of 3.5%. We note that the OMB later advised Federal agencies to use a 3% discount rate as a sensitivity for calculating the national economic impacts of regulatory policies.[g]

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[f] See http://www.whitehouse.gov/omb/circulars/a094/a094.html#9. Given the statement that "public investments and regulations displace both private investment and consumption," it is not clear why the OMB elected to base a discount rate only on displacement of private investment.

[g] OMB, Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting

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Statements.

Appendix 4
National Impacts Methodology

Overview

We estimate national energy savings from percentage efficiency improvement estimates that we apply to the base case forecast provided by EIA's Annual Energy Outlook (AEO) 2004. EIA gives base case energy consumption for each end use for each year of the forecast. Equipment installed after the standards effective year (2010 or 2020) consumes less energy than in the base case, either due to equipment efficiency standards, which apply to all new equipment, or to building codes, which apply to newly constructed homes or commercial buildings. In order to estimate the fraction of equipment stock for which the standard applies, we use a stock accounting model that tracks equipment retirements, replacements, and shipments to newly constructed buildings. Finally, net consumer financial impacts are derived according to implied utility bill savings and incremental capital expenditures.

### Stock Accounting for Equipment

The AEO end use energy consumption forecast represents each appliance's unit energy consumption, multiplied by the number of units in the stock in each year. For each technology, we estimate the average existing stock UEC and the UEC of new equipment in the absence of new standards. In the standards case, equipment shipped after the standard date has a lower UEC. National energy savings is derived from this improvement, according to the accumulation of post-standards stock in each year of the forecast.

New equipment enters the stock either by replacement of retired units or by installation into new buildings. In estimating the amount of new equipment entering the stock due to replacements, we model the retirement of old units, and assume that all retired units are replaced with the same type of equipment. Retirements are modeled with a simple algorithm based on the average lifetime L of each type of equipment, and the vintage v of the existing stock. The survival function $s(L,v)$ gives the ratio of stock in a given year to the total stock in the year of standards implementation. The survival algorithm assumes that no equipment is retired before it has reached two-thirds of its average lifetime, and that all are retired by four-thirds of the average lifetime. In between two-thirds and four-thirds of the lifetime, the survival function is linear. Mathematically, the survival algorithm is given by the following:

$$v < 2/(3L) \qquad\qquad s = 1$$
$$2/3\, L <= v <= 4/3\, L \qquad\qquad s = 2 - 3v/(2L)$$
$$v > 4/3\, L \qquad\qquad s = 0$$

The retirement function is equivalent to the assumption that a constant percentage of each cohort equal to 3/(2L) is retired each year between two-thirds and four-thirds of the average lifetime. Figure 1 shows the survival function for an equipment type having an average lifetime of 15 years. Application of the retirement function yields a stock factor for replacements, S_R.

Figure 1. Survival Function for Equipment Having an Average Lifetime of 15 Years
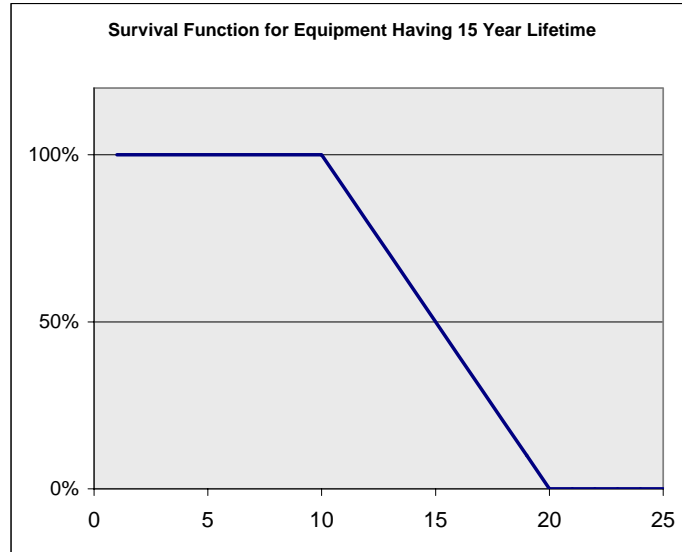
New housing and commercial building space are tracked from the year of standard implementation according to the AEO forecast. The ratio of new buildings constructed since the reference year to the building stock in the reference year is denoted S_N. We assume that only new equipment is installed in new buildings, and that equipment type market shares remain constant over time. None of the residential buildings built after 2010 are assumed to be subject to demolition during the forecast period. Energy cost savings benefits are assumed to accrue over the first 30 years of the lifetime of the building shell.

Energy Savings

We calculate a preliminary estimate of total site (delivered) energy use according to existing stock UEC, new equipment UEC, and the stock accounting model described in the previous section. This estimate is refined using the equipment efficiency growth rate incorporated in the AEO forecast. Slight differences between the preliminary estimate and the AEO reference forecast arise due to usage trends (e.g. residential floor space and fuel switching) not captured in our simplified model. To correct for this, we apply a service growth factor ρ, defined as the ratio of the AEO forecast to our preliminary estimate. Finally, a baseline factor b is defined as the percentage of new equipment accounted for by baseline models-- those that are not more efficient than required by standards. For residential appliances, we had data that allowed estimation of the portion of the products in the base case that are more efficient that the upgraded standard, and thus would not be impacted by upgraded standards. We estimated the share of units

sold expected to be more efficient than the upgraded standard based on recent market statistics on Energy Star products.

Site energy savings is equal to the product of the following factors: fractional improvement of equipment affected by standards or codes × post-standards stock factor × share of each end use (e.g. electric space heating) claimed by the affected technology (e.g. heat pump) × the unit energy consumption of new units in the base case; or:

$$\Delta E = \rho \times b \times E_0 \times \Delta \mathit{Eff} \times (S_N + S_R) \times MS \times UEC_N,$$

where:

$\Delta E =$ *Site Energy Savings*
$\rho =$ *Service Growth Factor*
$b =$ *Baseline Percentage Factor*
$E_0 =$ *Base Case End Use Energy Consumption*
$\Delta \mathit{Eff} =$ *Efficiency Improvement Percentage*
$S_N =$ *New Construction Stock Factor*
$S_R \times$ *Replacement Stock Factor*
$MS \times$ *Equipment Type Market Share*
$UEC_N =$ *New Equipment Unit Energy Consumption*

Primary energy savings is calculated from site savings using conversion provided by the AEO forecast.

Financial Impacts

Energy savings due to equipment standards and building codes has a direct financial benefit to consumers in the form of decreased utility bills. These are offset, however, by the increased capital expenditure involved in purchasing high-efficiency equipment. Our analysis considers the trade off between utility bill savings and incremental capital costs by calculating life-cycle cost and cost of conserved energy for each technology option. Cost of conserved energy (non-discounted) for each product is given by:

$$CCE = \frac{\Delta EC}{\sum_{1}^{L} \Delta OC}$$

where

CCE	$=$	Cost of Conserved Energy
ΔEC	$=$	Incremental Consumer Equipment Cost
ΔOC	$=$	Annual Consumer Operating Cost Savings
L	$=$	Equipment Lifetime

Since the CCE provides an incremental cost for higher-efficiency new equipment, the total incremental capital costs in each year are calculated from the incremental site energy savings

from one year to the next, which represents additional energy savings due to new equipment. This incremental savings is multiplied by the non-discounted cost of conserved energy of the technology affected by standards. In cases where more than one product in a given end use is affected by standards, a market-weighted average cost of conserved energy is used.

National operating cost savings in each year are equal to delivered energy savings multiplied by the projected price of gas or electricity in that year, as provided by AEO 2004. The net present value (NPV) of financial impacts are calculated using a fixed societal discount rate, applied to each year according to length of time from the reference year (2004).