OPPORTUNITIES FOR NEW APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS: ENERGY AND ECONOMIC SAVINGS BEYOND CURRENT STANDARDS PROGRAMS

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EXECUTIVE SUMMARY

Appliance and equipment efficiency standards have been one of the most successful policies used by state governments and the federal government to save energy. Appliance and equipment efficiency standards prohibit the production and import or sale of appliances and other energy-consuming products less efficient than the minimum requirements. These standards not only save energy but also reduce pollutants, improve electric system reliability, and save consumers and business owners significant amounts of money over the life of the equipment.

In the United States, minimum-efficiency standards for appliances and other equipment were adopted by Congress in 1987, 1988, and 1992 and signed by Presidents Reagan and Bush to address market failures and replace a patchwork of state standards. These initial efficiency standards focused on the "low-hanging fruit"—major residential appliances (e.g., refrigerators, air conditioners, water heaters, washers and dryers, etc.) as well as the most common commercial equipment (e.g., fluorescent lamps, motors, furnaces, etc.) Since then, technology and programmatic advances provide the opportunity to extend the standards programs to additional products that are now "ripe" for harvest of energy/economic savings. These developments include widespread availability of more advanced products; work on new standards by Canada and several states in the United States; development of ENERGY STAR® specifications for many products; updates of key industrial standards; and additional research on the energy savings potential, usage, and cost of these products.

While the efficiency standards established to date have provided significant energy and economic savings, the United States is still experiencing overall growth in energy demand and an increasingly tight supply. Many other regions might become "the next California"—the Northwest, Northeast, Midwest, and South currently face tight supply/demand balances and might face electricity shortages in the next few years. Savings from new products that are now "ripe" for appliance and efficiency standards could reduce the need for additional power plants and ease electric load on already stressed transmission lines and transformers, significantly contributing to improved system reliability.

In this report we describe opportunities for state governments and the federal government to set minimum-efficiency standards for 13 appliances and other types of equipment currently not covered by federal legislation. These are furnace, air conditioner, and heat pump fans[1]; ceiling fans; consumer electronics (standby power); residential torchiere lamps; commercial unit and duct heaters; distribution transformers; commercial food service refrigerators and freezers; refrigerated vending machines; traffic signals; exit signs; commercial clothes washers; commercial ice-makers; and large packaged air conditioners.

Table ES.1 summarizes the potential for energy and economic savings from adopting national minimum-efficiency standards for the above 13 products. Table ES.2 shows the potential peak load and emission reductions from adopting these standards.

[1] We generically refer to these fans as "furnace fans."

Table ES.1 Estimated Energy Savings and Economics of Proposed New Standards

Products	Effective Date	National Energy Savings in 2010		National Energy Savings in 2020		NPV for Purchases Thru 2020	Benefit-Cost Ratio
	(year)	(TWh)	(tril. Btu)	(TWh)	(tril. Btu)	($million)	
Furnace, A/C, & heat pump fans	2008	12.2	124.7	61.1	609.2	28,300	7.8
Consumer electronics (standby power)	2005	25.5	259.9	32.4	323.1	16,128	5.7
Ceiling fans	2008	7.4	75.1	29.4	293.3	8,074	2.8
Torchiere lamps	2005	10.6	108.0	19.3	191.9	7,658	3.4
Commercial unit and duct heaters	2005	NA	53.1	NA	149.7	4,241	6.2
Dry type transformers	2005	1.9	19.7	5.4	54.1	2,796	5.8
Beverage vending machines	2008	1.2	12.1	4.0	40.0	1,198	4.5
Commercial refrigerators & freezers	2005	1.9	19.9	3.2	31.8	1,375	6.8
Traffic signals	2005	1.0	9.8	2.6	26.2	710	2.6
Exit signs	2005	0.8	8.5	2.3	23.3	1,179	7.5
Commercial clothes washers	2008	0.7	6.8	2.1	21.3	2,000	6.7
Beverage merchandisers	2008	0.6	6.1	2.0	20.2	621	5.1
Ice-makers	2005	1.1	10.9	1.7	16.5	564	3.0
Large packaged A/C equipment	2008	0.3	2.9	1.4	14.2	387	3.4
TOTAL		**65**	**717**	**167**	**1,815**	**75,231**	**5.0**

Note: Net benefits are NPV benefits minus NPV costs.

Table ES.2 Estimated Summer Peak Load and Pollutant Reductions from New Standards

Products	Summer Peak Load Reduction in 2010	Summer Peak Load Reduction in 2020	Carbon Reduction in 2020	NOx Reduction in 2020	SOx Reduction in 2020	PM10 Reduction in 2020
	(GW)	(GW)	(MMT)	(1000MT)	(1000MT)	(1000MT)
Furnace, A/C, & heat pump fans	5.42	27.10	11.65	34.91	160.91	1.77
Consumer electronics (standby power)	3.44	4.38	6.18	18.52	85.36	0.94
Ceiling fans	2.36	9.42	5.61	16.81	77.48	0.85
Torchiere lamps	3.39	6.16	3.67	10.99	50.68	0.56
Commercial unit and duct heaters	-	-	2.21	6.26	0.04	0.51
Dry type transformers	0.36	1.00	1.04	3.10	14.30	0.16
Beverage vending machines	0.38	1.29	0.77	2.29	10.58	0.12
Commercial refrigerators & freezers	0.62	1.02	0.61	1.82	8.39	0.09
Traffic signals	0.13	0.35	0.50	1.50	6.91	0.08
Exit signs	0.11	0.32	0.45	1.34	6.16	0.07
Commercial clothes washers	0.21	0.69	0.41	1.22	5.63	0.06
Beverage merchandisers	0.19	0.65	0.39	1.16	5.32	0.06
Ice-makers	0.34	0.53	0.32	0.94	4.35	0.05
Large packaged A/C equipment	0.28	1.38	0.27	0.81	3.75	0.04
TOTAL	**17.2**	**54.3**	**34.1**	**101.7**	**439.9**	**5.3**

These new standards would save 167 terawatt-hours (TWh) of electricity and over 1.8 quads of primary energy in the year 2020, while generating $75 billion in net savings for consumers and business owners for equipment purchased through 2020. The electricity savings amounts to 5% of projected residential and commercial sector U.S. electricity use in 2020. Stated another way, these standards could reduce projected growth in residential and commercial electricity use over the next 2 decades by nearly 20%. The primary energy savings from new standards is well over one-third the savings from all existing federal standards, with an overall benefit-to-cost ratio of 5 to 1—far better than the 3 to 1 ratio for existing standards. These standards are also incredibly cost-effective from a government perspective, with net benefits probably on the order of 1,000 times greater than government expenditures.

Another significant benefit from appliance standards is their impact on summer peak load. We estimate that the proposed standards would save a total of over 54 gigawatts (GW) of power in the year 2020. This is roughly equal to the generating capacity of 180 average power plants (i.e., 300 MW each).

Emissions reductions from the reduced energy consumption would also be significant. In the year 2020, over 34 million metric tons (MMT) of carbon could be reduced, which is equivalent to the annual carbon emissions from over 27 million "average" passenger cars. In addition to carbon, emissions could be reduced significantly for smog-forming nitrogen oxides (NOx), sulfur oxides (SOx; the main component of acid rain), and fine particulate matter.

Clearly, significant savings potential exists for these products at a small increase in first cost, resulting in large energy savings, economic savings, peak load reductions, and emission reductions over the life of the equipment.

Given these benefits, we recommend that states and/or the federal government adopt new efficiency standards on these projects. For most of these, this report provides specific language and recommendations that can be used to craft the appropriate legislation and regulations.

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1. INTRODUCTION

1.1 History of Standards in the United States

Appliance efficiency standards were first enacted by the state of California in 1974 when then-Governor Reagan signed the State Energy Resources Conservation and Development Act as part of the state's policy to "reduce wasteful, uneconomical, and unnecessary uses of energy, thereby reducing the rate of growth of energy consumption, prudently conserving energy resources, and assuring statewide environmental, public safety, and land use goals" (CEC 1983). Other rationales for standards were to save consumers money by lowering appliance operating costs and helping to overcome market barriers that inhibit the sale of efficient products.

California's original standards applied to refrigerators, freezers, room air conditioners, and central air conditioners. California subsequently expanded the scope of its standards to include space heaters, water heaters, plumbing fittings, fluorescent ballasts, and large air conditioners (CEC 1983). In the early and mid-1980s, other states (including Florida, Kansas, and New York) began to adopt standards on central and room air conditioners (Geller 1983). In 1986, Massachusetts adopted standards on refrigerators, room air conditioners, water heaters, fluorescent ballasts, and showerheads (Nadel 1994).

In 1986, with the likely development of additional state standards, appliance manufacturers became increasingly concerned about the impact of differing state standards on manufacturers' ability to do business on a national basis. To address these concerns, they offered to negotiate with energy efficiency advocates and states in order to reach consensus on national efficiency standards that would largely preempt individual state standards. The resulting agreement was adopted by Congress and signed by President Reagan as the National Appliance Energy Conservation Act of 1987 (NAECA) (U.S. Congress 1987). In 1988, Congress added fluorescent ballasts to NAECA (U.S. Congress 1988). And in 1992, Congress adopted and President Bush signed the Energy Policy Act (EPAct) (U.S. Congress 1992), which added standards for many of the most common types of light bulbs, electric motors, commercial heating and cooling equipment, and plumbing fittings. Both the 1988 and 1992 laws were based on consensus agreements between product manufacturers and efficiency advocates (Nadel and Pye 1996). The specific products covered by these different federal standards are summarized in Table 1.1.1.

Since the original NAECA and EPAct standards were enacted, there have been several updates to the standard levels that have yielded/will yield significant additional energy and economic savings. The U.S. Department of Energy (DOE) is specifically instructed to update standards whenever "new available technology makes higher standard levels economically justifiable" (U.S. Congress 1987). These updates included new refrigerator, freezer, and room air conditioner standards published in 1997, new fluorescent ballast standards published in 2000, and new clothes washer, water heater, and central air conditioner and heat pump standards published early this year (in most cases new standards take effect 3 years after final publication).

Recently, there have been developments in several states on appliance and equipment efficiency standards. First, Minnesota and Massachusetts have adopted the National Electrical Manufacturers Association's (NEMA) Standard TP-1 as the minimum-efficiency requirement

for distribution transformers through the state building code and/or an equipment efficiency standard. New York and California are currently in the process of adopting a similar standard. Second, in September 2000, the California Energy Commission was directed by the state legislature to "adopt and implement updated and cost-effective standards to ensure the maximum feasible reductions in wasteful, uneconomic, inefficient, or unnecessary consumption of electricity." This directive was issued in response to power shortages in the summer of 2000, and expected continued shortages in the next few summers. As a result of this directive, the commission published an initial proposal at the end of 2000, which contains new and revised efficiency standards for 20 appliances, some of which are not within the scope of existing federal or state regulations. This proposal is currently being reviewed and is expected to be finalized and adopted in late 2001. Most of the standards will become effective 1 year after adoption.

Table 1.1.1 Products Subject to Existing Appliance Efficiency Standards

Products Included in the National Appliance Energy Conservation Act (NAECA)	
Refrigerator-freezers	Clothes washers
Freezers	Clothes dryers
Room air conditioners	Dishwashers
Central air conditioners and heat pumps	Ranges and ovens
Furnaces and boilers	Pool heaters
Water heaters	Fluorescent lamp ballasts
Direct-fired space heaters	Televisions*
Products Added in the Energy Policy Act of 1992	
Fluorescent lamps	Showerheads
Incandescent reflector lamps	Faucets and aerators
Electric motors (1–200 hp)	Toilets
Packaged air conditioners and heat pumps	Distribution transformers*
Furnaces and boilers	Small electric motors (<1 hp)*
Water heaters	High-intensity discharge lamps*

Source: Nadel and Pye 1996

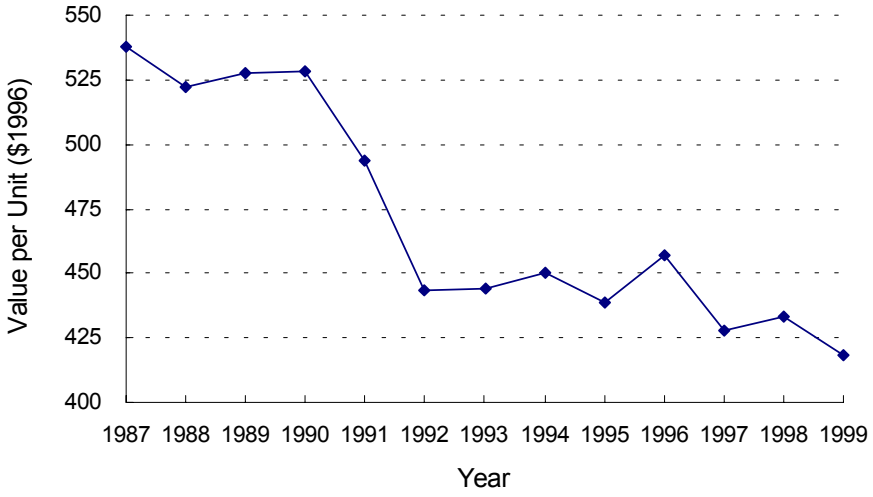
* Specific standards were not set in the legislation but instead DOE was instructed to investigate whether standards are technically feasible and economically justified and to set standards where these criteria are met.

1.2 Rationale for Standards

By setting a minimum-efficiency level, standards remove inefficient products from the market and ensure that efficiency improvements are incorporated into all new products. Without standards, in many cases, only premium products include efficiency improvements. Standards can help bring down costs for energy-efficient technologies due to economies of scale and because standards encourage manufacturers to focus on how to achieve efficiency improvements at minimum cost as manufacturers compete for the most price-sensitive portion of the market. As a result, higher-efficiency products become more affordable and widely available and all consumers enjoy the benefits from advances in product performance and design (deLaski 2001). For example, due to standards all new refrigerators use high-efficiency motors and compressors, better insulation, and improved heat exchangers and are three times more energy efficient than refrigerators in the 1970s. During this period, the average per unit value of refrigerators actually **declined** (see Figure 1.2.1).

Clearly, appliance and equipment efficiency standards save energy—standards already in place will save 4.2 quads in 2020, equivalent to the annual energy use of 23 million U.S. households (further details provided below). In addition, efficiency standards can also reduce pollutants, improve electric system reliability, and save consumers and business owners a significant amount of money during the life of the equipment from reduced energy bills. Due to these multiple benefits, it is important for the federal government, states, and utilities to include present and future standards in their energy use forecasts and plans and to take steps to ensure that the appliance standards process stays on track so that these many benefits can be realized.

Figure 1.2.1 Per Unit Value of Refrigerators, 1987–1999 (in 1996 dollars)



Source: Census Bureau 1999

Minimum-efficiency standards make sense when high-efficiency products are readily available or can be readily produced and are cost-effective to end-users but, due to a number of market barriers, many consumers and businesses are purchasing less efficient products. These market barriers include

Demand-Side

- *Lack of awareness:* Many purchasers and end-users underestimate the amount of energy consumption and the associated environmental impacts of operating the equipment. Very often, they are not even aware that different models can consume significantly different amounts of energy and that buying more efficient products can lead to energy and utility bill savings.

- *Uninformed decision-makers:* Even when the decision-maker is aware of variations in energy efficiency, often he/she is too busy to research the cost-effectiveness of a decision, or information on high-efficiency products is not readily available. In the commercial/industrial sector, many purchasing decisions are made by a purchasing department or maintenance staff who are unfamiliar with the relative efficiencies and operating costs of the equipment they purchase.

- *Third-party decision-makers ("split incentive"):* Many times the decision-maker (e.g., developer or landlord, purchasing department, bottling company, etc.) is responsible for purchasing equipment but someone else (e.g., tenant, operating department, store owner, etc.) is responsible for paying the energy bills. In these instances, the purchaser tends to buy the least expensive equipment because s/he receives none of the benefits from improved equipment efficiency.

- *Financial procedures that overemphasize initial costs and de-emphasize operating costs:* It is very common that accounting processes in the commercial and industrial sectors closely scrutinize capital costs and tend to favor purchase of inexpensive equipment while operating costs are generally not scrutinized as closely. Furthermore, when operating costs are reduced, the savings typically show up in a corporate-level account and are rarely passed on to the department that made the decision and the investment. This diversion of benefits discourages energy-saving investments (Nadel and Suozzo 1996).

Supply-Side

- *Limited stocking of efficient products:* Equipment distributors generally have limited storage space and therefore only stock equipment that is in high demand. This creates a "Catch-22" situation: users purchase inefficient equipment so distributors only stock inefficient equipment. Purchasing efficient equipment thus may require a special order, which takes more time. Most equipment that fails need to be replaced immediately. Thus, if efficient equipment is not in stock, even customers who want efficient equipment are often stuck purchasing standard equipment (Nadel and Suozzo 1996).

- *Manufacturer competition:* Since different manufacturers are competing for market share, if a manufacturer voluntarily increases efficiency, the small increases in retail cost to improve the efficiency of the product could adversely affect the business if there is little end-user demand for efficient products. A good example is beverage vending machines—the manufacturers agree in concept that energy savings could be achieved with very small incremental cost but they are not willing to participate in voluntary programs since purchasers (e.g., bottlers) only look at first cost. In contrast, mandatory standards ensure that the playing field is level for all manufacturers.

Besides minimum-efficiency standards, a number of other program and policy options are available to overcome these barriers, including education programs, rebate programs, and building code requirements. However, none of these options have the energy-savings impact of minimum-efficiency standards because the options do not affect all purchase decisions. Education programs generally only reach a small fraction of decision-makers (Nadel, Pye, and Jordan 1994). Building codes generally apply only to new or substantially renovated buildings, leaving the large number of existing buildings unaffected. Thus, while these other programs and policy options can have important benefits and complement efficiency standards (e.g., by encouraging higher-efficiency levels than can be mandated with efficiency standards), they are not a replacement for efficiency standards.

1.3 Savings from Current Standards

Several studies have been conducted on the impacts of efficiency standards to date on U.S. energy use. For example, both the American Council for an Energy-Efficient Economy (ACEEE) and Lawrence Berkeley National Laboratory (LBNL) have periodically published estimates of the national impacts of specific federal efficiency standards (Atkinson et al. 1992; Geller 1987; Geller 1995; Geller and Miller 1988; Geller and Nadel 1992; LBNL 1990; McMahon et al. 1990). These studies generally compare the efficiency of appliances with standards to what efficiencies would have been if pre-standard efficiency trends had continued. Most recently, ACEEE compiled a list of savings estimates including electricity savings, primary energy savings, peak load reductions, and carbon reductions in the years 2000, 2010, and 2020 from all standards adopted so far (Geller, Kubo, and Nadel 2001) (see Table 1.3.1).

Table 1.3.1 Savings from Federal Appliance and Equipment Efficiency Standards

Enact Year	Standards	Electricity Savings (TWh/yr)			Primary Energy Savings (quads/yr)			Peak Load Reductions (GW)			Carbon Reductions (MMT)			Net Benefit ($billion)
		2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020	Thru 2030
1987	NAECA	8.0	40.9	45.2	0.21	0.55	0.61	1.4	14.9	16.5	3.7	10.0	10.1	46.3
1988	Ballasts	18.0	22.8	25.2	0.21	0.27	0.29	5.7	7.1	7.9	4.4	5.0	5.0	8.9
1989&91	NAECA updates	20.0	37.1	41.0	0.23	0.43	0.47	3.6	6.9	7.7	4.8	8.1	8.1	15.2
1992	EPAct (lamps, motors, etc.)	42.0	110.3	121.9	0.59	1.51	1.67	10.1	26.2	28.9	11.8	27.5	27.9	84.2
1997	Refrigerator/freezer update	0.0	13.3	28.0	0.00	0.13	0.28	0.0	1.7	3.6	0.0	2.9	5.5	5.9
1997	Room A/C update	0.0	1.3	2.1	0.00	0.01	0.02	0.0	1.0	1.6	0.0	0.3	0.4	0.6
2000	Ballasts update	0.0	6.2	13.7	0.00	0.06	0.13	0.0	1.8	3.0	0.0	1.3	2.7	2.6
2001	Clothes washer update	0.0	8.0	22.6	0.00	0.11	0.28	0.0	1.3	6.1	0.0	2.2	5.4	15.3
2001	Water heater update	0.0	2.5	4.9	0.00	0.08	0.13	0.0	1.5	3.6	0.0	1.4	2.2	2.0
2001	Central A/C&HP update	0.0	10.7	36.4	0.00	0.11	0.35	0.0	3.5	41.5	0.0	2.3	7.2	5.0
	TOTAL	**88**	**253**	**341**	**1.2**	**3.3**	**4.2**	**21**	**66**	**120**	**25**	**61**	**75**	**186**
	% of projected U.S. use	**2.5%**	**6.5%**	**7.8%**	**1.3%**	**2.9%**	**3.5%**	**2.8%**	**7.6%**	**12.6%**	**1.7%**	**3.4%**	**3.8%**	

Source: Geller, Kubo, and Nadel 2001

The overall savings from established appliance and equipment efficiency standards are enormous. As of 2000, appliance standards had already cut U.S. electricity use by 2.5% and U.S. carbon emissions from fossil fuel use by nearly 2%. The total electricity savings are projected to reach 253 and 341 billion kilowatt-hours (kWh) per year, or 6.5% and 7.8% of the projected total U.S. electricity use, in 2010 and 2020, respectively. The primary energy savings from these standards should reach 4.2 quadrillion British thermal units (quads) in 2020—equivalent to the annual energy use of about 23 million American households. The peak load reduction is expected to reach 66,000 megawatts (MW) in 2010 and 120,000 MW in 2020, which is equivalent to the power produced by 400 average (i.e., 300 MW) fossil fuel power plants. The standards also will reduce carbon emissions by 61 MMT in 2010 and 75 MMT in 2020. The latter value is equivalent to the annual carbon emissions from approximately 50 million "average" passenger cars (EPA 1997). These savings will occur while simultaneously the standards will provide a cumulative net benefit through 2030 of about $186 billion to U.S. consumers, about $1,750/household (Geller, Kubo, and Nadel 2001).

Of particular interest in Table 1.3.1 are the six updates to NAECA issued by the Clinton Administration in 1997, 2000, and early 2001. These standards include refrigerators and freezers, room air conditioners (A/C), fluorescent ballasts, clothes washers, water heaters, and central A/C and heat pumps. These six standards combined are expected to reduce electricity use by 107 billion kWh/yr and peak electric demand by 59,000 MW by 2020.[2] Consumers and businesses are projected to save over $31 billion net through to 2030 due to this new set of standards. These savings represent a significant portion of the overall savings from appliance and equipment standards to date and illustrate the importance of regularly updating the standard levels whenever new technology proves both feasible and beneficial.

Furthermore, from the point of view of government expenditures, standards are incredibly cost-effective. A 1995 analysis estimated that as of 1995, DOE had spent approximately $50 million cumulatively on the standards program, and standards enacted as of then would result in net benefits to consumers of $132 billion. These benefits are more than 2,500 times greater than program costs (Geller 1995). More recently, DOE staff have estimated that it costs DOE approximately $2.5 million for each rulemaking (Pollock 2001). As noted above, the six latest final rules are expected to result in net benefits of about $31 billion, which is more than 2,000 times greater than the approximately $15 million cost of these rulemakings.

1.4 Savings from Updated Federal Standards

In addition to the recent standard updates, several other existing standards are now ready for updating. Some of these updates are now underway (e.g., commercial A/C and residential furnaces and boilers) while others have yet to be scheduled (e.g., dishwashers and reflector lamps). Furthermore, some of the standards recently updated will be ready for another round of revisions later this decade because of opportunities for significant additional cost-effective savings beyond the new standards. Products that likely fall into this category are residential refrigerators, residential gas-fired water heaters, and residential central A/C and heat pumps. Table 1.4.1 summarizes additional updates to existing standards that DOE should act on in the next few years to harvest additional savings opportunities.

These updates to current standards will yield over 53 TWh of electricity savings and 0.7 quads of primary energy savings while generating net present value savings of approximately $19 billion for consumers and business owners. The cost-benefit ratio is 2.8 to 1, nearly as cost-effective as the standards already in place (3 to 1). However, the cost-effectiveness in Table 1.4.1 is calculated using today's incremental equipment costs and thus the economics should significantly improve for equipment costs will come down as standards move efficient products from niche-market to mass-market status (see Section 1.2).

[2] Most of the peak demand reduction result from the new central A/C and heat pump standard. DOE has proposed to roll back the standards issued in January from SEER 13 to SEER 12. This "roll back" proposal was published in late July 2001 but is already being challenged in the courts. In our calculations we use the originally published SEER 13 level.

Table 1.4.1 Savings from Future Updates to NAECA and EPAct Standards

Products	Effective Date	National Energy Savings in 2010		National Energy Savings in 2020		NPV for Purchases Thru 2020	Benefit-Cost Ratio
	(year)	(TWh)	(tril. Btu)	(TWh)	(tril. Btu)	($million)	
Comm'l packaged A/C and HP	2006	5.0	50.7	16.0	159	5,038	4.4
Refrigerators	2010	0.6	6.1	12.5	125	3,671	2.5
Central A/C	2012	0.0	0.0	10.2	101	1,548	1.5
Furnaces and boilers	2009	NA	12.8	NA	98	3,034	3.8
Central heat pumps	2012	0.0	0.0	8.3	83	2,931	4.7
Water heaters—gas	2010	NA	0.0	NA	59	1,138	3.8
Dishwashers	2008	0.7	10.5	3.4	52	992	2.1
R/BR reflector lamps	2008	3.0	30.0	3.0	30	895	2.8
Commercial boilers	2006	NA	3.7	NA	12	238	2.5
TOTAL		**9**	**114**	**53**	**719**	**19,486**	**2.8**

Source: ACEEE analysis
Note: See Appendix B.1 and B.2 for assumptions and methodology.

1.5 Need for a New Round of Standards

While the efficiency standards established to date have provided significant energy and economic savings, the United States is still experiencing overall growth in energy demand and an increasingly tight supply. Many other regions might become "the next California"—the Northwest, Northeast, Midwest, and South regions currently face tight supply/demand balances and might face electricity shortages in the next few years. Savings from new products that are now "ripe" for appliance and efficiency standards could reduce the need for additional power plants and ease electric load on already stressed transmission lines and transformers, significantly contributing to improved system reliability.

When NAECA and EPAct were established 10 years ago, Congress focused on the most common residential appliances and commercial equipment that had significant energy and economic savings potential. Since then, there have been quite a few technical and programmatic developments that have created a new batch of "low-hanging fruit." These developments include work on new standards by Canada and several states in the United States; development of ENERGY STAR specifications for many products; development/updates of key industrial standards (i.e., American Society of Heating, Refrigerating, and Air-Conditioning Engineers [ASHRAE] and NEMA); and additional research on the energy savings potential, usage, and cost of these products (these developments are discussed further in Sections 2 and 3).

The recently announced Bush/Cheney *National Energy Policy* devotes a half-page to the federal standards program and notes that these "standards will stimulate energy savings that benefit the consumer, and reduce fossil fuel consumption, thus reducing air emissions." The plan then recommends that the Secretary of Energy: (1) "support [the] appliance standards program for covered products, setting higher standards where technologically feasible and economically justified;" and (2) "expand the scope of the appliance standard program, setting standards for additional appliances where technologically feasible and economically justified." (National Energy Policy Development Group 2001) In the following sections we will focus on the second point and recommend federal or state standards for 13 products not covered by NAECA or EPAct.

2. POTENTIAL ENERGY SAVINGS FROM NEW EQUIPMENT STANDARDS

We recommend that state governments adopt and/or the federal standards program extended to cover 13 additional products. For federal standards, we recommend Congressional action over DOE action where possible since a DOE rulemaking takes at least 3 years and often far longer (DOE is still working on several rulemakings called for in the 1992 Energy Policy Act). For the majority of the standards in both categories, Congressional action is needed because under current laws, DOE is only authorized to extend the standards program to "consumer products" and many of the opportunities for new standards involve products used by businesses and not consumers.

In the paragraphs below, we briefly describe the products that should be covered under the standards program. We present these products in order of estimated energy savings in 2020, starting with products with the largest savings. For detailed discussions of the savings and economics, as well as sources for data and information, see Section 3. For definitions, test methods, and recommended standard language, see Appendix A.

2.1 New Equipment for Standards

Furnace, Air Conditioner, and Heat Pump Fans

The efficiency of residential furnaces and heat pumps is covered by current federal standards, but these standards do not include the energy used by the blower to circulate conditioned air around the home. The typical furnace fan uses 800–1,000 kWh/yr, but more efficient fans now on the market use less than 300 kWh, a savings of more than 60% (and additional energy is saved in homes that use the furnace fan to circulate air cooled by a central A/C). In mass production the more efficient fans cost on the order of $100 more than a conventional fan, resulting in a simple payback to the homeowner of less than 3 years. Additional technical work is needed to decide how best to set a fan power limit (i.e., these limits need to take into account the heating capacity and airflow of the system), so responsibility for setting the standard should be delegated to DOE or state agencies with sufficient technical staff or consultants.

Consumer Electronics (Standby Power)

Many types of electronic equipment used in the home continuously use small amounts of power, even when they are turned off. Examples include TVs, VCRs, microwave ovens, and many rechargeable products. Aggregated over the many hours in a year and the number of products in a typical home, this "standby" power use amounts to about 5% of electricity use in a typical home. More efficient power supplies and other technical improvements could reduce this standby power use by about 75% in the vast majority of cases, at a typical cost of only a few dollars per product. President Bush recently called these equipment "vampires" and announced his proposal to generally require government agencies to purchase products with standby energy use of 1 W or less. For some of these products, the ENERGY STAR program awards special labels to identify power-thrifty designs. We recommend that states and/or Congress adopt a standby power limit of 1 W for all of these products, but allow state agencies or DOE to set higher

standards where manufacturers can demonstrate that a 1 W limit is not technically feasible and economically justified.

Ceiling Fans

Large "Casablanca style" ceiling fans are used in many homes to circulate air around the room and help occupants feel more comfortable. However, most of these fans have inefficient motors and blade designs. A major manufacturer recently introduced a more optimized design that reduces fan energy use by 40%. The incremental cost of this efficient model relative to standard models with similar features is about $20, resulting in a simple payback of about 3.5 years. Additional cost-effective savings are available from upgrading the lights contained in most ceiling fans from incandescent to compact fluorescent bulbs. Just recently, the U.S. Environmental Protection Agency (EPA) worked with manufacturers and finalized specifications for ENERGY STAR ceiling fans. We recommend Congress and state energy offices consider minimum-efficiency standards based on the ENERGY STAR specification but wait 1–2 years to monitor the viability of the specification before setting minimum-efficiency levels.

Torchiere Lighting Fixtures

Torchieres are portable lighting fixtures that aim light upward and bounce it off the ceiling to provide indirect lighting. In recent years they have become ubiquitous in American homes and apartments due to their low costs and high versatility (lightweight, variable light output, and compact, sleek style that fits into most décors). However, these products can be major energy hogs (and safety hazards as well). The typical product consumes 300 watts (W) or more of power. Much more efficient torchieres based on high-output compact fluorescent designs are available and use less than 100 W to provide equivalent light output. The simple payback for these more efficient units is typically less than 2 years. CEC has developed minimum-efficiency standards for these products that cap energy use at 190 W and include other important technical details. These same standards should be adopted nationally.

Commercial Unit and Duct Heaters

Unit heaters are used in open commercial (and industrial) spaces to provide heating. The typical system has a seasonal efficiency of about 63%, whereas systems with power or induced-draft burners typically have seasonal efficiencies of about 82%. The more efficient systems reduce energy use by an average of 26% and have a simple payback of approximately 2 years. Due to the impact of federal standards, residential heating systems now predominantly use power or induced-draft burners and DOE has just adopted new regulations for commercial furnaces that require similar improvements. We recommend that Congress and states adopt requirements for unit heaters the same as those just adopted by DOE for commercial furnaces.

Distribution Transformers

Distribution transformers are used in many commercial and industrial buildings to reduce voltages from line voltages to voltages used to power building systems. These systems are typically purchased on the basis of first cost, leaving significant opportunities for cost-effective energy savings. The National Electrical Manufacturers Association has developed a recommended standard that reduces the energy losses associated with this equipment by an average of about 40%, with a payback period of about 3 years. Massachusetts and Minnesota have adopted the NEMA standard as a mandatory standard and California and New York are now in similar adoption processes. Other states should follow suit. DOE was instructed in the Energy Policy Act of 1992 to develop standards for these products but 9 years later this process is still dragging on. We recommend that Congress adopt the NEMA standard, thereby saving the time and expense of continuing the DOE rulemaking process.

Commercial Food Service Refrigerators and Freezers (including Beverage Merchandisers)

Federal standards currently cover residential refrigerators and freezers but do not cover the larger commercial units used in restaurants, hotels, hospitals, and other commercial applications. Research by the Arthur D. Little (ADL) Company found that the energy use of typical commercial refrigerators and freezers could be reduced by 45–55% using improvements with an average simple payback to the user of just over 2 years. CEC has developed minimum-efficiency standards for many of these products based on the energy use of the average product on the market today. These same standards should be adopted in other states and as national standards.

Refrigerated Beverage Vending Machines

Beverage vending machines are primarily purchased by beverage distributors and placed in a variety of locations at no cost to the property owner. However, the property owner does pay for the electricity to operate these machines. Since the purchaser does not pay operating costs, there is little incentive to purchase efficient machines and as a result most beverage vending machines are inefficient. A study by ADL for DOE estimated that the energy use of vending machines could be reduced by 44–51% using measures with an average simple payback of 2.4–3.2 years. However, there is insufficient information on the energy use of the full range of machines sold today, so further data collection is needed before standards can be set. CEC is now planning to collect this data and develop a standard. DOE should be directed to set new standards based on this data and its own technical and economic analyses. CEC is developing an interim standard that requires the use of T-8 lamps or a lighting source of greater efficacy, which will save 10–12% of the electricity consumption with a simple payback of 0.7 years. Other states could quickly move to adopt this lighting-only standard or wait for data to become available to adopt a more comprehensive standard.

Traffic Signals

Most traffic signals today use incandescent bulbs, but traffic signals that use light emitting diodes (LEDs) are now available that reduce energy use by about 90% and have additional maintenance and safety benefits. There is an ENERGY STAR specification for these products that

California is now adopting as a mandatory state standard. A similar standard should be adopted by other states and at the national level. Such a standard should apply to red and green lamps, since these account for the vast majority of traffic signal energy use and have the most favorable economics (typically simple paybacks of 1–4 years, depending on the application). As prices of yellow LEDs come down, a standard on yellow lamps may be appropriate in the future.

Exit Signs

Many exit signs use incandescent bulbs (40 W is typical) and, since they are continuously illuminated, typically cost around $30/yr to operate. New exit sign designs use LEDs and consume on the order of 3 W, reducing energy use by more than 90% relative to an incandescent sign. The simple payback time period is declining rapidly as LED manufacturing costs continue to drop and is currently less than 1 year. The ENERGY STAR program has established an energy and safety performance specification for the more efficient signs requiring maximum electricity consumption of less than 5 W/face. California is in the process of adopting this specification as a mandatory minimum performance standard. Other states should follow California, or a national standard should be adopted along these same lines.

Commercial Family-Sized Clothes Washers

NAECA does not cover commercial clothes washers that are identical to those in the residential sector but have a coin box or a different revenue-collecting device (e.g., credit card reader). These are frequently referred to as "coin-op" washing machines and are used in Laundromats, multi-family homes, and large institutions (e.g., military facilities, university dorms, and hospitals). Just like their residential counterparts, significant energy and economic savings potential exists. Energy use can be reduced by 50% and water use reduced by 35–50% with a simple payback of 1.5–4.5 years. ENERGY STAR now includes commercial clothes washers and California is currently developing a state standard at the same efficiency level. We recommend that states and the federal government adopt a standard along these lines. A major benefit of this standard would be water savings. On the basis of energy savings alone, these products are not the highest priority product.

Ice-Makers

Ice-makers are commonly used in hotels, motels, restaurants, and hospitals to produce ice in large quantities. These products use a substantial amount of energy in order to freeze water and then keep the ice cold. Products now on the market vary substantially in efficiency, with the most efficient products typically using about 30% less energy than the least efficient. Relative to the least efficient machines, the most efficient ones typically have a simple payback of 1 year or less. The Federal Energy Management Program (FEMP) has developed a specification that identifies the top performing units on the market today for each product category (features and size). This specification should be adopted by states and as a national standard. However, savings from this standard are not as large as savings from many of the other products discussed in this report, so standards for ice-makers are not the highest priority.

Large Packaged Air Conditioning Equipment

NAECA and EPAct only cover packaged A/C equipment under 20 tons of cooling capacity. Large packaged A/C equipment have low annual sales relative to smaller equipment, but due to their large size, packaged units over 20 tons account for over 20% of commercial cooling capacity. ASHRAE and the Consortium for Energy Efficiency (CEE) have set and updated voluntary efficiency levels for packaged A/C equipment including those over 20 tons. The CEE Tier 2 level would save an estimated 15% of the electricity consumption of current models with a payback of just over 3 years. We recommend that states and the federal government adopt this level as a mandatory standard, either through building codes or as an equipment standard. However, savings from this standard are modest, so this is not the highest priority.

2.2 Overall Savings Potential

Table 2.2.1 summarizes the overall energy savings potential and economics from minimum-efficiency standards for the above products. Table 2.2.2 shows the estimated peak load reduction and emission reductions from the proposed standards. For the methodology and sources we used to estimate these savings, see Appendix B.

Table 2.2.1 Estimated Energy Savings and Economics of Proposed New Standards

Products	Effective Date	National Energy Savings in 2010		National Energy Savings in 2020		NPV for Purchases Thru 2020	Benefit-Cost Ratio
	(year)	(TWh)	(tril. Btu)	(TWh)	(tril. Btu)	($million)	
Furnace, A/C, & heat pump fans	2008	12.2	124.7	61.1	609.2	28,300	7.8
Consumer electronics (standby power)	2005	25.5	259.9	32.4	323.1	16,128	5.7
Ceiling fans	2008	7.4	75.1	29.4	293.3	8,074	2.8
Torchiere lamps	2005	10.6	108.0	19.3	191.9	7,658	3.4
Commercial unit and duct heaters	2005	NA	53.1	NA	149.7	4,241	6.2
Dry type transformers	2005	1.9	19.7	5.4	54.1	2,796	5.8
Beverage vending machines	2008	1.2	12.1	4.0	40.0	1,198	4.5
Commercial refrigerators & freezers	2005	1.9	19.9	3.2	31.8	1,375	6.8
Traffic signals	2005	1.0	9.8	2.6	26.2	710	2.6
Exit signs	2005	0.8	8.5	2.3	23.3	1,179	7.5
Commercial clothes washers	2008	0.7	6.8	2.1	21.3	2,000	6.7
Beverage merchandisers	2008	0.6	6.1	2.0	20.2	621	5.1
Ice-makers	2005	1.1	10.9	1.7	16.5	564	3.0
Large packaged A/C equipment	2008	0.3	2.9	1.4	14.2	387	3.4
TOTAL		**65**	**717**	**167**	**1,815**	**75,231**	**5.0**

Note: See Appendix B.1 and B.2 for assumptions and methodology and Appendix B.3 for sources.

These new standards will save 167 TWh of electricity and over 1.8 quads of primary energy in the year 2020, while generating $75 billion in net savings for consumers and business owners for equipment purchased through 2020. The primary energy savings from new standards is well over one-third the savings from all existing federal standards including the most recent updates. The overall benefit-to-cost ratio is 5 to 1, far better than the 3 to 1 ratio for existing standards. Clearly, significant savings potential exists for these products at a small increase in first cost, resulting in large energy and economic savings over the life of the equipment.

These standards are also incredibly cost-effective from a government perspective, with net benefits probably on the order of 1,000 times greater than government expenditures. This can be

illustrated with the following rough calculations. For a typical state, developing and implementing the standards recommended here would require perhaps half a person-year of staff time to develop state standards, and perhaps a quarter person-year to implement them. Assuming $150,000/person-year (including salary and overhead), this works out to a 10-year cost (undiscounted) of roughly $412,500 (beyond 10 years, costs should be very low as the market will have transformed and little implementation support will be needed). As noted in Table 2.2.1, national net benefits from these standards would be approximately $75 billion, or an average of $1.5 billion/state (more for large states, less for small states). These benefits are more than 3,000 times greater than our estimate of direct costs to a state government, and even allowing for the very rough nature of these calculations, it is clear that these new standards will be highly cost-effective from a governmental perspective.

Table 2.2.2 Estimated Summer Peak Load and Pollutant Reductions from New Standards

Products	Summer Peak Load Reduction in 2010 (GW)	Summer Peak Load Reduction in 2020 (GW)	Carbon Reduction in 2020 (MMT)	NOx Reduction in 2020 (1000MT)	SOx Reduction in 2020 (1000MT)	PM10 Reduction in 2020 (1000MT)
Furnace, A/C, & heat pump fans	5.42	27.10	11.65	34.91	160.91	1.77
Consumer electronics (standby power)	3.44	4.38	6.18	18.52	85.36	0.94
Ceiling fans	2.36	9.42	5.61	16.81	77.48	0.85
Torchiere lamps	3.39	6.16	3.67	10.99	50.68	0.56
Commercial unit and duct heaters	-	-	2.21	6.26	0.04	0.51
Dry type transformers	0.36	1.00	1.04	3.10	14.30	0.16
Beverage vending machines	0.38	1.29	0.77	2.29	10.58	0.12
Commercial refrigerators & freezers	0.62	1.02	0.61	1.82	8.39	0.09
Traffic signals	0.13	0.35	0.50	1.50	6.91	0.08
Exit signs	0.11	0.32	0.45	1.34	6.16	0.07
Commercial clothes washers	0.21	0.69	0.41	1.22	5.63	0.06
Beverage merchandisers	0.19	0.65	0.39	1.16	5.32	0.06
Ice-makers	0.34	0.53	0.32	0.94	4.35	0.05
Large packaged A/C equipment	0.28	1.38	0.27	0.81	3.75	0.04
TOTAL	**17.2**	**54.3**	**34.1**	**101.7**	**439.9**	**5.3**

Note: See Appendix B.1 and B.2 for assumptions and methodology and B.3 for sources.

Another significant benefit from appliance standards is their impact on summer peak load. We estimate that the proposed standards would save a total of over 54 GW of power in the year 2020. This is roughly equal to the generating capacity of 180 average power plants (i.e., 300 MW). This could significantly contribute to improved electric system reliability by eliminating the need for additional power plants and reducing the load on already stressed transmission and distribution systems.

Emissions reductions from the reduced energy consumption would also be significant. In the year 2020, over 34 MMT of carbon could be reduced, which would not only improve air quality, but would also help the United States meet the global goal of reducing greenhouse gas emissions. The 34 MMT of carbon is equivalent to the annual carbon emissions from over 27 million “average” passenger cars (EPA 1997). These standards would also contribute to better air quality by reducing over 100,000 metric tons (MT) of smog-forming NOx, 440,000 MT of SOx (the main component of acid rain), and 5,300 tons of fine particulate matter.

2.3 Process and Status of Standard Establishment

Across equipment types, there are several key steps necessary to achieve energy and consumer utility bill savings from efficiency standards. In most cases, these steps will be as follows:

1. Develop standard test procedures for measuring energy use of equipment, where these methods are not already available;
2. Compile testing data established under standard test procedures, and develop a database of comparative energy use information (and cost data, if possible);
3. Finalize and promote voluntary initiatives (such as ENERGY STAR labeling or FEMP's "Federal Purchasing Reccommendations") to increase both demand and supply for more efficient products;
4. Where it is clear that there is significant energy savings potential with favorable economics and when voluntary efforts are not making progress, develop, enact, and regularly update mandatory minimum-efficiency standards at the state or federal levels; and
5. Where there is, or likely will be, a patchwork of state standards, enact federal standards that are preemptive, unless there are specific reasons that a state needs a tighter standard. Periodically update the federal standards.

Table 2.3.1 summarizes the status and various organizations involved in the energy efficiency of the 13 products we describe in this report.

Table 2.3.1 Current Status of New Products for Standards Development

	Test Method	Energy Use Database	Voluntary Programs	Mandatory Standards
Furnace, A/C, & HP fans	DOE, ARI	GAMA		
Ceiling fans	E-Star (developed by Hunter Fans)		E-Star	
Consumer electronics	E-Star	FSEC, LBNL, EPA	E-Star, Executive Order	
Torchiere lamps	UL (safety std)		E-Star	CEC (pending)
Unit and duct heaters	ASHRAE			
Distribution transformers	NEMA	EPA	E-Star, NEMA, CEE, FEMP	MA, MN; CA & NY (pending)
Food service refrigerators	ASHRAE, CSA	CEC	CSA, E-Star	Ontario, CEC (pending)
Beverage vending machines	ASHRAE, CSA	CEC (developing)	CSA	CEC (lighting only; pending)
Traffic lights	ITE, CalTrans		E-Star, CEE	CEC (pending)
Exit signs	NFPA, UL	LRC	E-Star	CEC (pending)
Commercial clothes washers	CFR, AHAM, E-Star	CEE	E-Star, CEE	CEC (pending)
Ice-makers	ARI	ARI	FEMP	Canada
Large packaged A/C	ARI	ARI (voluntary)	CEE	Many state bldg. codes

Note: E-Star = EPA/DOE ENERGY STAR program; ASHRAE = American Society of Heating, Refrigerating, and Air-Conditioning Engineers; UL = Underwriters Laboratories; GAMA = Gas Appliance Manufacturers' Association; CFR = Code of Federal Regulations; CSA = Canadian Standards Association; NFPA = National Fire Protection Association; AHAM = Association of Home Appliance Manufacturers; LRC=Lighting Research Center, Rensselaer Polytechnic Institute; ARI = Air-Conditioning and Refrigeration Institute; and FSEC = Florida Solar Energy Center.

For consumer electronics, food service refrigerators, ice-makers, exit signs, distribution transformers, large packaged air conditioners, and commercial clothes washers, these products have reached a point where they are "ripe" for action—state and/or federal standards should be

enacted. For traffic lights and torchiere lamps there is no database that compares the energy use of different products. However, energy use is highly dependent on the product's lighting technology, and products using the same technology usually fall within a narrow range of efficiency and cost (this is true for exit signs as well). Thus, these two products do not require a comprehensive database in order to set national and/or state standards and are also ready for action.

On the other hand, vending machines, furnace fans, unit and duct heaters, and ceiling fans are in the earlier stage of market transformation and need further research before a specific performance-based standard level can be set. This task could be delegated to DOE or standard associations (i.e., ASHRAE or CSA), or state energy offices could have research firms take on this task. However, for these equipment, prescriptive standards—such as the use of T-8 lamps for vending machines and power or induced-draft burners for unit heaters—can be set while equipment databases are developed and analyzed.

3. Detailed Discussion by Type of Equipment

The following section describes in detail the energy savings potential, economics, past and current efforts that can be a basis for a standard, and our proposed standard level for each of the 13 appliances and other types of equipment for which we recommend that standards be adopted.

3.1 Furnace, Air Conditioner, and Heat Pump Fan Blowers

Overview

Improving the motors and fan systems on residential furnaces, A/C, and heat pumps promises substantial, cost-effective efficiency gains. Furnaces are sold as systems that include both the furnace (burner, heat exchanger, and controls) and the air handler (motor and fan, often with an integral filter rack). When central air conditioning is also provided, the evaporator coil is field-installed in a locally fabricated plenum downstream from the furnace heat exchanger. For heat pump systems that lack a fossil fuel furnace, the motor, fan, and controls are part of the package that includes the indoor evaporator/condenser coil. Since the air-moving technology is the same for the two product classes, we refer generically to "air handlers."

DOE's Energy Information Administration (EIA) Residential Energy Consumption Survey (1999) estimated that 66.3 million residences have warm air furnaces or heat pumps. 5.67 million units were shipped in 2000 (Appliance Magazine 2001). Each of these devices has a centrifugal fan, usually directly connected to a fractional-horsepower alternating current (AC) motor. Systems generally use low-cost, multi-speed motors. High-end furnaces and heat pumps may offer better motors that have higher efficiency and other features such as modulating capacity controlled by the thermostat.

Furnace manufacturers disclose fan energy (kilowatt-hour per year) as required by NAECA but the value is not used in computing AFUE (annual fuel utilization efficiency). Manufacturers' data show enormous variations in energy use by furnace fans under standard test conditions, from less than 200 kWh/yr for a 75,000 British thermal unit per hour (Btu/hr) furnace to over

1,300 kWh/yr for a residential unit smaller than 112,000 Btu/hr (ACEEE 2001).[3] There is substantial opportunity for improving fan energy efficiency in residential air handler motors and fans.

Low fan energy consumption can be attained by a more efficient fan motor and fan, better airflow, or downsizing the fan. The last is of particular interest. Today, at least some manufacturers offer different regional models. For example, an efficient 75,000 Btu/hr furnace sold in the North would have a fan sized for that heating load and a 3-ton air conditioner's airflow. With a different model number, the otherwise identical unit sold in the South would be equipped with a fan and motor sized to move air for a 5-ton air conditioner since cooling loads are greater in the South for a similarly sized house. If regulations only limited kilowatt-hour per year by furnace size, a possible market response would be to discontinue the "southern" models (which consume more fan power to meet higher air conditioning loads) and thus force installers to buy oversized furnaces to get large enough fans.

Instead, we propose a standard based on air-moving efficiency. A measure such as watts per cubic feet of air per minute (cfm) at standard static pressure (duct resistance metric) would encourage adoption of better fan designs and better motors, as discussed below.

Technology Description

The air handler of a residential central furnace or heat pump comprises a motor on whose shaft a centrifugal fan impeller is mounted. The assembly with the fan shroud is mounted in a rectangular box at the base of an up-flow furnace or the entry end of a horizontal unit. This plenum box may have an integral air filter rack. The output of the fan goes directly to the air side of the (furnace) heat exchanger, and then through the indoor coil of the air conditioner or heat pump. A field-designed supply plenum houses this "A-coil." In general, the fan box is too small for optimum airflow and lacks any shrouds or other air guides. Residential duct work typically does not include turning vanes or other airflow aids and consequently has relatively high friction losses (static pressure).

There are potentially at least three different routes to improved air handler efficiency. Each promises savings and non-economic benefits, but all face some barriers.

Better fan motors. The conventional furnace fan is a multi-speed (permanent split capacitor) inductive motor (typically 4 speed). The installer selects appropriate speeds independently for heating and air conditioning, to match fan power to the system's static pressure and airflow requirements. There is substantial field evidence that a large fraction of installations have airflow, in cubic feet of air per minute per ton of air conditioning, that is well outside the manufacturers' design guidance for efficiency and humidity control. High-end air handlers frequently incorporate *electronically commutated permanent magnet motors* (ECPMs). These

[3] ACEEE (2001) gives efficiency ratings (AFUE) and kilowatt-hours per year by furnace output. For 60–76 kBtuh units, the best uses 103 kWh/yr; the worst 795. For 111–130 kBtuh furnaces, the comparable values are 252 and 1,493 kWh/yr. The relative consistency of these ratios suggests that the furnace fans are the dominant contributor, rather than ignitors or controls.

units have many advantages for heating and air conditioning applications, including the following:

- Much higher efficiency, up to about 80% full load, with little fall-off at partial loads.
- Outstanding control. Some models on the market today automatically adapt to maintain airflow to factory specifications, across a wide range of system static pressures. Others, less expensive, provide constant torque.
- A "soft-start" capability, meaning that they can be slowly (and quietly) brought up to operating speed. This could, for example, be matched to the increasing cooling capacity of the evaporator as the air conditioner starts up or to allow varying fan speed to control humidity in the space.

These motors are more expensive than conventional inductive motors today. In manufacturer quantities, a high-efficiency 0.5 horsepower (hp) multi-tap inductive motor costs about $25 and its ECPM counterpart about $105–115, a very large premium. With greater manufacturing volume and more competitors, we expect the price to fall to $50–70 during this decade, but it may not disappear. ECPM motors are more complicated and built to high precision. This represents a long-term (mature technology) incremental cost of $35–60, which would appear as a consumer price increase of $70–120.

Better fans. Residential heating, ventilating, and air conditioning (HVAC) equipment uses centrifugal fans with large numbers of thin, forward-curved, impeller blades. They are compact, inexpensive, and easily manufactured, and easily meet static pressure requirements. With the advent of ECPMs, we expect manufacturers to consider using impellers with smaller numbers of deeper, backward-inclined blades. These may offer somewhat better efficiency and less noise. However, they are bigger, which is a problem in some installations, and they will cost more: To achieve better performance, these fans require tighter tolerances, particularly between the air inlet and the fan cage. In addition, the pressure produced drops off more quickly with decreasing speed than for forward-inclined blades. The exquisite controllability of the ECPM is probably required to match these systems to residential systems with their varied external static pressure (flow resistance in the ducts).

Conventional fan designs have relatively low peak efficiency, about 60% (shaft to air). As importantly, most designs do not maintain that efficiency across a very large flow ratio (varying cubic feet of air per minute). They are typically low-cost, low-precision, sheet metal devices. We are not aware of new designs with as much potential for improvement in these characteristics as ECPM motors offer and do not expect that standards will be set that require substantial changes in fans.

Better matching of fans to duct systems. Manufacturers feel pressure from builders and dealers to make designs as compact as possible. Common residential duct connections, such as smaller distribution ducts butted into supply ducts, have disproportionally large frictional losses. Similarly, the lack of attention to the aerodynamics of the air handler and its (field) transitions on both the inlet and outlet side doom current systems to lower efficiency and more noise than should be attainable. However, changes all appear to require more space, as well as additional costs. We see little opportunity for standards to have an impact in this area, although there may be opportunities for premium products and installations.

Energy Savings Potential

Without detailed knowledge of ECPM motor shipments, it is difficult to precisely estimate savings potential, but an "order-of-magnitude" estimate can be made (Table 3.1.1). For this, we begin with the following data:

1. The average furnace or heat pump system's multi-speed permanent split-capacitor (PSC) fan motor consumes 900 kWh/yr on the DOE AFUE test, and a good ECPM motor, with an efficient fan, will use 250 kWh/yr.[4]
2. Annual shipments of devices with air handler fans are about 6.9 million units (Appliance Magazine 2001). If we assume that ECPM motors have a 10% market share today (which is probably too large), then the net shipments of PSC-equipped units are 6.2 million units.

Table 3.1.1 outlines the air handler fan and motor savings available.

Table 3.1.1 Air Handler Fan and Motor Savings Estimate

Per unit annual savings from ECPM motor, heating cycle	650 kWh
Per unit annual savings from ECPM motor including reduced A/C demand, cooling cycle	254 kWh
Per unit annual savings from ECPM motor, total	904 kWh
Annual sales with PSC motors, furnaces, central A/C, + heat pumps	6.2 million
Total U.S. electricity savings per annual sales	5.6 TWh

From the data above and the table above, we can draw some conclusions.

- A single year's shipments of furnaces, central A/C, and heat pumps with ECPMs saves about 4.1 TWh/yr, in the heating mode, each year the units operate. To displace the electricity saved by the more efficient fans, the heating electricity would require approximately 126 million therms of gas. At $0.60/therm, the gas is worth $75 million. At $0.08/kWh, the avoided electricity is worth $328 million.
- Cooling mode savings are about 1.6 TWh/yr for the ECPM and the reduced compressor load (since less heat is dissipated by the motor) per annual sales.
- As important, the cooling mode reduces peak demand by almost 0.5 kW (441 W). This means that a full year's production of 6.2 million units (exclusive of those already shipped with ECPMs) would reduce demand by about 2.3 GW.[5]

Economics

Table 3.1.2 outlines the approximate economic case.

[4] The most energy-efficient 110–130 kBtuh furnaces, the largest size listed in ACEEE (2001), use 252 kWh. The best 60–76 kBtuh units use 103 kWh.
[5] Using a 0.85 diversity factor for A/C on the peak demand day.

Table 3.1.2 Simple Payback Analysis

Per unit annual electricity savings, heating mode	650 kWh
Per unit annual electricity savings, cooling mode	254 kWh
Annual per unit electricity savings, total	904 kWh
Average residential electricity price	$0.08 $/kWh
Per unit annual consumer bill savings	$72.32
Highest estimate of incremental price, if a standard	$120
Simple payback period, cooling and heating	1.7 years

We expect mass-produced ECPMs with good fans to add no more than $100 to the consumer price of a unit.[6] Assuming that the average consumer pays $0.08/kWh for electricity, without any time-of-day differentials, the payback for the more efficient fan motor is less than 2 years, based on heating and cooling season savings.

Past and Current Efforts

DOE has published a framework document for its rulemaking on new standards for residential furnaces and boilers (DOE 2001a). A workshop was held July 17, 2001, to begin exploring issues that include furnace fans. Furnace fans are not covered in the current set of proposed California efficiency standards.

Discussion

At present, the cost of ECPM motors is higher than that of standard, multi-speed fan motors. However, we know of few opportunities for saving as many kilowatt-hours per year: air handlers are used up to several thousand hours per year, they use significant energy, and there is enormous potential savings from the adoption of more efficient motors and fans. In addition, there are other motor technologies that may compete with ECPM motors, offering multiple competitive paths to improved performance and reduced consumer costs.

There are significant reasons in addition to simple efficiency to require efficient, adaptive, variable speed motor systems as a standard. These include:

1. *Adaptability:* The ECPM and its controls can maintain airflow across a range of duct static pressures encountered in residential systems. This is required for both system efficiency and effective humidity control, so it is a win-win situation.
2. *Noise:* The soft-start feature avoids annoying "ramp-up" sounds propagated through the air handler with each equipment on-off cycle.
3. *Controllability:* The ability to operate in a "closed-loop" control mode in which airflow and/or pressure differentials are monitored may allow the use of alternative fan designs (such as backward-leaning blades) that may improve noise and efficiency further.

The important issue is establishing an appropriate metric for a standard. As a start, we suggest watts per cubic feet of air per minute at a specified static pressure, i.e., the power required to

[6] This is two times our estimate for the OEM (manufacturer) incremental price for the mature product, reflecting mark-ups in the manufacturing, distribution, and installation chain.

move a standard cubic foot of air per minute *through the furnace or air handler.*[7] This is capacity-neutral. In contrast, a limitation on kilowatt-hours per year would make it twice as difficult to provide an air handler for a 100,000 Btu/hr furnace as for a 50,000 Btu/hr unit. This would affect the ability of manufacturers to size air handlers in furnaces for different regional air conditioning needs.

Future Steps and Proposed Standards

We propose that DOE establish a "wire-to-air" standard. As a starting point, we recommend a "strawman" of 0.2 W/cfm. The standard test procedure assumes 0.356 W/cfm.[8] Given the demand reductions published by manufacturers (e.g., Lennox brochure [34L36] G32V-8/98)—32% (cooling) to 70% or more (heating and ventilation)—this seems to be within the potential range of ECPM-based systems. As indicated by these data, "wire-to-air" ratings at two points, such as cooling and low-speed heating, are required for meaningful standards. The values may turn out to be different.

The reason for a "wire-to-air" standard is that the same furnace may be sold in different forms for "northern" and "southern" applications. As an example, consider an air handler with a 3-ton coil requiring 400 cfm/ton, or 1,200 cfm. This would correspond to a "northern" model 75,000 Btu/hr furnace. This situation, at 0.2 W/cfm, would require 240 W. For the "southern" model with 75,000 Btu/hr heating capability, the fan size would be upped to 2,000 cfm (5 tons x 400 cfm/ton) to meet the A/C load. At the same criterion, this would need 400 W.

In addition to varying air conditioning loads, the standard should require certification at static pressures appropriate for the systems in which these air handlers are installed. That is likely to be at least twice the static pressure required in today's tests, which are widely considered to underestimate actual duct systems enough to impact performance.

3.2 Consumer Electronics (Standby Power)

Overview

Major consumer electronic products such as TVs, VCRs, set-top boxes, and telephones in U.S. homes consumed 75 TWh and accounted for nearly 7% of U.S. residential electricity consumption in 1999 (Rosen, Meier, and Zandelin 2000). The electricity consumption of these consumer devices is expected to grow substantially as products with new or advanced functionality are introduced to the market. Many of these consumer electronics found in homes and businesses draw energy not only when they are in use, but also when they are off or in

[7] It is important that airflow be measured across the furnace (or heat pump) outlet so it includes the losses through the furnace heat exchanger. Ideally, we would also include the A/C evaporator coil, but this is out of the control of the furnace or A/C manufacturer.

[8] ARI (1994), Section 5 (Testing and Rating Requirements) assumes 365 watts/1,000 cfm, or 0.365 watts/cfm. This would be based on the performance of conventional multi-speed motors. Given 4 to 1 or better annual energy use differences between furnaces with ECPMs and standard motors, a downward adjustment (higher-efficiency standard) is warranted. On the other hand, the ECPM motor achieves most of its efficiency improvement at part load (variable speed) so a full 4 to 1 change is not feasible. The value 0.11 watts/cfm is chosen as the basis for discussion with manufacturers and agency experts.

standby mode. This phenomenon, commonly described as "leaking electricity" or "phantom load,"[9] is the energy consumption of equipment when they are not performing their principal function. Standby electricity for U.S. homes averages approximately 50 W/yr and is responsible for an estimated 40–50 TWh/yr of electricity—amounting to 4–5% of total residential electricity use (Rainer, Greenberg, and Meier 1996). Assuming an average residential electricity rate of 8 cents/kWh, consumers are "wasting" $3.6 billion/yr.

Since the late 1990s, various initiatives have been taken to reduce the standby consumption of these products, including EPA and DOE's ENERGY STAR program and Lawrence Berkeley National Laboratory's (LBNL) global 1 W proposal (explained later). It is estimated that if all appliances were replaced by units meeting the 1 W standby power target, aggregate standby losses could be reduced about 75%, saving consumers in the United States over $2 billion/yr (Webber 1998). Several innovative manufacturers already sell many products including TVs and audio equipment that meet or come close to meeting the 1 W target without any increase in first cost or sacrifice in services (Meier, Huber, and Rosen 1998).

In this section we will describe the national impacts of reducing standby power consumption and propose a minimum-efficiency standard that states or the federal government can adopt.

Technology Description

Home electronic equipment that consume standby electricity falls into three major categories: video, audio, and communication. These devices consume an estimated 75 TWh annually (Sanchez et al. 1998). Video equipment such as TVs, VCRs, cable boxes, and satellite earth stations account for the largest share of residential standby power consumption, approximately 35%, while audio equipment accounts for 25% and communication devices (answering machines, cordless phones, and fax machines) are responsible for an additional 10%. Standby electricity is consumed when these equipment support features such as instant-on, remote control, channel memory, and LED clock displays. In addition, DC transformers that power answering machines, alarm systems, cordless phones, and rechargeable tools all consume standby electricity. These square, black "wall pack" boxes each draw 2–6 W of electricity as long as they are plugged in, even when the appliance is fully charged or turned off.

Table 3.2.1 shows a list of the 10 major appliances with standby power consumption, measured by the Florida Solar Energy Center (FSEC), EPA, and LBNL. They account for about 70 % of all standby power consumption in the residential sector.

Televisions and VCRs are the largest consumers of standby power. The range for the standby power of TVs is from 0.5 to 12.3 W with an average of 4.0 W. For VCRs, standby power ranges from 2.0 to 12.8 W with an average of 5.6 W. However, TVs and VCRs' contribution is expected to fall rapidly as new, efficient machines (with the help of the ENERGY STAR program) will gradually replace existing units, reducing the leakage rates for new TVs and VCRs.

[9] President Bush called these consumer electronics with significant standby power consumption "vampires" and on July 31, 2001 signed an Executive Order instructing federal agencies to generally purchase products with standby energy use of 1 W or less (The White House 2001).

Table 3.2.1 Top Ten Appliances with Standby Power Consumption

End-Use Name	Millions of Units	Average Standby Power (W)	Total Standby Loss (TWh/year)
TV sets	186	4.0	5.4
VCRs	120	5.6	4.9
Compact audios	53	10.6	4.7
Cable boxes	58	11.6	3.7
Rack audios	55	7.0	3.2
Microwave ovens	78	3.1	2.1
Battery chargers	98	2.4	2.1
Answering machines	66	3.3	1.9
Clock radios	105	2.0	1.8
Cordless phones	61	2.8	1.5

Source: Meier and Huber 2000

Compact audio equipment have surprisingly high standby consumption. Nationally, they consume about 4.7 TWh/yr in standby mode, making them the third biggest “leaker” in the United States. There is a wide range in the standby mode among compact audio units, from 2.1 W up to 28.6 W even though the features are essentially the same, suggesting that modest design improvements could greatly reduce standby electricity.

The fourth largest consumer of standby power is cable boxes, with 3.7 TWh/yr. Currently, most of them are cable television boxes but in the near future there will be more multi-media boxes and digital music boxes, which consume even more standby power due to the increased number of functions they support when ostensibly “off.” LBNL metered 7 different units, with a range of standby power from 4.8 to 18.0 W and an average of 11.6 W (Ross and Meier 2000).

The important thing is that the rankings presented in Table 3.4.1 are undergoing rapid change as the standby use of some appliances are cut and new appliances suddenly appear. For example, satellite receiver boxes are becoming very popular in the United States, and standby losses for these units range from 11.3 to 18.4 W. They are expected to become in the near future one of the largest consumers of standby electricity. For both TV cable and satellite receiver boxes, there is almost no difference in power consumption between the on and off modes (when set by the remote control). Switching off these appliances appears to do nothing more than turn off the digital display and the "power" light; all of the internal circuitry remains energized (Ross and Meier 2000).

With the recent growth in mobile communication, battery chargers for cellular telephones will also have significant standby consumption in the near future. Rechargeable lawn mowers are being encouraged because they emit less air pollution than gasoline units. Measurements suggest that the charging unit waste up to 20 W even when the battery is fully charged (LBNL 2001). Other appliances such as home digital satellite systems are also expected to become more important sources of standby power consumption.

Most sensors, displays, and memories need much less than 1 W. Unfortunately, the most common power supplies are inefficient and consume many times more power. LBNL reports that by limiting the standby power of these electronics to 1 W or less, losses can be reduced by nearly

70% (Ross and Meier 2000). One or more of the following technologies could be employed to reduce standby power by consumer electronics:

- Improve the efficiency of the low-voltage transformer;
- Move the power switch to the high-voltage side;
- Energize only the components needed for the standby services; and
- Install "smart" recharge circuit in rechargeable appliances.

The use of efficient power supplies is one of the simplest and most effective ways to improve the energy efficiency of consumer electronics. Several innovative companies have developed more efficient low-voltage transformers. These switches cost only a little more than the popular linear power supplies and are expected to be competitive in the near future in almost all situations (Meier 2001). Products that do not have standby functionality could be designed to draw 0 W by properly implementing a hard-switch (a switch at the high-voltage side). The advantage is that the appliance is "off" but the disadvantage is that it can't perform any services. Finally, smarter recharge circuits could greatly reduce battery overcharging and switch off or reduce power after recharge is complete. Some circuits performing these tasks already exist and others have been proposed.

Together, these technologies could reduce leaking electricity by over 70% with little increase in first cost and significant life-cycle cost savings to consumers. Some technical challenges still exist such as radio interference from switching power supplies, but none of these challenges appear insurmountable. There are also products that require further research to reduce standby consumption, such as satellite system set-top boxes.

Energy Savings Potential and Economics

Table 3.2.2 represents a sample calculation of the energy savings potential, using the average per unit standby power explained above, and specifications of the ENERGY STAR programs.

The incremental cost of lowering standby power is heavily dependent on the type of equipment and which functions it must perform during standby conditions. Unfortunately, a comprehensive cost data set is not available, but according to some manufacturers, the cost is declining rapidly (Meier 2001). For example, Power Integration's innovative switches that can reduce energy leakage by up to 90% compared to conventional systems cost $0.75–0.81 in 1998 for ten-thousand-piece quantities and now costs $0.64–0.67. The switches are even less expensive for larger bulk orders, which are common when large electronics manufacturers purchase power supply components (Selleck 2001). The company claims that these switches have a payback to consumers of less than 1 year, saving $1–4/unit annually. A typical household has 4–11 wall-packs plugged in continuously, so this can save them $4–44 annually with a minimum increase in first cost.

Table 3.2.2 Energy and Consumer Bill Savings for the Top Ten Standby Power Consumers

End-Use	Number of Units (millions)	Per Unit Average Standby Power (watts)	Reduced per Unit Standby Power (watts)	Per Unit Annual Electricity Savings (kWh)	Per Unit Annual Electricity Bill Savings ($)	U.S. Annual Electricity Savings (TWh)	U.S. Consumer Bill Savings ($million)
TVs	186	4.0	1.0	21.8	1.7	4.1	324
VCRs	120	5.6	2.0	26.3	2.1	3.2	252
Compact audios	53	10.6	2.0	71.9	5.8	3.8	305
Cable boxes	58	11.6	3.0	47.3	3.8	2.7	219
Rack audios	55	7.0	2.0	41.6	3.3	2.3	183
Microwave ovens	78	3.1	0.5	22.6	1.8	1.8	141
Battery chargers	98	2.4	0.5	17.0	1.4	1.7	133
Answering machines	66	3.3	0.5	24.4	2.0	1.6	129
Clock radios	105	2.0	0.5	12.9	1.0	1.4	108
Cordless phones	61	2.8	0.5	20.2	1.6	1.2	99
TOTAL or AVERAGE	**880**	**5.2**	**1.3**	**30.6**	**2.4**	**23.7**	**1,893**

Sources: EPA/DOE 2001a; LBNL 2001

Note: For the reduced per unit standby power we use the ENERGY STAR proposals for Phase I as of June 2001, except microwave ovens and clock radios where we use ACEEE estimates.

Past and Current Efforts

In the United States, DOE and EPA established its ENERGY STAR home electronics program, setting a set of criteria for maximum wattage draw during standby mode for TVs, VCRs, combination units, audio equipment, and set-top boxes in order for manufacturers to use the ENERGY STAR logo to differentiate the efficiency products from others. EPA is also developing a program for telephony products. A draft of the specifications has been released to manufacturers for their review. Table 3.2.3 shows the current ENERGY STAR criteria and current proposals to tighten the criteria as demand for more efficient components increases.

Table 3.2.3 Current and Proposed Future ENERGY STAR Criteria

Category	Current Criteria	Proposed Criteria I		Proposed Criteria II	
	watts	watts	effective date	watts	effective date
TVs	3	1	TBD	1	January 1, 2003
VCRs	4	2	TBD	1	January 1, 2003
Combination units	6	3	TBD	1	January 1, 2003
Audio	2	1	January 1, 2003		
DVD	3	1	January 1, 2003		
Set-top boxes	3–20	7	January 1, 2004		
Telephony	NA	0.5	TBD		

Source: EPA/DOE 2001a

Note: TBD = to be determined.

Worldwide, LBNL presented a global 1 W proposal that would limit the standby losses of appliances to 1 W as one of the strategies to curb global greenhouse gas emissions (Meier, Huber, and Rosen 1998). A program that reduces all standby power consumption in residential

appliances to 1 W/unit has the potential to reduce U.S. standby consumption to 22 TWh, saving roughly $1–2 billion annually.

Future Steps and Proposed Standard

Appliance efficiency standards should be adopted by states or the federal government to limit the standby power consumption of all consumer electronics and other household appliances. Standby power is the power consumed by an appliance or equipment when switched off or not performing its primary function.

We propose several options for states and Congress, which are summarized in the table below. First, states should immediately adopt the current ENERGY STAR criteria (shown as Option 1) as a mandatory minimum standard for standby power consumption of TVs, VCRs, combination units, audio equipment, and set-top boxes. In addition, for telephony products that use an external power supply, standby power should not be more than 1 W. For state standards that might take effect in 2004 or later, we recommend that ENERGY STAR's Tier 2 levels be adopted. For a national standard, which will probably take several years to phase in, we recommend a simple standard– "1 W standby power"—be adopted, but DOE should be allowed to set higher standards where 1 W is not technically feasible or economically justified. This "1 W" standard is currently proposed in several Congressional bills.

Table 3.2.4 Proposed Standards

Category	Option 1 (E-Star Tier I) watts	Option 2 (E-Star Tier II) watts	Option 3 watts
TV & video			
TV	3	1	1
VCR	4	2	1
TV/VCR Combo	6	3	1
DVD	3	1	1
Video game	3	1	1
Set-top boxes[a]			
Category 1	3	3	1
Category 2	15 (+5)	7 (+5)	Exception?
Category 3	20 (+5)	7 (+5)	Exception?
Audio	2	1	1
Telephony	1	0.5	1 (or 0.5)
Wall packs	1	0.5	1 (or 0.5)
Microwave	1	0.5	1 (or 0.5)

[a] "ENERGY STAR Program Requirements for Set-Top Boxes" groups various types of set-top boxes into three categories. Category 2 and 3 add 5 W to the minimum standby power for each additional LNB (low noise block down converter). The categories are:

1) analog cable TV, digital TV converter, internet access device, video game console, and videophone;
2) digital cable TV, satellite TV, wireless TV, and personal video recorder; and
3) multifunction device (a physically integrated device that has the core function of a Category 2 set-top box plus one or more additional functionalities.

3.3 Ceiling Fans

Overview

Ceiling fans have become ubiquitous appliances in U.S. houses. Approximately 15 million/yr are sold (EPA/DOE 2001c). There are an estimated 153 million ceiling fans in the United States, operating as fans an average of 6.3 hr/day and used as lights 3.3 hrs/day. Use of ceiling fans varies regionally, being more common in hotter climates. In such climates, the average home may have 5 or more ceiling fans. From these data, ceiling fans as fixtures use more energy for lighting than for moving air (Calwell and Horowitz 2001).

Ceiling fans were introduced to allow moving air to provide a cooling effect for people, thus allowing comfort at higher air temperatures. In theory this would reduce air conditioning energy use. Savings from higher set-points have not been well documented (Parker et al. 1999).

According to an industry meeting to develop a standard for an ENERGY STAR program, "…the average selling price of ceiling fans is roughly $60–65. There is, however, a large sales volume at price points as low as $20, as well as smaller but significant sales of products priced at the upper end, above $100. The three highest volume retailers for ceiling fans are Home Depot, Lowes, and Walmart. The private label market was stated to be as great as 75% of all sales. It was also noted that many new homes being sold have 3 or 4 installed ceiling fans and that the typical home in Florida has 5 ceiling fans" (EPA/DOE 2001b).

Technology Description

In this discussion, the term "ceiling fan" signifies devices that are suspended from ceilings in residential settings, are less than 80" in diameter, and rotate at relatively low velocity. The term includes any lighting fixture sold with or designed to be installed with these fans.

There are potentially at least four different routes to improved ceiling fan efficiency. These are lighting performance, blade design, motor design, and better controls. For this report, we focus on the first three. Although the voluntary EPA/DOE ENERGY STAR program includes prescriptive control specifications, we do not now suggest that first round standards include controls.

Illumination standards. Ceiling fans often replace existing ceiling lighting fixtures. In these cases, the owner generally wants to preserve the lighting amenity. Even when the ceiling fan is installed as a retrofit requiring new wiring, or in new construction, the incremental cost of including lighting with the fan package is moderate. For this reason, a large fraction of ceiling fans are sold with lights, or are designed so a coordinated lighting fixture, sold separately, is available. In this case, the fan and light fixture are designed (in their wiring and screw connections) to be installed together.

As noted above, ceiling fan lighting is likely to use more energy than the fan itself.[10] For this reason, the new *"Gossamer Wind"* ceiling fans developed at the Florida Solar Energy Center (Parker et al. 1999) include a dimmable 30 W compact fluorescent lamp with a remote control. More importantly from a standards perspective, the ENERGY STAR specification includes an illumination standard, as quoted below.

> **Initially (Tier 1, to take effect on January 1, 2002)**
>
> Qualifying fans sold with integral or attachable light kits must meet one of the following requirements:
>
> Pin-based approach—The ceiling fan lighting system shall meet the requirements of the ENERGY STAR specification for residential light fixtures; or
> Screw-based approach—The number of ENERGY STAR-qualified screw-based bulbs needed to occupy each standard Edison-based socket shall be included within the fan packaging.
>
> Qualifying fans sold without integral or attachable light kits need not meet any additional lighting requirements.
>
> **Tier Two (to take effect on October 1, 2003)**
>
> Qualifying fans sold with integral or attachable light kits must meet the requirements of the ENERGY STAR specification for residential light fixtures.
>
> Qualifying fans sold without integral or attachable light kits must provide information on product packaging or with product instructions regarding ENERGY STAR-compliant light kits that may be used with that fan. (EPA/DOE 2001c)

There are two inferences from this discussion: First, if a ceiling fan standard is at all appropriate, then a standard that includes lighting efficiency is also appropriate since the lights use more energy than the fans. Second, by the time a standard can be adopted and take effect, there will be extensive market experience from the ENERGY STAR program.

Better fan motors and better fan blades. Conventional ceiling fans have two major problems: poor, low-cost motors and flat blades that are aerodynamically inefficient. The motors are special purpose, with the rotor outside the stator. This is required to allow a lamp fixture and the controls to be hung below the fan and remain stationary. For economic reasons, the typical fan motor uses a shaded pole design, the least efficient commonly available.

In addition, in contrast with almost all other turbine and propeller designs commonly in use (from "box" fans to aircraft propellers), ceiling fans use flat blades that have no airfoil characteristics. These successfully create turbulence beating the air, but relatively little air movement.

[10] Calwell and Horowitz (2001) suggest that the ceiling fan motors average perhaps 200 kWh/yr, while the lights use about 320 kWh/yr.

Together, these effects give rise to fans that may convert as little as 1–2% of the electrical energy reaching the fan motor to beneficial air movement (at low speeds; they may be better than 10% at higher speeds) (Calwell and Horowitz 2001). The remaining energy, comparable to that used by a light bulb, is dissipated as heat to be removed by the air conditioning system—if there is one.

Controls. Typical ceiling fans with lights, designed for inexpensive retrofits, have four controls:

- A wall switch to control the electricity to the ceiling fixture.
- A pull-chain switch to control fan status (off, on-high, on-low, etc.).
- A pull-chain switch to control the light (off/on).
- A slide switch to control fan direction.

For new installations, it is typical to have separate wall switches for the light and the fan, but this requires additional wiring for retrofits, at high cost.

These controls have the potential for saving energy by allowing users to turn off the fixture when the room is not in use: fans cool people by promoting evaporation; they don't cool furniture. Similarly, unoccupied rooms rarely require light. Thus, some models offer controls that sense occupancy and turn off the fixture when the room is unoccupied (after a variable delay set by the user). Some fan sets also come with hand-held remote controls for the fan and lighting and remote controls with thermostats. We do not recommend that a first-round standard include requirements for controls since the market has not had time to coalesce around preferred approaches.

Energy Savings Potential

Without changing the fan motor, Parker and others reduced ceiling fan energy use by 40% in the design for the recently commercialized *Gossamer Wind* ceiling fan (Parker et al. 1999). Table 3.3.1 compares the efficiency of the commercial version of this fan with a poor efficiency product and an ENERGY STAR commercial product.[11]

Table 3.3.1 Cubic Feet of Air per Minute per Watt at High, Medium, and Low Speeds Relative to ENERGY STAR Requirement

Fan Speed	Fan Model		
	Best	Poor	ENERGY STAR
High	105	47	75
Medium	127	90	110
Low	159	120	155

Note: Higher numbers reflect better energy efficiency. ENERGY STAR minimum airflow requirements are 5,000 cfm (high), 2,500 (medium), and 1,250 (low speed).

For a sample of 26 fans tested by one manufacturer, the modal high-speed fan efficiency was between 70 and 75 cfm/W, but 11 had lower values. Fifteen already would pass or are within 7% of the EPA draft efficiency level, but six of those models have lower airflow than ENERGY STAR

[11] Data from Mehta 2001. Comparisons based on "solid state method" for ceiling fan performance testing.

will require at high speed. Thus, the ENERGY STAR level as a standard would require some redesign for a significant fraction of the models recently tested. However, the data show that a performance-based standard could lead to substantial increases in efficiency without prescribing specific technologies since either or both the fan motor and the blade design could be changed by the manufacturer to meet requirements.

If lighting is also improved (by substituting fluorescent for incandescent sources), ACEEE estimates savings of 7.4 TWh in 2010 and 29.4 TWh in 2020 from the adoption of a standard that includes fan savings and lighting savings comparable to the *Gossamer Wind* (See Section 2 and Appendix B).

Economics

The commercial version of the *Gossamer Wind* series of fans carries an estimated price premium of $20 (E Source 2001). To this cost we add an additional $20 to account for the cost premium of high-efficiency lighting (e.g., compact fluorescent lamps). Assume the fan plus lighting system saves 180 kWh/yr and that electricity is valued at $0.08/kWh. Then the payback is 2.8 years, which will be very attractive.

Current Efforts towards Standards

We know of no efforts toward a standard per se, but there are two important developments that are closely related. First, the industry is accepting a performance standard offered by Hunter Fans as a method of comparing performance of ceiling fans under the same (laboratory) conditions (EPA/DOE 2001c). Second, EPA has prepared a final specification for an initial ENERGY STAR ceiling fan program. It is to have two tiers corresponding to two start dates. Tier 1 is to begin January 1, 2002, with the performance specifications outlined in Table 3.3.2.

Table 3.3.2 Key Specifications for ENERGY STAR Ceiling Fans Tier I

A. Airflow Efficiency		
Fan Speed	Minimum Airflow	Efficiency Requirement
Low	1,250 cfm	155 cfm/W
Medium	2,500 cfm	110 cfm/W
High	5,000 cfm	75 cfm/W
B. Controls		
Products shall permit convenient adjustment of fan speed. For those models that accommodate lighting, the lights and the fans must be controllable separately.		
C. Lighting		
Ceiling fans with integral or attachable light kits must meet one of the following: • Pin-based approach—The residential ceiling fan lighting systems shall meet the requirements of the ENERGY STAR specification for residential light fixtures, or • Screw-based approach—The number of ENERGY STAR-qualified screw-based bulbs needed to occupy each standard Edison-based socket shall be included within the residential ceiling fan packaging.		

Source: EPA/DOE 2001c
Note: ENERGY STAR also includes noise, warranty, and labeling specifications that are not shown in this table.

ACEEE believes that this is a good basis for a national standard. By the time it could be implemented, ENERGY STAR will have moved beyond to a Tier 2 performance (not yet defined). As for most standards, this level would eliminate the most egregiously poor performers from the marketplace. Because there are multiple routes toward compliance, the impact on any single manufacturer should be acceptable.

Future Steps and Proposed Standard

Congress should adopt language requiring DOE to develop a performance standard for ceiling fans. This should include a lighting component. For both lighting and fan performance, the ENERGY STAR Tier 1 performance levels represent an appropriate level for standards.

States could adopt the ENERGY STAR level for state standards, effective approximately 2 years after the ENERGY STAR Tier 1 takes effect (i.e., 2004). This timing would permit field experience with the ENERGY STAR specification, allowing regulators to assess how workable the specification is in practice.

3.4 Residential Torchiere Lamps

Overview

Across the United States, an estimated 50 million torchiere-style halogen floor lamps are in use today, consuming 20 TWh/yr of electricity.[12] Lighting designers and consumers have been attracted by the appearance, indirect lighting, and versatility of these torchieres since they were first introduced to the market more than a decade ago. They are used most commonly in homes, apartments, and university dormitories where hard-wired ceiling lights are sparse, but they can also be found in some workplaces where employees use them to combat glare from overhead fluorescent fixtures. Today, halogen torchieres are widely available at department stores, lighting distributors, home improvement centers, and other retail outlets at prices as low as $10–15. Annual sales have grown from an estimated 1 million lamps in 1990 to 20 million in 1995 and 1996, although sales decreased to around 12 million in 1998 and 9 million in 2000 due to highly publicized safety concerns (Calwell et al. 2000; Calwell and Horowitz 2001).

Unfortunately, halogen torchieres are among the most energy-wasting appliances found in a typical U.S. household. Ninety percent of power consumed by a halogen torchiere lamp converts to instant heat and only 10% into visible light. The “warm glow" that makes halogen torchieres popular is in fact more than warm—as hot as 700–1,100°F, which is hot enough to burn paper, cloth, wood, and even plastic. According to Ecos Consulting, halogen torchieres have caused at least 435 fires, 32 deaths, 114 injuries, and millions of dollars in property damage (LightSite 2000).

These energy concerns and well-publicized fires have increased interest in alternatives to halogen torchieres. Manufacturers have introduced a number of compact fluorescent lamp (CFL) torchieres and at least one metal halide torchiere that offer similar light output and better energy efficiency than halogen torchieres and greatly reduce safety concerns. Incandescent (A-lamp)

[12] Assuming 4 hours of use at full power per day, per torchiere.

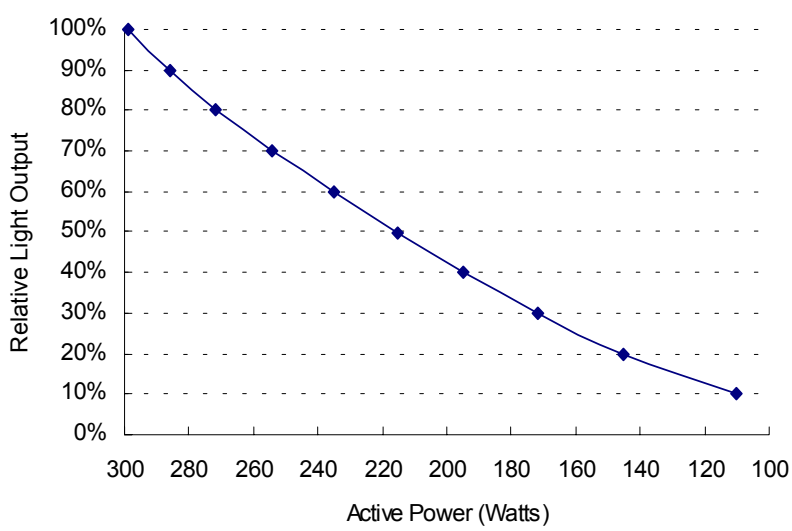
torchieres are another alternative to reduce the risk of fire, although they are not necessarily more efficient than halogen torchieres and only provide energy savings from reduced light output. CFL torchiere lamps are the most promising, with an increasing number of products becoming available on the market and cost declining rapidly. Various CFL lamp designs offer lighting efficacies (efficiency) of 70–80 lumens/W, compared to 10–12 for halogen lamps. If the 50 million halogen torchieres in use today were replaced by ENERGY STAR CFL torchieres, energy savings would surpass 16 TWh, with a simple payback to consumers of less than 3 years.

Technology Description

A typical halogen torchiere stands 6 feet tall and has a weighted base and a bowl-shaped reflector on top with its light shining upwards toward the ceiling. The majority of these units house a 300 W double-ended tubular halogen bulb. They provide indirect lighting, making it appropriate for situations where shadows and glare should be minimized. They are an inexpensive source of lighting that does not require an electrician to install, while their slim, upright design helps them fit into almost any decor. Halogen torchieres are often sold with continuous dimming or bi-level or tri-level switching. Light from undimmed halogen lamps has a correlated color temperature (CCT)[13] of approximately 3,000 Kelvin (K)—slightly higher (and thus whiter) than the regular incandescent lamps used in most residential luminaires—and a color rendering index (CRI)[14] of 95 or more. Dimming a halogen lamp reduces the CCT of the light, making it appear warmer.

Dimming further reduces the efficacy of halogen lamps. Figure 3.4.1 illustrates that a halogen lamp dimmed to 50% of maximum light output still requires 73% of its maximum wattage. When active power is reduced to 50%, the lamp produces only about 20% of its maximum light output.

Figure 3.4.1 Light Output and Required Power of Halogen Lamps



Source: LRC 2000

The exterior appearance of CFL torchieres is indistinguishable from halogen versions. They require a ballast that increases the weight of the torchiere, yet are still lightweight and compact enough to be

[13] CCT is a specification of the apparent color of a light source relative to the color appearance of a reference source. The CCT rating for a lamp is a general indication of the "warmth" or "coolness" of its color. Lamps with a CCT below 3,200 K are usually considered warm (more yellow) sources, whereas those with a CCT above 4,000 K are usually considered cool (more blue) in appearance.

moved easily. Several CFL torchieres include bi-level or tri-level switching, and a few offer continuous dimming. Dimming generally increases the CCT of CFLs, making their color appear cooler. CFL torchieres are available in a number of lamp configurations, including flat, circular, quad-tube, and long-tube types. These CFLs typically consume 55–80 W. They are also available in a range of CCTs with CRIs of at least 82. The CFLs' efficacy is 60–86 lumens/W (compared to 10–20 lumens/W for halogen) (LRC 2000).

Metal halide lamps offer superior efficacy—80 lumens/W—the highest among alternative torchiere light sources. Metal halide lamps are high-intensity discharge (HID) lamps that use mercury and several halide additives as light-producing elements. The lamps also require ballasts to regulate starting voltage and operating current. One commercialized metal halide torchiere uses a 68 W metal halide lamp. Two incandescent lamps (25 W each) are included in the torchiere to provide supplemental light during the warm-up until the metal halide lamp reaches full light output. The incandescent lamps can be turned off separately. The 68 W metal halide lamp has a CCT of 3,200 with a CRI of about 75. The metal halide lamp is also more efficacious (at 88 lumens/W) than CFLs. However, metal halide lamps cannot be dimmed, a major disadvantage relative to other technologies (LRC 2000). Table 3.4.1 lists the characteristics of different torchiere lamp technologies, which were tested by the Lighting Research Center.

Table 3.4.1 Types of Different Torchiere Lamp Technologies

Lamp Type	Number & Type of Lamps	Lamp-Wall Temperature °F (°C)	Rated Light Output from Lamp(s) lumens	Rated Active Power (inc. Ballast) watts	Rated Efficacy lumens/W
Halogen	one 300 W tubular double-ended halogen	970 (521)	4,800–6,000	300	16–20
Incandescent A-lamp	one 3-way (50–100–150 W) incandescent	477 (247)	2,220	150	15
Quad CFL	three 26 W quad-tube CFLs	104–140 (40–60)	5,400	80	68
Flat CFL	two 36 W flat CFLs	104–140 (40–60)	5,600	65	86
Circular CFL	one 20 W circular CFL and one 30 W circular CFL	104–140 (40–60)	3,800	55	69
Metal halide	one 68 W metal halide and two 25 W incandescents	NA	6,000	68	88

Source: LRC 2000

Energy Savings Potential

Energy use by torchiere lamps is expected to grow rapidly in the next decade. LBNL estimates that in 1995 halogen torchieres consumed 11.9 TWh/yr in the United States, and the laboratory forecasts that consumption will grow to 39.4 TWh by 2010 (Sanchez et al. 1998). This forecast caps the total number of torchieres at full saturation at one lamp per household (about 100 million), a very conservative estimate considering the annual sales volume and the lifetime of

[14] A measure of the degree of color shift that objects undergo when illuminated by the light source as compared with those same objects when illuminated by a reference source of comparable correlated color temperature. The maximum CRI is 100.

these lamps (up to 20 years). Table 3.4.2 summarizes the estimated savings potential from converting 100 million halogen torchieres to each alternative technology.

Table 3.4.2 Energy Savings Potential

Torchiere Type	Number & Types of Lamps in Torchiere	Unit Electricity Consumption kWh/yr	National Electricity Use with One per Household TWh/yr	National Energy Savings with One per Household TWh/yr
Halogen	one 300 W tubular double-ended halogen	438.0	43.8	—
Incandescent A-lamp	one 3-way (50–100–150 W) incandescent	219.0	21.9	21.9
Quad CFL	three 26 W quad-tube CFLs	113.9	11.4	32.4
Flat CFL	two 36 W flat CFLs	105.1	10.5	33.3
Circular CFL	one 20 W circular CFL & one 30 W circular CFL	73.0	7.3	36.5
Metal halide	one 68 W metal halide & two 25 W incandescent	99.3	9.9	33.9

Source: ACEEE calculation using data from LRC 2000

Economics

Due to the high energy use of halogen torchieres, the economics of more efficient torchieres are generally very favorable. Halogen torchieres can cost as much as $25–100/yr to operate. They represent a significant portion of residential energy use; high wattage systems can use more energy than a refrigerator.

Using data for the halogen torchieres and alternative technologies presented above, Table 3.4.3 summarizes the initial and maintenance costs of different torchieres. Two simple payback periods are calculated—one for purchasing an alternative torchiere over a halogen torchiere and one for replacing an existing halogen torchiere.

Although the alternative torchieres cost more to purchase, their lower operating expenses (electricity and replacement lamps) make most of them more economical than halogen torchieres. To buy and operate a halogen torchiere for 1 year costs about $40 while an incandescent lamp torchiere costs $35–60 (torchiere, electricity, and one replacement lamp). A circular CFL torchiere, although costing more to buy, actually costs less in that first year ($38–58). The simple payback periods for the three CFL products range from less than 1 to 5 years. Considering that the typical life of torchieres is 10–20 years, these energy saving technologies are clearly cost-effective.

Table 3.4.3. Cost and Payback Analysis of Various Torchiere Lamp Technologies

Torchiere Type	Number & Types of Lamps in Torchiere	Rated Lamp Life hours	Initial Cost of Torchiere $	Replace-ment Cost per Lamp $	Electricity Cost per Year[a)] $	Annual Operating Cost[b)] $	**Simple Payback (New)[c)] years**	**Simple Payback (Replace)[d)] years**
Halogen	one 300-W tubular double-ended halogen	2,000	15–20	7	35.0	40.2	**-**	**-**
Incandescent A-lamp	one 3-way (50-100-150-W) incandescent	1,200–1,500	16–40	2	17.5	19.7	**0.5**	**1.4**
Quad CFL	three 26-W quad-tube CFLs	10,000	90	8	9.1	10.3	**2.4**	**3.0**
Flat CFL	two 36-W flat CFLs	10,000	150	10	8.4	9.9	**4.4**	**5.0**
Circular CFL	one 20-W circular CFL & one 30-W circular CFL	10,000	30–50	18	5.8	8.5	**0.7**	**1.3**
Metal halide[e)]	one 68-W metal halide & two 25-W incandescent	15,000	375	25	7.9	10.4	**12.0**	**12.6**

Source: ACEEE calculation based on data from LRC 2000

Notes: a) Assuming four hr/day use at full power (or highest switch setting) @ 8¢/kWh.
b) Includes electricity and annualized lamp replacement costs.
c) Simple payback when purchasing an alternative torchiere over a halogen torchiere.
d) Simple payback when replacing existing halogen torchiere with an alternative torchiere.
e) Calculations assume that the incandescent lamps are switched off.

Other Benefits

Ecos Consulting examined data from the U.S. Consumer Product Safety Commission (CPSC), insurance companies, law firms, and newspapers. As of August 1999, Ecos attributed 435 fires to halogen torchieres, resulting in 32 deaths, 114 injuries, and $2 million in damage (LightSite 2000). As a result of potential fire hazards, halogen torchieres have been banned in dormitories by two-thirds of the colleges and universities in the United States (Calwell, Cody, and Oster 1998). In 1996, Underwriters Laboratories (UL) withdrew its listing for halogen torchieres with 500 W lamps to reduce the risk of fire. They urged consumers to replace 500 W lamps with 300 W lamps. UL also tightened its safety requirements for halogen torchieres in 1997 and again in June 1999 (Underwriters Laboratories 1999).

Another safety concern for tubular halogen lamps is that when they fail, they sometimes explode or shatter. For this reason, a tempered glass "shatter shield" is required in halogen torchieres to enclose any fragments of hot quartz glass that could scatter onto nearby combustibles. This shield closely covers the lamp and offers shatter protection but very little heat protection (LRC 2000).

A switch to CFL, or even incandescent models, would greatly reduce the risk of these hazards. Schools and universities, offices, and even manufacturers have an incentive since this switch would avoid the potential liability costs associated with halogen lamps.

Past and Current Efforts

Several utilities (including those serving consumers in California, Connecticut, Idaho, Massachusetts, Montana, New Hampshire, Oregon, Rhode Island, Vermont, Washington, and Wisconsin) have provided incentives for ENERGY STAR torchieres. Some utilities offer instant or mail-in rebates typically for $20, while others offer a trade-in program: turn in a halogen

torchiere at a participating store and receive a $10–20 discount on a new ENERGY STAR torchiere. Many universities have teamed with ENERGY STAR and purchased in bulk for use in their residence halls.

ENERGY STAR torchieres are becoming more widely available at home supply and department stores, as well as through mail order catalogs. An up-to-date list of manufacturers and models is maintained at the ENERGY STAR Web site (EPA/DOE 2001d).

This year, the California Energy Commission included residential torchiere lamps in its proposal to amend the state's appliance efficiency regulations. The proposed new standard would require all torchiere lamps to draw less than 190 W, starting on July 1, 2002. Although this performance-based standard would essentially rule out the use of halogen lamps, it is not expected to meet significant opposition due to the numerous safety concerns with halogen torchieres explained above. However, the standard would allow the use of low-wattage incandescent bulbs typically under 150 W. A final adoption hearing for this standard is scheduled for late 2001.

Future Steps and Proposed Standards

We recommend that state governments and the federal government adopt a mandatory standard to regulate the maximum wattage of residential torchiere lamps. The standard could borrow from the current CEC proposed language, which proposes a maximum power draw of 190 W. This should meet minimum resistance due to the safety concerns with halogen lamps and liability costs associated with these safety concerns. However, while the 190 W standard would encourage the use of energy-saving CFL and metal halide lamps, it would also allow the use of incandescent bulbs, which simply reduce the light output without efficiency improvements. Incandescent lamps would also be the least-cost method for manufacturers to meet the 190 W standard and we fear that some of the manufacturers would choose this path rather than investing in CFLs or other energy-saving technologies. Thus, we recommend that the standard incorporate a second tier, perhaps 2–3 years from the initial standard, requiring torchieres to consume 80 W or less.

3.5 Unit and Duct Heaters

Overview[15]

Warehouses, factories, automotive and machinery repair shops typically have high ceilings and open floor plans. Wider temperature variations are tolerated than in office or school spaces; frequently there is no air conditioning, and often only enough heating service to prevent freezing. Many buildings are prefabricated, and minimizing first costs is the overwhelming concern of owners.

In such situations, HVAC systems are generally rudimentary. Unducted, ceiling-hung, gas *unit heaters* are pervasive, because they are the lowest cost option. They include a burner, a fan, and some guide vanes to direct air in the preferred direction. In 1989, such units accounted for 38% of the commercial sector heating energy used and were the most important way to heat

[15] The narrative in this chapter is largely based on Kraus et al. 1992.

commercial buildings. As of 1989, the inventory of approximately 3 million units used over 0.5 quads of gas.

This high market penetration is despite their virtual absence in offices, schools, and other major commercial applications. The industrial market is considered to be about as large as the commercial market—that is, another 0.5 quads of gas. As discussed in the next section, there are significant opportunities to cost-effectively improve unit heater performance. However, owner priorities and market barriers prevent achieving significant penetration of better unit heaters in the absence of standards.

Technology Description

The unit heater, in its simplest form (which dominates the market) is a very simple box. It contains burners, an air-to-air heat exchanger isolating the combustion gases from the room air, and an exhaust for the combustion gases. There is also a propeller-type fan (to push room air through the heat exchanger and blow it into the room) and a thermostat for control.[16] In its generic form, the unit heater pulls combustion air from the heated space, and buoyancy forces (gravity) act on the hot exhaust gases to exhaust them. There is a barometric damper or a draft hood that provides pressure equalization during operation but allows substantial stack losses during the off cycle. The result is a long-lived, simple, robust heater that blows warm air around the facility. Several variations on this theme offer better efficiency. These include

- **Energy-efficient, power vent,** or **power exhaust** units use a fan to push or pull combustion air through the unit. This requires a sealed exhaust stack, without draft diverter, and cuts off-cycle losses to a very low level.[17] Because the stack is blocked during the off-cycle, these units all have an intermittent ignition device (IID) instead of a standing pilot. However, the units continue to draw inside air for combustion instead of outside air. In 1989, these accounted for less than 20% of the market and were primarily sold to the rare owners who specified more efficient equipment.
- **Vent dampers** were offered as an option for gravity-vented units. In these units, an electric motor closes a stack valve above the draft diverter to prevent flow through the stack during the off cycle. Controls are required to assure that this damper is in its open position before the ignition sequence begins. Market penetration is inconsequential, and availability today is unknown.
- **Separated combustion** units are substantially more expensive and have a very small market share. These draw in outside air for combustion and thus can have higher efficiency than power vent units. Market fraction was extremely small in 1992, but the units were listed by at least one major manufacturer.

Currently, unit heaters are rated by manufacturers by their steady-state performance while firing, or *thermal efficiency.* Thermal efficiency ignores the relatively modest losses during start-up and

[16] Less than 20% of unit heaters are equipped with centrifugal blowers, instead of axial fans, to allow connection to ductwork. The static pressure losses (air friction) of the ducts require the blower instead of an axial (propeller) fan.

[17] Since the unit heater is located in the heated space, standby losses from the shell contribute to heating the building. Since the fan does not rotate when the unit is off, this effectively blocks the flow of hot air out through the stack. Thus, the heat stored in the furnace at the end of the operation cycle is made available for heating the space.

shut-down and the much larger potential losses while the unit is off. In particular, the base model "gravity" unit heater, which accounts for the preponderance of sales, is designed to allow a continual flow of heated air from the interior of the space to the outside, through an open exhaust flue, at all times. The major improvements in efficiency will come from limiting these off-cycle losses.

Efficiencies are only published at steady state (thermal efficiency) and cluster at 80–83% thermal efficiency.[18] As with all gas-fired combustion equipment, raising efficiency much higher raises the likelihood of flue gas condensation (and ensuing corrosion) in the stack.[19] Thus, the most attractive route to improved energy efficiency for unit heaters appears to be limiting off-cycle losses. In particular, gravity-vented units without vent dampers continually exhaust heated air from the building during their off cycle. Because power vents largely eliminate these losses and also minimize excess air, this appears to be the best available route for standards. This can be done in one of two ways:

1. A prescriptive standard that bans "open" or atmospheric flue systems. Such requirements could be met with flue dampers that close the vent or with power vents. There seems to be little reason to favor one approach over the other. Both approaches should require adopting an intermittent ignition device by banning the standing pilot. This is the route taken for commercial gas furnaces in ASHRAE 90.1-1999 (ASHRAE 1999) and the new DOE standards for commercial furnaces that were published in January 2001 (Federal Register 2001). Responsible manufacturers will not use standing pilots without atmospheric flues, but it may be necessary to level the playing field with an explicit ban. This could, of course, be made a quasi-performance system by banning off-cycle gas consumption.

2. A performance standards based on annual fuel use by the device. This would require development of a procedure analogous to the "annual fuel utilization efficiency" cycle for residential units and will take longer to develop than the prescriptive standards. No such accepted standard now exists and it would likely require a multi-year process to develop one.

In contrast with residential HVAC equipment, unit heaters typically have propeller fans that do not supply against the pressure head associated with ducted systems. Even so, field studies may reveal that there is potential for reducing parasitic losses by adding some minimum cubic feet of air per minute per watt air handling performance. An appropriate standard would prevent manufacturers from competing by using very low-efficiency motors, for example. Improved motor/fan performance is likely to be very cost-effective if some manufacturers are currently offering very low-efficiency fans.

[18] 1999 ASHRAE building code standard specifies a minimum thermal efficiency of 80%. This is essentially no change from the 1989 ASHRAE standard that specified 78% combustion efficiency. Thermal efficiency is typically 2% higher than combustion efficiency.

[19] It would be possible to build and market *condensing unit heaters* with efficiencies greater than 90%, but they are unlikely in the present business climate: Costs to purchase and install would be high, particularly since ceiling-hung units would generally require a separate condensate pump and lines.

Energy Savings Potential and Economics

Reducing off-cycle losses by either a prescriptive (banning gravity flue systems) or performance (AFUE-like) approach could reduce energy use by an average of 26%, from 1,749 to 1,298 therms/unit. Of the 13 standards measures included in this report, only three have greater near-term savings potential.

Our $425 incremental cost estimate (based on Kraus et al. 1992) is probably generous. Paybacks would depend on heating degree days (HDD), but under the conditions modeled in Appendix B (5,000 HDD) the payback is less than 1 year when gas is $1/therm and less than 2 years when gas is $0.50/therm.

Past and Current Efforts

Unit heaters do not command much attention, despite their prevalence. DOE has put unit heaters on a long list of products to consider for possible future standards (DOE 2001b).

Future Steps and Proposed Standard

We recommend the following actions for consideration:

1. Pass federal and/or state legislation that includes commercial unit heaters.
2. Adopt an interim prescriptive standard to eliminate pilot lights and gravity units without automatic flue dampers (power vents would continue to be allowed).
3. Consider bringing ducted unit heaters into the EPACT system for commercial furnaces and boilers.
4. Determine fan/motor performance levels of available equipment in order to decide whether it is justified to develop a parasitic power standard or require a separate cubic feet of air per minute per watt standard for the air moving performance of unducted unit heaters.

3.6 Commercial Building Transformers[20]

Overview

Larger buildings (schools, major office buildings, etc.) often purchase electricity at distribution voltages (4–35 kilovolts, three-phase). For building applications, this AC power must be stepped down to lower voltages. Lights and HVAC equipment operate at secondary voltage levels, such as 240 or 477 volts, and most plug loads for computers, task lights, and the ubiquitous coffee makers are 120 volts. Distribution transformers change voltages in buildings. They are referred to as low voltage transformers, because their output is less than 600 volts. This contrasts with medium voltage transformers, whose outputs are at higher voltages. Many of the latter are owned and used by utilities to step down power within the grid.

[20] This section treats transformers used inside buildings only. Most outside transformers are single-phase, liquid-insulated, and utility-owned. In contrast, most transformers used in buildings are three-phase, air-insulated, and part of the building equipment, purchased with the electrical panels, switchgear, etc.

In general, distribution transformers are reliable and expected to operate without maintenance or performance degradation for 30 years or more. Usually, transformers are bought as part of a package of electrical distribution equipment (including switchgear, circuit breakers, etc.) in a single bid at construction time. They are generally considered commodity products sold on a first cost basis and given little attention by designers. Most distribution transformers are more than 95% efficient, and the best exceed 99%. Ratings methods and standards for distribution transformers are managed by the National Electrical Manufacturers Association (NEMA 1996; NEMA 1998). The NEMA TP-1 standard covers high-efficiency distribution transformers.

The economic case for more efficient transformers is based on three factors:

- Transformers are constantly energized and thus dissipate some energy as heat regardless of the load served.
- Transformers handle so much electricity that saving a small fraction of this energy, even a fraction of 1%, may have significant economic benefits.
- Because the incremental cost of better efficiency is generally low, higher-efficiency transformers can be economically attractive.

Technology Description

The transformer is one of the basic elements of electric grids. If a wire carrying alternating current is wrapped around a bar of magnetically permeable material (such as steel), an alternating magnetic field will be generated. This will induce a current in a second coil of conducting wire wrapped around the same iron bar. The voltage across the second coil depends on the incoming voltage and the ratio of turns on the two coils of wire.

In practice, "the devil is in the details:" better core materials, better designs, and more precise construction yield greater efficiency—but with some incremental cost. Standard distribution transformer cores are made of many thin laminations of high silicon iron. The newest and most efficient transformers use much thinner laminations of amorphous (non-crystalline) iron.

We differentiate two classes of losses in distribution transformers. Core or "no-load" losses don't vary with the amount of current flowing through the transformer. Transformers dissipate electric energy as heat whenever they are energized (connected to a live circuit). In contrast, winding losses (load losses) vary with the amount of current carried. Empirically, most building transformers are very lightly loaded, so core losses are more important in most building applications than winding losses. This is important because the routes to cost-effective efficiency gains vary, depending on the transformer's loading. For low-load transformers, changes in core materials (thinner laminations, varying composition, or amorphous materials) drive efficiency gains. For high-load transformers such as those in some industrial applications, copper windings give higher efficiency than aluminum, because the wire resistivity is lower.

Building transformers are often lightly loaded. Metering experiments generally show loads about 20% of capacity (Korn, Fax, and Siegmund 1999). There are several reasons for this. Within a given transformer type, the incremental cost of increased capacity is small, averaging

$14/kVA.[21] For example, if a 30 kVA standard transformer costs $692, the cost of the upsized 45 kVA transformer is only $102 more. More importantly, transformers are sized to match distribution circuit panels, and the panels are generally sized generously to allow for future circuits to serve new loads.

Since distribution transformers in buildings are so oversized, the "no-load" losses are a key driver for efficiency for transformers used in buildings.

The electric energy that the transformer does not convert is rejected as heat. Medium voltage utility transformers that are typically installed outside buildings are generally cooled (and partially insulated) by a non-conductive oil. In contrast, low voltage transformers installed in building are almost always "dry" or air-filled. For a given voltage and capacity, oil-filled transformers are smaller, less expensive, and more efficient. Indeed, the NEMA TP-1 rating system requires higher performance for liquid-filled transformers than "dry" (air-cooled) ones, typically by 0.3–0.7%. Liquid-filled transformers are usually avoided for use in buildings. Older oils were associated with some fire and spillage risk. It is thought that many designers are very cautious about new fluids because of negative experience with PCB-insulated transformers that were removed at great expense to meet environmental concerns.

About 90% of liquid-filled transformers are purchased by utilities, and utilities generally use some form of life-cycle ownership cost formulas to make purchase decisions, rather than least first cost rules. In contrast, most dry transformers are installed in buildings as part of the building's electrical system. These are generally chosen on a minimum first-cost criterion. Therefore, in this report we focus on the dry (air-insulated) transformers that are not generally selected with life-cycle cost criteria. Data on the market for dry and liquid-filled transformers are summarized in Table 3.6.1.

Table 3.6.1 Estimate of the Market for Distribution Transformers

	Liquid-Filled	Dry
Number in place	44 million	>12 million
Annual sales (1993)	1.14 million	0.38 million
Utility-owned	90%	
Customer-owned	10%	12 million

Source: Barnes et al. 1997

Energy Savings Potential

As noted above, distribution transformers present a paradox. On the one hand, they are very efficient, generally above 95%. On the other hand, the remaining inefficiencies are large enough that investments in more efficient transformers are often cost-effective.

There is an additional challenge for rating methods or programs to influence selection of more efficient transformers. The measures to improve efficiency of a lightly loaded transformer (the typical building application) focus on "no-load" (primarily core) losses, while those addressing more heavily loaded transformers (sometimes found in industrial applications) focus on

[21] All numbers based on analysis by H.M.S of data in the NYSERDA transformer cost calculator, available at http://64.85.13.65/calculatorInput.asp (NYSERDA 2001a)

windings. This is important because some features that reduce core losses slightly increase windings losses, and vice versa. Based on some empirical evidence, the NEMA TP-1 standard for energy-efficient transformers rates liquid transformers at 50% of nameplate capacity, and dry transformers at 35% of capacity. These values are considered high for average installations, since available data suggest that 20% load factor is closer to average for dry transformers. On the other hand, the difference in rating points is not significant enough to justify changes to the test procedure.

A recent review of energy savings potential was made by ORNL, incorporating the NEMA TP-1 standard (Barnes et al. 1997). This standard has been adopted as the basis for current recommendations for dry transformers by several programs:[22]

- ENERGY STAR level by the EPA.
- FEMP for federal purchasing.
- CEE for coordinated utility incentive programs.

ORNL estimates annual savings from universal adoption of the TP-1 standard to be 7.67 GWh/yr for three-phase dry transformers to be sold in 2004 (Barnes et al. 1997).[23]

Table 3.6.2 gives the CEE tabulation of energy-efficient transformers, based on ORNL work. ACEEE estimates savings of 1.9 TWh in 2010 and 5.4 TWh in 2020 from a standard requiring TP-1 performance from dry transformers (see Section 2 and Appendix B).

Table 3.6.2 CEE Criteria and Savings for Three-Phase Dry Transformers

kVA	Low Voltage		
	Baseline Efficiency	"Energy-Efficient"	Reduction in losses
15	95.7	97	29.4%
30	96.5	97.5	29.0%
45	97	97.7	23.4%
75	97.3	98	24.0%
112.5	97.6	98.2	23.5%
150	97.9	98.3	19.3%
225	98.1	98.5	19.0%
300	98.3	98.6	18.1%
500	98.4	98.7	16.4%
750	98.6	98.8	13.0%
1,000	98.7	98.9	13.1%
1,500	98.8		
2,000	98.9		
2,500	99		

Source: CEE 2001a

Notes: CEE "energy-efficient" criteria are identical to NEMA Class 1 efficiencies for covered equipment. Baseline = average efficiency sold in market today (Source: Barnes et al. 1997). The equipment classes in the chart that are shaded each constitute less than 1% of sales by MVA volume. The range of potential reduction in losses for those classes of equipment that make up at least 1% of sales is 0–33.7%.

[22] As discussed in Section 4, TP-1 is not very useful for liquid-filled transformers.

[23] Three-phase transformers are generally used in buildings.

For the size and type classes that dominate the market, Table 3.5.2 shows that loss reduction potential for TP-1 units is greatest in the smaller sizes, ranging from 24–34% for transformers smaller than 100 kVA. Larger transformers are generally more efficient already. We infer that this reflects the tendency of utilities (which use life-cycle costing) to be more active in the larger transformer market, while building owners, who tend to seek lowest first cost, are more important customers for smaller transformers. *This strongly supports the potential of standards to improve efficiency of products available in the buildings marketplace.*

Economics

Based on an average electricity tariff of $0.0692/kWh and incremental prices provided by manufacturers, ORNL calculated simple payback periods of 2.2–4.7 years for single-phase TP-1 dry transformers relative to baseline transformers sold today, and 2.6–4.4 years for three-phase dry transformers (Barnes et al. 1996).

These may be conservative estimates of economic gains in the future. First, as electricity costs rise, rates of return for saving energy are better. Second, as discussed below, two states have already adopted NEMA TP-1 levels as floors for building codes. As more states adopt similar requirements and as the market share of TP-1 equipment rises, the market is expected to become more competitive, with lower incremental costs.

Table 3.6.3, adapted by CEE from ORNL data on costs, gives calculated paybacks for energy-efficient transformers. The *worst* calculated payback is 6.1 years, for those customers whose energy costs $0.05/kWh, substantially lower than the average today. Again, this strongly argues for a standard.

Table 3.6.3 Annual Savings and Paybacks for Selected Energy-Efficient Transformers

Dry Type: Three Phase, Low Voltage									
Capacity (kVA)	% of Total MVA Sales	Incremental Cost	Annual kWh Savings	at $.05/kWh		at $.08/kWh		at $.11/kWh	
				Annual Savings	Payback (years)	Annual Savings	Payback (years)	Annual Savings	Payback (years)
15	8.90%	$314	1,032	$52	6.1	$83	3.8	$113	2.8
30	12.50%	$296	1,299	$65	4.6	$104	2.8	$143	2.1
45	13.80%	$313	1,687	$84	3.7	$135	2.3	$186	1.7
75	15.00%	$476	2,071	$104	4.6	$166	2.9	$228	2.1
112.5	13.60%	$629	3,030	$151	4.2	$242	2.6	$333	1.9
150	14.20%	$789	3,944	$197	4	$316	2.5	$434	1.8
225	5.60%	$879	4,964	$248	3.5	$397	2.2	$546	1.6
500	7.50%	$1,274	6,178	$309	4.1	$494	2.6	$680	1.9
750	12.90%	$3,176	16,747	$837	3.8	$1,340	2.4	$1,842	1.7
1,000	15.30%	$3,554	22,172	$1,109	3.2	$1,774	2	$2,439	1.5
1,500	29.90%	$3,865	25,302	$1,265	3.1	$2,024	1.9	$2,783	1.4
2,000	11.90%	$3,974	25,403	$1,270	3.1	$2,032	2	$2,794	1.4
2,500	16.60%	$4,467	30,065	$1,503	3	$2,405	1.9	$3,307	1.4

Source: CEE 2001a

Current and Past Efforts

Minnesota has adopted NEMA Standard TP-1 as the minimum-efficiency requirement in the state building code (effective July 20, 1999). Massachusetts has adopted TP-1 as a minimum-efficiency equipment standard (for both new equipment and replacements), and a requirement in the building code, effective January 1, 2000 (Lowinger 2001). A New York standard at TP-1 levels is scheduled to be adopted and take effect on January 1, 2002 (Addario 2001). California has proposed TP-1 as an equipment standard which is expected to be adopted in the next few months.

DOE has begun a rulemaking proceeding for distribution transformers. Staff there expect that DOE will promulgate a minimum-efficiency standard, and that the test procedure will be based on NEMA TP-2, which describes the tests for rating TP-1 transformers. Based on DOE's slow progress on this issue, ACEEE does not expect that a standard will be promulgated before 2003, and its minimum requirements would not take effect for another 3 years.

Voluntary programs including CEE and ENERGY STAR have agreed to use the TP-1 specification for spotlighting efficient products and coordinating incentive programs (CEE 2001a; EPA/DOE 2001e). FEMP has also adopted TP-1 levels as recommended practice for federal purchasers (military and civilian). NYSERDA offers incentives for purchasing TP-1 or better transformers (NYSERDA 2001b).

Future Steps and Proposed Standard

1. States should adopt NEMA TP-1 efficiency levels as mandatory components in equipment standards and/or building codes. This should cover low voltage three-phase transformers installed inside buildings, and rated between 15 kVA and 1000 kVA.

2. DOE should accelerate its distribution transformer rulemaking and adopt a standard for building transformers at the TP-1 level. If the process continues to drag out, then DOE should consider a standard beyond TP-1.[24]

3. To speed implementation, Congress should add requirements at the TP-1 level to any efficiency standards legislation that deals with commercial buildings.

4. There is room for voluntary efforts beyond the TP-1 level. ENERGY STAR, CEE, and other voluntary programs should consider incentives and recognition for buildings transformers with loss levels approximately 50% lower than TP-1 dry transformers (details need to be researched). These incentives should be available for both dry and liquid-type transformers. It is the responsibility of the owners and their teams to determine if liquid transformers, with appropriate insulating liquids, meet their needs—not the job of a voluntary program.[25]

[24] For example, one option is to adopt levels included in the Inslee tax credit bill (H.R. 2392), which calls for efficiencies 0.5% higher than TP-1.

[25] The desired level would correspond to high-efficiency liquid-cooled distribution transformers. This is not as aggressive as a standard that would require performance levels now achieved only by amorphous cores.

3.7 Food Service Refrigerators and Freezers (Including Beverage Merchandisers)

Overview

Refrigeration systems account for approximately 7% of commercial sector energy use. About one-third is consumed by "built-up" systems for food processing, refrigerated warehouses, and supermarkets, while the remaining two-thirds of the energy is consumed by factory-built, "packaged" systems that are shipped ready to use (Kubo, Nadel, and Suozzo 2000). Most efforts to improve energy efficiency to date has focused on supermarket built-up systems and little attention has been given to packaged systems despite their large energy savings potential. In this section we describe the energy and economic saving potential for food service refrigerators and propose minimum-efficiency standards to be adopted.

Food service refrigerators account for approximately 17% of commercial refrigeration energy use and about 26% of packaged commercial refrigeration energy use. A significant number of different classifications exist among food service refrigerators, but the most common types are reach-in refrigerators, reach-in freezers, and beverage merchandisers. "Reach-in" units usually include standard reach-in, roll-in, roll-through, and pass-through cabinet types. In addition, there are milk or beverage, worktop table, and undercounter cabinet types. The estimated inventory of reach-in refrigerators, freezers, and beverage merchandisers totals 2.9 million units, and consume 4.9, 6.0, and 4.7 billion kWh/yr, respectively (ADL 1996).

Opportunities for improving energy efficiency of food service refrigerators are large. Per unit savings of 44–55% are possible with a payback of 2.2 years or less. However, the barriers hindering adoption of these measures are also significant. Among the major barriers are: (1) a focus by most purchasers on first cost; (2) limited information about and awareness of energy use differences between competing products; and (3) the fact that manufacturers make little effort to differentiate equipment on the basis of energy efficiency, with the result that many options for improving efficiency are not incorporated into commercial models. As is the case with vending machines, for beverage merchandisers there is also a split incentive– the bottlers who purchase the systems do not pay the electricity bill for operating the units. Thus, bottlers have no incentive to purchase energy-efficient models and simply look for lowest cost.

The reach-in market is highly fragmented due to the diversity of system types; complex distribution, sales and service chains; and the large variety and size of food stores, food service establishments and other users. Typically, manufacturers work through regional sales offices or manufacturer's representatives to sell equipment to equipment dealers, beverage and food distributors, or franchises. These various parties in turn sell equipment to end-users (or in the case of beverage merchandisers, equipment is usually provided on consignment). In addition, there is also a sizable used equipment market.

The market structure for beverage merchandisers resembles that of vending machines. Beverage-Air and True dominate over 90% of the manufacturing. Nearly all beverage merchandisers are purchased direct from manufacturers by bottling companies for use in convenience stores, supermarkets, retail stores and small food service establishments. Major bottlers such as Coca-

Cola and Pepsi bottling companies account for about 85–90% of sales. Smaller bottlers account for less than 10% (ADL 1996).

Technology Discription

Food service refrigerators are upright, refrigerated cases with solid or transparent doors. They consist of a case, insulation, shelves, refrigeration system, defrost system, and in the case of beverage merchandisers, a fluorescent lighting system to illuminate logos. Reach-in systems include standard reach-in (with doors on one side), roll-in (the bottom is level with the outside floor, permitting wheeled carts to be rolled in), pass-through (with doors on opposite sides), and roll-through (combination of roll-in and pass-through) cabinet types. Beverage merchandisers are a special type of reach-in with glass doors and sometimes glass sides to permit customers to see beverages for sale (see Figure 3.7.1 for illustrative examples). For reach-in refrigerators and freezers, about 80% of the electricity is consumed by the refrigeration system (compressor, evaporator fans, and condenser fan), while the remainder is used for the defrost system. For beverage merchandisers, almost 30% is consumed by the lighting system. A typical beverage merchandiser uses a T-12 fluorescent lamp and a magnetic ballast. The expected equipment life of food service refrigerators is approximately 8–10 years.

Figure 3.7.1 Illustrations of Common Food Service Refrigeration Systems

Reach-in Refrigerator & Freezer

Roll-in Refrigerator & Freezer

Beverage Merchandiser

Source: Manufacturer Web sites

Energy Savings Potential and Economics

Like the other packaged commercial refrigeration equipment, there are substantial opportunities to improve the efficiency of food service refrigerators. For example, ADL (1996) found that energy use of reach-in refrigerators and freezers can be reduced by approximately 45% using measures with an average simple payback of just over 2 years. For beverage merchandisers, reductions of 55% are possible with an average simple payback of just over 2 years. In total, approximately 7.4 TWh can be saved annually in the United States. The ADL findings for reach-in refrigerators and beverage merchandisers are summarized in Tables 3.7.1 and 3.7.2.

Table 3.7.1 Reach-In Refrigerator Energy Savings

Technology	Electricity Savings (%)	Cost Premium ($)	Annual Savings ($)(@$.0782/kWh)	Payback (years)
High-efficiency compressors	12	16	40	0.4
Non-electric antisweat	20	93	67	1.4
Condenser fan ECM motor	3.3	22	11	2.0
Evaporator fan ECM motor	7	48	23	2.1
ECM/variable speed compressor	16	150	54	2.8
Thicker insulation	2	100	8	13
Total for measures with <2-year payback	**35**	**131**	**118**	**1.1**
Total for measures with <5-year payback	**45**	**313**	**152**	**2.1**

Source: ADL 1996
Note: Savings not additive due to interactions between measures.

Table 3.7.2 Beverage Merchandiser Energy Savings

Technology	Electricity Savings (%)	Cost Premium ($)	Savings ($) (@ $.0782/kWh)	Payback (years)
High-efficiency compressors	9.0	16	26	0.6
Electronic ballasts	10	30	30	1.0
Evaporator fan ECM	29	120	85	1.4
ECM/variable speed compressors	14	150	42	3.6
Condenser fan ECM motor	4.5	60	14	4.4
Thicker insulation (1.5–2.5")	3.0	56	9	6.2
Total for measures with <2-year payback	**44**	**166**	**134**	**1.2**
Total for measures with <5-year payback	**55**	**376**	**168**	**2.2**

Source: ADL 1996
Note: Savings not additive due to interactions between measures.

Past and Current Efforts

In the 1980s, CEC adopted regulations requiring manufacturers who sell commercial refrigerators and freezers in California to provide energy performance and other basic information to the Commission (based on ASHRAE test procedures). These regulations cover refrigerators with interior volumes up to 39 cubic feet and freezers with volumes up to 30 cubic feet. CEC compiles this information in a database and posts this database on their Web page (CEC 2000). The CEC is now in the process of updating its regulations in order to refine coverage and requirements and close a few loopholes. This database provides a fairly good foundation for setting standards on most reach-in products. However this database only contains a few beverage merchandisers—CEC is now working with manufacturers to fill in this gap in the database.

During the 1996–1998 period the Canadian Standards Association (CSA) developed an "Energy Performance Standard for Food Service Refrigerators and Freezers, CSA 827" (CSA 1998b). The standard includes testing requirements (building on ASHRAE standard 117), minimum-efficiency levels, and recommended efficiency levels (labeled "high efficiency"). The minimum levels were selected to allow about 75% of existing units to pass while the high-efficiency levels include the top 25% of existing units. The Canadian federal government is considering adopting

the CSA minimum levels as a mandatory Canadian federal standard (Oprisan 2000). The CSA standard is summarized in Table 3.7.3. However, a glitch in the analysis process for glass-door units (including beverage merchandisers) led to much weaker standards for these products. According to an ACEEE analysis, nearly all glass-door units in the CSA database meet the high-efficiency levels (Nadel 1998).

Table 3.7.3 Efficiency Levels in CSA Standard

Equipment Type	Maximum Annual Energy Consumption (kWh)	
	Minimum-Efficiency Standard	High-Efficiency Threshold
Refrigerators		
Reach-in	59 V + 1010	54 V + 470
Reach-in wine cooler	51 V + 300	47 V + 10
Milk or beverage type	31 V + 450	28 V + 260
Worktop table/undercounter	87 V + 780	79 V + 210
Freezers		
Reach-in	172 V + 930	156 V – 1270
Ice cream cabinet	86 V + 1270	78 V + 755
Worktop table/undercounter	367 V + 2200	334 V – 400
Refrigerator-Freezers		
Reach-in vertical split	92 AV + 1900	84 AV + 1160

Source: CSA 1998b

Notes:

1. Volume is measured in cubic feet. Adjusted volume (AV) is equal to the refrigerator volume plus 1.63 times the freezer volume.
2. Columns show formulas for calculating maximum energy use. Thus, for a 40 cf reach-in unit, the minimum-efficiency standard is (59*40 + 1010), which is 3370 kWh/yr.
3. Solid-door values are shown. Glass-door values are all double the solid-door values.

Also in 1999, EPA began investigating the possibility of establishing an ENERGY STAR program for reach-in refrigerators and freezers. EPA circulated a draft specification to collect comments from manufacturers and interested parties earlier this year, and has recently finalized its specification (EPA/DOE 2001f). The EPA specification is based on an analysis of the CEC database, and is designed to differentiate the most efficient quartile of products. As such it is more stringent than the proposed CEC minimum-efficiency standards (discussed below).

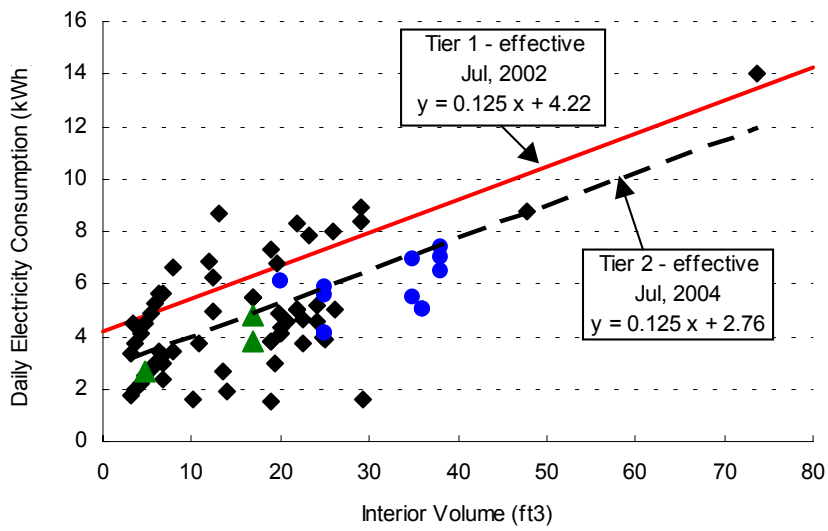
CEC is undergoing a rulemaking to amend its appliance efficiency standards, and has proposed standards for commercial food service refrigerators that are listed in Table 3.7.4 based on an analysis of the CEC database by ACEEE. Tier 1 is approximately the 25th percentile (25% of the models do not meet the standard) and Tier 2 is approximately the 50th percentile (see Figure 3.7.2).

Table 3.7.4 CEC Prposed Standards for Food Service Refrigerators

Appliance	Door Type	Maximum Daily Energy Consumption, kWh	
		July 1, 2002	July 1, 2004
Reach-in, roll-in, roll-through, pass-through, and wine chilling refrigerators	Solid	0.125 V + 4.22	0.125 V + 2.76
Reach-in, roll-in, roll-through, pass-through, and wine chilling refrigerators	Transparent	0.172 V + 5.78	0.172 V + 4.77
Reach-in, roll-in, roll-through, and pass-through freezers	Solid	0.398 V + 2.83	0.398 V + 2.28
Reach-in, roll-in, roll-through, and pass-through freezers	Transparent	0.94 V + 5.10	0.94 V + 5.10
Reach-in, roll-in, roll-through, and pass-through refrigerator-freezers	Solid	0.273 AV + 2.63	0.273 AV + 1.65

Source: CEC 2001
Note: V = total volume (ft^3); AV = adjusted volume = 1.63 x freezer volume (ft^3) + refrigerator volume (ft^3)

Figure 3.7.2 CEC Tier 1 and Tier 2 Standards for Solid Door, Reach-In, Roll-In/Through, Pass-Through, and Wine Chilling Refrigerators[26]



Future Steps and Proposed Standard

We recommend states adopt CEC levels for solid door and transparent door reach-in, roll-in, roll-through, and pass-through refrigerators and freezers. The federal government should also adopt these standards, although since federal standards generally take 3 years to phase in, the federal standards should start with Tier 2. The Tier 2 level in the CEC proposal is based on the best fit model for the existing products in each category as of early 2001. On average, upgrading non-compliant models to equal the average performance of compliant models will reduce energy usage by approximately 20%.[27] According to the ADL 1996 study, per unit energy savings of 44–50% were achievable with a payback period of 2.2 years. Setting the standard at a lower level

[26] Reach-ins are shown in diamonds, roll-in/through and pass-through are shown in circles, and wine chillers are shown in triangles.
[27] Calculation is based on an assumption that each model in CEC's commercial food service refrigerator/freezer database has equal distribution. This may differ significantly from actual case but it is the best estimate possible absent shipment data.

of savings as recommended here is highly likely to be at least equally cost-effective. Figure 3.7.2 shows the distribution of capacity and energy efficiency of food service refrigerators in the CEC equipment database in relation to these proposed standards. In the future, consideration should be given to tightening the standard to the level of savings ADL estimates is technically feasible and economically justified.

For beverage merchandisers, there are two primary options as follows: (1) wait for the CEC to collect more data on beverage merchandisers and analyze these data in order to set standards; or (2) use the CEC values for transparent-door reach-in refrigerators, but include an additional allowance for lighting energy use (this latter figure should assume use of electronic ballasts and T8 lamps or a lighting system with better efficacy).

3.8 Refrigerated Beverage Vending Machines

Overview

The 3.5 million refrigerated beverage vending machines (hereafter referred to as "vending machines") in place in the United States consume approximately 10 TWh/yr and cost American businesses over $700 million/yr. The average expected equipment life of vending machines is 10 years, so new vending machine sales are estimated on the order of 350,000/yr (ADL 1996; Horowitz et al. 1998). Technical opportunities for improving vending machine efficiency are large, with a potential for reducing energy consumption by 20–50% with simple paybacks of only 1–3 years (ADL 1996). The national energy savings potential using cost-effective technology is approximately 4 TWh/yr (see Section 2 and Appendix B).

The greatest difficulty towards improving the efficiency of vending machines is due to "split incentives"—the vending machine owner (i.e., the distributor) purchases the machine, but the end-user (e.g., hotels, office buildings, gas stations, universities, etc.) pays the electricity bill. Because the machine owner does not have to consider operation costs, he/she has virtually no interest in efficiency gains and instead seeks products with the lowest first cost. On the other hand, end-users should have some interest in efficiency improvement, but they are unaware that energy-savings opportunities exist. This is a situation where there is no market incentive to improve energy efficiency and thus minimum-efficiency standards can play a significant role.

Technology Description

A typical beverage vending machine is a 6-feet-tall, refrigerated case that can hold canned or bottled beverages cold at about 35°F. It consists of a case, insulation, illuminated door with controller, coin and bill validator, insulated partition door, product racks, delivery mechanism, refrigeration system, and an optional heater for outdoor machines (Cane 2001).

The two major energy-consuming systems in beverage vending machines are lighting and refrigeration. Surprisingly, lighting accounts for as much as 30–40% of the total energy use, making vending machines distinctly different in energy use characteristics from most other commercial refrigeration equipment. This is because vending machines must attract customers, so they incorporate bright internal lighting to illuminate fancy logos. The lighting system

generally consists of two T12 5-foot fluorescent lamps and a magnetic ballast, and hence does not make use of widely available, more efficient technology such as T8 lamps and electronic ballasts. However, lamp manufacturers do not widely produce efficient 5-foot high-output lamps—which are a key component for improving the efficiency of lighting in vending machines—in part because vending machine companies are unwilling to commit to widely using these lamps. The lights are also generally left on continuously, even during off-peak periods, such as nights and weekends. While there may be some advertising value in this for machines located outdoors (e.g., at gas stations and road stops), the advertising value is likely to be minimal for the many machines located inside buildings. Low cost technologies, such as timers or motion detectors, could easily be employed to reduce the time that the lights are on and wasting electricity (Kubo, Nadel, and Suozzo 2000).

Cooling the vending machine accounts for the remaining 60–70% of machine energy use, and several options for improving the refrigeration system and vending machine envelope (e.g., through improved evaporator and condenser fan motors, more efficient compressors, and improved insulation) have been identified by ADL (1996) and others (see Table 3.8.1).

Energy Savings Potential and Economics

Table 3.8.1 provides a summary of potential energy savings and payback periods from 5 major studies on vending machines.

Table 3.8.1 Summary of Studies of Vending Machine Energy Savings

Characterization	ADL-1 (best available)		ADL-2 (high output lighting)		CEA	E SOURCE	LABS
	1996		1996		1996	1996	
	Measures with <2-Yr Payback	Measures with <5-Yr Payback	Measure with <2-Yr Payback	Measures with <5-Yr Payback	High Baseline	Average Baseline	Average Baseline
Baseline Energy Use (kWh/yr)	2,763	2,763	3,165	3,165	4,050	3,650	3,600
Baseline Energy Cost ($/yr)	$207	$207	$237	$237	$304	$274	$270
Number of Cans per Machine	400	400	400	400	372	450	400
Energy Savings (%)	33%	44%	41%	51%	21%	24%	28%
Lighting, electronic ballasts	9%	9%	21%	21%	NA	24%	15%
Refrigeration, basic	24%	35%	21%	30%	NA	NA	13%
Energy Savings (kWh/yr)	910	1,213	1,312	1,615	851	878	990
Energy Savings (kWh/yr/can)	2.28	3.03	3.28	4.04	2.29	1.95	2.48
Energy Cost Savings ($/yr)	$68	$91	$98	$121	$64	$66	$74
New Annual Energy Use (kWh/yr)	1,853	1,550	1,853	1,550	3,200	2,772	2,610
Machine Lifetime (years)					10	10	NA
Machine Price ($)	NA	NA	NA	NA	$1,667	$2,000	NA
Incremental Cost ($)	$102	$290	$102	$290	$167	$50	$40
Average Simple Payback	**1.49**	**3.19**	**1.04**	**2.39**	**2.61**	**0.76**	**0.54**

Source: Kubo, Nadel, and Suozzo 2000

Notes: ADL-1 and ADL-2 differ only in that one assumes typical T-12 lamps in the baseline, which consumes approximately 2.8 kWh/day and the other assumes high output lighting in the baseline at 3.9 kWh/day. LABS combines preliminary findings of researchers at two national laboratories in 1997. Typical lighting improvements include more efficient lamp/ballast combinations and typical refrigeration/ envelope measures include thicker insulation, more efficient compressors and fan motors.

Collectively, these studies suggest that through the adoption of more efficient, low-cost lighting and refrigeration technologies, potential energy savings from more efficient vending machines ranges from about 20–50%, with simple paybacks in the range of 1–3 years. Using the ADL estimates, total savings potential using available, cost-effective technology can total over 4 TWh/yr in the United States. The incremental cost to make these improvements ranges from $40–290/machine, which is less than 10% of the cost of a new machine and less than the annual operating costs. However, because of the split incentive in that the vending machine owner does not pay the electricity bill, distributors have been known to balk even at efficiency-improvement measures with a $1 added machine cost, let alone the $40–290 required to make substantial improvements in machine efficiency.

Past and Current Efforts

EPA began to investigate beverage vending machines as a possible target for ENERGY STAR labeling program as early as 1994. Although technical work performed under agreements between DOE and major beverage companies demonstrated sizable energy savings from both lighting and refrigeration systems, the companies were reluctant to support a comprehensive ENERGY STAR program. This was due to several reasons including added cost and concerns of possible additional testing requirements. In a continuing effort to start-up the program, EPA is currently focusing on gathering agreement on just the lighting specifications that would lead to 10% savings with a payback of 1.6 years (Kubo, Nadel, and Suozzo 2000), but as of September 2001 an agreement between EPA and the manufacturers is yet to be reached.

In 1996, the Canadian Standards Association (CSA) issued a voluntary standard for beverage vending machines that includes uniform procedures for measuring energy consumption and maximum daily energy consumption levels. Most existing machines meet the standard, so it eliminates only the least efficient models on the market. The province of Ontario has adopted this CSA criteria as a mandatory standard, and the Canadian government is currently considering a pending national standards amendment that may include vending machines as well (Cane 2001; Oprisan 2000).

In 1998, ASHRAE published a test method for measuring daily energy consumption of vending machines, based on the test method in the CSA standard. This test procedure is now being widely used by vending machine manufacturers. It provides a mechanism for interested parties to reliably compare the energy performance of various vending machines; however, the results of the test method are not published in one place; hence, end-users cannot easily find the information.

The California Energy Commission (CEC) is currently in the process of finalizing its appliance rulemaking that would require vending machine manufacturers to report daily energy consumption, type of lighting system, and storage capacity (number of cans or bottles) for products sold in the California market. This data would be an invaluable source of information for purchasers as well as energy efficiency program planners. CEC's proposal also requires beverage vending machines to use T-8 fluorescent lamps with an electronic ballast, or a lighting system of equal or higher efficacy. They estimate that this will to lead to a 10–12% energy savings with a simple payback of 0.7 years (Martin 2001).

Future Steps and Proposed Standard

We recommend that state governments adopt the proposed CEC standard which requires vending machines to use T-8 lamps or by a lighting system of equal or greater efficiency. This would lead to a 10–12% savings, amounting to over 1 TWh of electricity savings each year. However, this does not realize the significant savings potential using readily available and cost-effective refrigeration system improvements. Therefore, we recommend that states and/or the federal government develop a Tier 2 standard that requires a 30–40% improvement in the refrigeration system, bringing down the average annual electricity consumption of a typical, 400-can beverage vending machine to about 1,500–1,800 kWh. The standard should be a step or a linear function so that it is simple yet size-neutral (i.e., limits daily electricity use as a function of storage capacity). Tier 2 should commence 2–3 years after the initial standard, and the exact specification should be determined using the CEC database that will be collected after California's efficiency standards amendments take effect in 2002.

3.9 Traffic Signals

Overview

Replacing incandescent lamps in traffic signals with light emitting diodes (LEDs) offer significant energy and financial savings. LED signals save energy, but also last much longer than incandescent lamps and thus offer additional savings from reduced operating and maintenance costs. According to the U.S. Department of Transportation (DOT), there are about 260,000 signalized traffic intersections in the United States (E Source 1994), with 3 million traffic signals illuminated simultaneously at a given moment (assuming approximately 12 signals per intersection). The overall savings from retrofitting these with LED traffic signals is estimated to be 3 billion kWh/yr, equivalent to the electricity consumption of 300,000 households (CEE 2000).

Technology Description

Traffic signals, including vehicle and pedestrian lights, typically use incandescent lamps that use between 67 and 150 W, depending on the signal size (67 W for 8-inch, 150 W for 12-inch). In contrast, an 8-inch LED signal consumes 15 W or less, and a 12-inch LED signal consumes 25 W or less. LED signals which produce colored light that need not be filtered, save 80–90% of the energy consumed, and last 5–10 times longer than incandescent bulbs. An LED is a semiconductor device that uses solid-state electronics to create light. An LED light source consists of a layer of electron-rich material and a layer of electron-deficient material, both sitting on a semiconductor base. When electricity is applied between the two layers, the electrons are excited and emit light when they return to steady state. The wavelength created is dependent on the chemical composition of the LED.

Energy Savings Potential

Traffic signals are usually on 24 hours/day (although some lights are operated in flashing modes late at night, which reduces lamp burn-time by about 50%). Red lights have the highest load

factor—55–60% for disks and 90% for arrows, while green lights are on about 40% of the time and yellow lights about 3%. Replacing the incandescent lamps in red signals with 15 W LEDs can save over one half of the annual energy consumption. Replacing green signals with LEDs also saves energy, but since the technology to manufacture green LEDs is much more difficult than for red ones, it has taken more time for the green LEDs to become cost-effective based on just energy savings. Another advantage of switching to red AND green LED traffic signals is that by using them with an extended-life incandescent lamp for yellow signals, the regular maintenance cycle can be reduced from every 10–12 months to every 5–7 years.

EPA's ENERGY STAR traffic light program reports that replacing all existing incandescent traffic signals with labeled signals can save 2.7 billion kWh/yr, or 80–90% of the energy consumed by traffic signals. In addition, replacing all pedestrian signals could save another 0.5 billion kWh/yr (EPA/DOE 2001g).

ACEEE reports that an estimated 3 billion kWh in electricity can be saved annually by replacing incandescent signals with LED signals (Suozzo 1998). The breakdown of savings is shown in Table 3.9.1.

Table 3.9.1 LED Traffic Signal Energy Savings

	Red Balls		Green Balls		Yellow Balls		Red Arrows	Green Arrows
	12-inch	8-inch	12-inch	8-inch	12-inch	8-inch	12-inch	8-inch
Signals in place (thousand)	1,690	910	1,300	1,300	1,300	1,300	650	650
Base case indicator (W)	150	67	150	67	150	67	150	150
LED indicator (W)	15	10	25	15	25	15	9	12
Per unit savings (W)	135	57	125	52	125	52	141	138
Duty factor (%)	55	55	42	42	3	3	90	10
Per unit savings (kWh/yr)	650	275	460	191	33	14	1,112	121
Total Savings (GWh/yr)	**1,099**	**250**	**598**	**249**	**43**	**18**	**723**	**79**

Source: Suozzo 1998

Nearly 2.0 TWh can be saved annually just through replacement of red incandescent signals with LEDs (12-inch, 8-inch, and arrows). An additional 0.9 GWh could be saved by switching green signals. Savings from green LEDs are less than that from red LEDs, in part, because the per unit energy savings for green LED signals are less than that for red signals, and in part due to the lower on-time of green signals.

Economics

A typical incandescent lamp for traffic signals costs approximately $2.50 to $3.00. When first introduced in the early 1990s, red LED retrofit modules cost about $750/head. Today, improved red LED retrofit kits (i.e., with better dies, lensing, weather resistance, and controller circuitry) are available for less than $150 (and some are available for as little as $100). As a result, red LED balls pay for themselves in energy savings in about 1–3 years, depending on the electricity rate, and red arrows pay for themselves in an even shorter amount of time (about 1 year) (see Table 3.9.2). Many communities that have retrofitted their red signals have also shifted from an annual maintenance schedule to a 2-year cycle, cutting their major maintenance expenditures in half.

For green signals, the economics are not as strong, but still compelling. The number of suppliers of green LEDs at this time is low and the brightness requirements are fairly stringent (and therefore greater LED source material is required). To date, the cost of green LED signals has rendered their purchase uneconomic in many regions, when considered alone. However, like red signals, the cost of green signals has come down in recent years since adequate green dies are now available. Costs are expected to further decrease as additional source material manufacturers enter the market. Currently, a 12" green ball costs about $200; one manufacturer of LED source material expects the price to decline within the next few years to approach $150 (Suozzo 1998; NYOGS 2001).

Many states and cities are now beginning to install both red and green balls and arrows. Furthermore, communities replacing both green and red signals can save substantially more on maintenance than can communities that do red-only retrofits. In a study examining the feasibility of replacing red and green signals with LEDs in Staten Island, New York, the regular relamping schedule is anticipated to shift from once every year to every 5–7 years, potentially reducing maintenance costs by as much as 85% (Suozzo 1998). Table 3.9.2 summarizes payback estimates and the cost of saved energy from retrofitting red, green, and both color balls and arrows.

Table 3.9.2 LED Traffic Signal Costs and Paybacks

	12-inch Balls			12-inch Arrows		
	Red	Green	Two-Color	Red	Green	Two-Color
Current per unit initial cost ($)	99	198	298	56	101	158
Wattage	11	12		9	13	
Annual load (%)	55	42		84	11	
Per unit annual energy savings (kWh)	670	508	1,177	1,038	132	1170
Annual energy cost savings ($)						
@ $0.05/kWh	33	25	59	52	7	58
@ $0.08/kWh	54	41	94	83	11	94
Annual maintenance cost savings ($)	10	10	140	10	10	140
Simple payback—energy only (yrs)						
@ $0.05/kWh	3.0	7.8	5.1	1.1	15.4	2.7
@ $0.08/kWh	1.9	4.9	3.2	0.7	9.6	1.7
Simple payback—energy and maintenance (yrs)						
@ $0.05/kWh	2.3	5.6	1.5	0.9	6.1	0.8
@ $0.08/kWh	1.6	3.9	1.3	0.6	4.9	0.7

Source: CEC 2001; NYOGS 2001; Suozzo 1998; Vrabel 2001

Past and Current Efforts

The Institute of Transportation Engineers is the standard setting body for vehicle control devices. The current standards for incandescent traffic signals were developed in the 1930s. For LED traffic lights, ITE currently has an interim specification. However, many experts note that the light output requirements, especially for yellow and green are higher than necessary, which creates a substantial technological burden on manufacturers and increases cost. However, various localities have gone forward in the absence of a final specification from the ITE, and have written their own specifications for LED traffic signals. For example, a specification

developed by the California Department of Transportation (CalTrans) is now used extensively in California and is also used in some other states.

Efforts to promote LED traffic lights are probably most extensive in California. CalTrans began researching the potential for applying LED traffic signals in the early 1990s. Caltrans announced its plans to switch all red signals under its control (i.e., 75,000 signal heads) completely to LEDs and has prepared and made publicly available its performance specification (in advance of a final national specification from ITE) (CalTrans 1999). California utilities have taken this approach further and provided rebates to municipalities for installation of LED traffic signals. In 2000, as part of its response to California's electricity crisis, the California Energy Commission (CEC) proposed a minimum-efficiency standard for traffic signals that require all three color signals to be LED (CEC 2001). The CEC estimates that they can achieve savings of 1,200 GWh/yr from changing all red, green, and yellow lights to LEDs. The test method for traffic signal modules is the CalTrans Traffic Signal Specifications for LED Signal Modules. The current proposed standards for traffic lights are shown in Table 3.9.3. There will be an additional hearing on the amendments just prior to the planned adoption of the final regulations in late 2001. The current draft regulations call for the standards to become effective 1 year after adoption.

Table 3.9.3 Proposed California Standards for Traffic Signals (watts)

Type	Red		Yellow		Green	
	at 25°C	at 74°C	at 25°C	at 74°C	at 25°C	at 74°C
300 mm circular (12-inch)	11	17	22	25	12	12
200 mm circular (8-inch)	8	13	13	16	10	10
300 mm arrow (12-inch)	9	12	10	12	13	13
Lane control (X)	9	12	N/A	N/A	N/A	N/A
Lane control (arrow)	N/A	N/A	N/A	N/A	13	13

Source: CEC 2001

In addition to California, many state and city departments of transportation far too numerous to list have begun using LED traffic signals. CEE's Web site lists numerous case studies by various state and city energy offices (CEE 2000).

EPA started an ENERGY STAR traffic light program in 2000. The ENERGY STAR criteria for traffic signals are shown in Table 3.9.4.

Table 3.9.4 ENERGY STAR Criteria for Traffic Signals

Module Type	Maximum Wattage (at 74°C)	Nominal Wattage (at 25°C)
Red Signal		
300 mm circular (12-inch)	17	11
200 mm circular (8-inch)	13	8
300 mm arrow (12-inch)	12	9
Green Signal		
300 mm circular (12-inch)	15	15
200 mm circular (8-inch)	12	12
300 mm arrow (12-inch)	11	11
Pedestrian Head		
Walking Man	12	9
Orange Hand	12	10

Source: EPA/DOE 2001g

Future Steps and Proposed Standard

ITE should develop performance-based criteria to allow reasonable light intensities for yellow and green LED signals. This will provide adequate safety and reduce the cost of green and yellow LED signals.

We recommend DOE or states to adopt performance standards that essentially require LEDs for red and green lights. These standards can be based on the ENERGY STAR specifications and the proposed California efficiency standard. A performance standard would not limit technology options to just LED, but will allow new equivalent technologies to be developed and enter the market. Such a standard will eventually save on the order of 3 billion kWh/yr once the existing traffic signal stock turns over. At this time, we are hesitant to include yellow LEDs in the minimum standard due to their high cost and low load factor. By using an extended-life incandescent bulb in yellow signals a 5-year life can be achieved, which is the maintenance period for the red and green LED signals. A standard for yellow lights can be included for applications where yellow lamps are on at least 30% of the time (e.g., blinkers). However, converting all signals to LED can have additional benefits beyond just energy and maintenance savings, such as increasing driver safety by eliminating full signal outages, reducing the cost of supporting traffic signals (the housing will be lighter), and reducing occupational hazard to installation and maintenance crews because of the lower required voltages relative to incandescent lamps (12 Volts instead of 120 Volts). As prices of yellow LEDs come down, a standard on yellow lights may be appropriate in the future.

3.10 Exit Signs

Overview

Exit signs across the United States are illuminated 24 hrs/day, 365 days/yr. With more than 100 million units installed and 9 million units sold annually, these exit signs use a total of 25–35 TWh of energy/yr and cost American businesses more than $1 billion annually (EPA/DOE 2001h). Although exit signs illuminated by compact fluorescent lamps (CFLs) became popular in the 1990s and products using light emitting diodes (LEDs) are becoming widely available for

new sales, the vast majority of installed exit signs are still lighted by incandescent lamps, typically consuming 24 to 40 W/unit. In contrast, a typical LED exit sign consumes only 1–4 W/face while creating the same amount of light, thus saving 80–90% of the energy. LEDs have a very long life (at least 50,000 hours) and provide even illumination. They offer significant maintenance cost savings by lasting 10–25 years without replacement compared to less than 1 year for incandescent lamps (EPA/DOE 2001h). Recent developments in green LEDs make both red and green signs available and cost-effective. Existing incandescent exit signs can also be replaced with LED adapters. The overall savings potential from replacing existing current incandescent source exit signs with LED exit signs could reach over 22 TWh. EPA estimates that the use of ENERGY STAR exit signs could save 19 TWh annually by the year 2010.

Technology Description

There are five light source technologies commonly used for internally illuminated exit signs. These include incandescent lamps, fluorescent lamps, LEDs, electro-luminescent (EL) lighting, and radio-luminescent (RL) lighting.

The current standard technology is to use two 20 W incandescent lamps to illuminate exit signs. Incandescent lamps produce light by electrically heating a filament. The color of the light that is emitted depends on the temperature of the filament, but is usually white. Most of the light produced from a filament is beyond the visible spectrum and is wasted as heat. The remainder must be filtered out to produce the red or green used for the exit sign. Incandescent exit signs are thus inherently much less inefficient than LED or electro-luminescent lamps that convert almost all of the electrical energy into a single visible wavelength, with the color depending on the composition of the semiconductor.

In the early 1990s, CFL exit signs became a popular alternative to incandescent signs. These consume 10–24 W/sign while lasting between 1 to 2 year–more than twice as long as incandescent bulbs. Fluorescent lamps produce light when an electric discharge occurs through a low-pressure mercury atmosphere. The discharge generates light and ultraviolet radiation; the ultraviolet radiation is absorbed by the phosphor coating on the walls of the lamp and reradiated as light. Similar to incandescent lamps, the light produced is white and must be filtered for use in red or green exit signs.

Among the energy saving technologies, LEDs are the most promising, and are quickly emerging to become the new standard in exit signs. LEDs have a very long projected life, with manufacturer claims of 50,000 to 438,000 hours.[28] They also offer low power consumption, even letter luminance, various fixture designs, and relatively low incremental cost. Newer edge-lit LED exit lights draw less than 2 W.[29] LED signals, which produce colored light that need not be filtered, reduce energy use 80–90%, and last more than 25 times longer than incandescent bulbs. LEDs are a semiconductor device that use solid-state electronics to create light. An LED light source consists of a layer of electron rich material and a layer of electron deficient material, both

[28] LED exit signs do not burn out like incandescent or CFL lamps. Instead, they slowly fade away and thus it is difficult to define their effective life. Some manufacturers claim over a 100-year life, but most are hesitant to claim a lifetime beyond their experience with these systems.
[29] Older "matrix" designs used a still-impressive 5 watts.

sitting on a semiconductor base. When electricity is applied in between the two layers, the electrons are excited and emit light when they return to steady state. The wavelength created is dependent on the chemical composition of the LED. LEDs are monochromatic, and are efficient sources of light.

There are other types of energy saving technologies, such as electro-luminescent (EL) and radio-luminescent (RL) lighting. EL exit signs use the lowest amount of energy, but do not last as long and have a higher first cost and lifecycle cost relative to LED sources. An EL panel contains a thin layer of a phosphor-impregnated material that is sandwiched between two layers of conducting material, one of which is clear. The phosphor layer produces light when voltage is applied between the two conductive layers. The luminance depends on the voltage and the frequency of the voltage that is applied. Unlike a standard incandescent light source, which uses resistance to produce heat and light, EL panels directly convert electric energy into light only and consume less than 1 W/panel. RL signs function similar to EL signs, but produce light from a phosphor that is irradiated by a radioactive source—tritium gas—rather than electricity. The color of the light is determined by the phosphor that is used, and in exit signs the light is usually green. The major advantage of using RL exit signs is that they do not require an external power source, and can be placed anywhere. However, the tritium poses a disposal problem and a safety hazard if the glass tube is broken. Manufacturers of radio luminescent tubes are licensed by the Nuclear Regulatory Commission in the United States and by the Atomic Energy Control Board in Canada.

There are four different fixture designs for exit signs: matrix, panel, stencil, or edge-lit. Matrix signs use arrays or LEDs to form the lettering. The panel format uses a translucent panel that diffuses a light source—both the lettering and the background are luminous. A stencil sign has an opaque panel that conceals the source, with the translucent lettering being luminous. Edge-lit signs feature lettering etched into a glass or plastic panel illuminated through its edge; both the lettering and background are luminous.

Energy Savings Potential

Table 3.10.1 shows the typical energy consumption of four lighting technologies.

Table 3.10.1 Characteristics of Exit Sign Lighting Technology

Lighting Type	Load per Sign	Average Wattage	Electricity Use	Electricity Savings		Lamp Life
	(watts)	(watts)	(kWh/yr)	(kWh/yr)	(%)	(years)
Incandescent	24 to 40	32	280	—	—	0.2–0.7
CFL	10 to 24	17	149	131	47%	1 to 2
LED	1 to 5	3	26	254	91%	10 to 25
Electro-luminescent	less than 1	0.75	6.6	274	98%	8

Assuming that 80%, 15%, and 5% of all installed exit signs are incandescent, CFL, and LED, respectively, the national savings potential from replacing all installed exit signs with LED signs is over 22 TWh/yr. EPA estimates that by implementing their ENERGY STAR Exit Sign label, annual savings can reach 19 TWh by the year 2010 (EPA/DOE 2001h). However, this number is

based on a baseline consumption of 40 W/sign. In fact, the current practice is to install energy-saving incandescent exit signs (which typically consume 10–15 W/sign) or LED exit signs. LED models are already less expensive than CFL lighted signs. In California, 78% of the exit signs sold are LED exit signs (PG&E 2000). Compared against a baseline of the average efficiency of new sales, we estimate annual kWh savings potential after replacement of full stock to be 4.2, 3.1, and 2.1 TWh, assuming 50%, 63%,[30] and 75% LED market share, respectively.

Economics

Figure 3.10.1 shows a lifecycle cost comparison of replacing an existing incandescent exit sign with an ENERGY STAR-labeled sign. Here the payback period for an LED exit sign without batteries is 1.6 years. According to a study last year by PG&E, a typical LED exit sign costs $44 to purchase with an incremental cost of $20 over an incandescent sign (PG&E 2000). Using this number, the payback period is reduced to a mere 7–8 months. Based on PG&E's discussions with ENERGY STAR partner manufacturers, the initial cost of LED exit signs is already cheaper than CFL models.

Table 3.10.2 compares the annual cost of a typical incandescent, CFL, and an LED exit sign, and calculates the simple payback period of replacing an incandescent lamp with CFL and LED sources.

Furthermore, E Source predicts that with the rate of decline in costs for manufacturing LED models, LED signs will soon become less expensive than incandescent models (PG&E 2000). This means that the majority of new sales will convert to LED sources even without a standard. However, a minimum-efficiency standard can probably accelerate this process and will ensure that when existing exit signs fail, they will be replaced by energy-efficient alternatives that meet the standard.

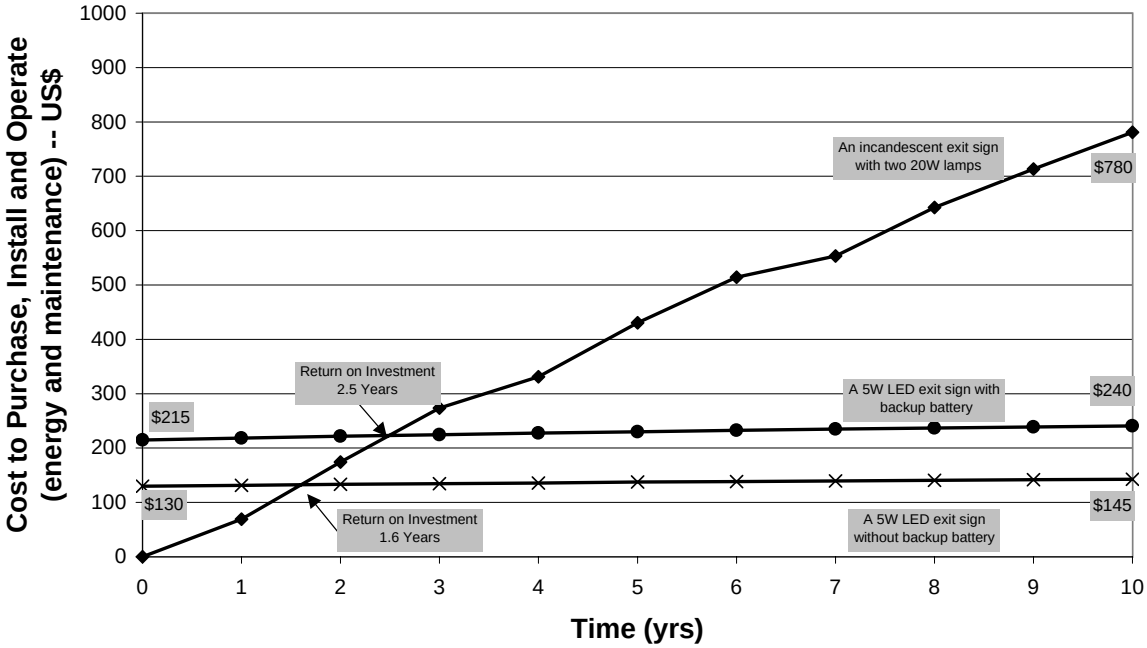
Past and Current Efforts

In the United States, readily visible exit signs are required by law—specified in the United States. Occupational Safety and Health Standards. The National Fire Protection Association's Life Safety Code (NFPA 101) details the visibility of exit signs and how they should be applied (1991). The NFPA code is also specified in various building codes, such as the Uniform Building Code by the International Conference of Building Officials (ICBO).

The Underwriter Laboratories Specification 924 (UL 924) gives more detailed specifications of the performance of exit signs under clear atmospheric conditions. Surprisingly, there are no standards for visibility under smoke-conditions, but the National Lighting Product Information Program's (NLPIP) "Specifier Reports" on exit signs provide test results for various exit signs under smoke conditions (LRC 1994).

[30] 63% market share is what EPA uses to estimate the savings from its ENERGY STAR labeling program.

Figure 3.10.1 Cost Comparison of Incandescent and ENERGY STAR LED Exit Signs



Source: EPA/DOE 2001h
Note: Uses 5.7% nominal discount rate and 10 cents/kWh electricity rate

Table 3.10.2 Exit Sign Economics

		Incandescent	Fluorescent	LED
Typical wattage	watts	40	17	4
First cost	$	25	60	45
Annual energy consumption	kWh	350.4	148.9	35.0
Annual energy cost	$	24.5	10.4	2.5
Rated lamp life	years	0.5	1.5	10–25
Yearly replacement	times	2.0	0.7	0
Replacement lamp	$	5.5	9.7	0
Annual lamp cost	$	11	6.5	0
Annual labor cost	$	15	5	0
Total annual cost	$	50.5	21.9	2.5
Simple payback	years	—	1.2	0.4

Source: ACEEE from PG&E 2000 data
Notes: Annual energy cost calculated @ 7cents/kWh. Annual labor cost calculated using 25 minutes for replacement @ $18/hour

Several organizations have been involved since the early 1990s to improve the efficiency of exit signs. To help consumers identify energy-efficient exit signs, EPA allows manufacturers of these signs to use the ENERGY STAR level. Qualifying exit signs must consume less than 5 W/face, meet the NFPA visibility and luminance criteria, and come with a 5-year manufacturer's warrantee on parts. A list of qualifying products is available from the ENERGY STAR exit sign program (EPA/DOE 2001h). This list includes products from more than 30 companies.

The State of California, as a part of their strategy to deal with the current electricity crisis, has proposed a mandatory standard for exit signs using the ENERGY STAR criteria. Several public hearings have been held and the final standards are scheduled to be adopted by the end of 2001, and become effective 1 year later.

Proposed Standards

We recommend minimum-efficiency standards be adopted for exit signs that effectively require LED or electro-luminescent technology. The language could borrow heavily from the current U.S. EPA/DOE ENERGY STAR specification as does the current CEC proposal. Table 3.10.3 shows the current ENERGY STAR specifications.

Table 3.10.3 ENERGY STAR Specifications for Exit Signs

Standard	Requirement
Input power	≤ 5 W/face
Luminance contrast	> 0.8
Minimum luminance	> 8.6 candelas/meter^2 measured at normal (0°) and 45° viewing angles
Average luminance	□15 candelas /meter^2 at normal (0°) and 45° viewing angles
Maximum luminance to minimum luminance ratio	< 20:1 measured at normal (0°) and 45° viewing angles

A performance-based approach is technology neutral in that any new technology that can potentially meet the standard is allowed. Although the wattage requirement for new exit signs can borrow from the ENERGY STAR language– requiring less than 5 W/face– the maximum wattage can perhaps be lower depending on technology advances prior to the effective date. For example a "2 W or less/face" standard might be readily achievable since the current average for new double-faced LED exit signs is approximately 4 W. On the other hand, if a 5 W/face standard is easier to adopt, this is probably desirable since even this standard will capture most of the available savings.

3.11 Commercial Laundry Equipment

Overview

An estimated 2 to 3 million commercial, family-sized washing machines are installed in the United States, with annual sales of approximately 265,000 (CEE 2001b). These residential-equivalent, coin-operated, commercial washers present a significant opportunity for saving both energy and water in commercial Laundromats, multi-family common laundry rooms, and institutions. High-efficiency commercial washers can save up to 50% of energy costs and use about 35–50% less water compared to typical machines (EPA/DOE 2001i).

Laundromats are estimated to comprise only 15% of annual production volume, with multi-family buildings and institutions making up the remainder.[31] In the multi-family common area laundry market and in institutions, 50 to 90% of machines are operated by contracting companies or "route operators" who supply machines to building owners, perform installation and service, and receive a share of the coin receipts (CEE 2001b). Since the route operator pays the up-front cost for the washer but the building/complex owner/manager realizes the utility savings, there is a "split incentive" barrier in this sector.

A minimum-efficiency standard is an effective way of overcoming market barriers to realize energy savings while providing consumers savings through reduced utility bills. In the case of commercial washing machines in multi-family homes, the building owner will benefit from reduced water and energy bills. In return, route operators can perhaps negotiate a larger portion of the coin receipt (e.g., a dime per wash) to recover the added purchase cost of the machine. The route operator market is very competitive (Suozzo and Nadel 1998), but a mandatory efficiency standard will provide an equal opportunity for route operators to justify adjusting their contracts with building owners. For Laundromats, there is no significant market barrier since due to the high daily wash cycles of their equipment, business owners will typically be able to recover the added first cost of more efficient machines within a few years.

Technology Description

Family-sized commercial clothes washers are very similar to residential-style clothes washers in terms of size, features, connections, and mounting/installation. The differences compared to residential models are typically a sturdier frame and mechanical components, a modified control panel (with fewer choices of control settings), and a revenue-collecting device (i.e., coin box or debit card reader).

High-performance commercial clothes washers achieve energy and water savings by reducing the amount of water used per wash cycle. Water-heating accounts for about 90% of the energy use of clothes washers (Wilson, Thorne, and Morrill 2000). A smaller portion of the energy savings is achieved through the use of higher-efficiency motors. Most manufacturers accomplish water savings by changing their washer design from a vertical-axis (V-axis) to a horizontal-axis (H-axis). The benefit of the H-axis washer design is that the drum only partially fills with water during the wash and rinse cycles; as the drum turns, the clothes are tumbled into and out of water. In contrast, a *standard* V-axis (note that there are a few very efficient V-axis models on the market) clothes washer requires that the clothes be fully immersed in water and moving about a central agitator for proper washing and rinsing. "Front-loading machines" are used synonymously with H-axis design washers, but there are types of H-axis machines that are loaded from the top, like a typical V-axis machine.

Energy Savings Potential and Economics

Several studies have recently looked at the energy, water, and economic savings of high-efficiency commercial clothes washers.

[31] Although laundromats represent less than 20 percent of the market, washers in these locations are in use much more frequently on a daily basis.

FEMP's Technology Installation Review represented the first comprehensive, field-based study of efficient family-sized commercial washers using four machines from different brands. The study found that, on average, high-efficiency brands saved 0.06 kWh/cycle (23%) on motor and controls electricity use. Annually, the average machine energy savings was 140 kWh, and the average hot water energy savings was 8.1 million Btu/machine. In addition, the four brands saved an average of 5.6 gallons of hot water (62%), 11.0 gallons of cold water (42%), and 16.6 gallons of total water (47%) per cycle. Annually, total water savings were estimated to be 38,780 gallons/machine. Using Federal utility rates and discount rates, and a 5-year life (typical life of a clothes washer is 8–9 years, but depending on the usage rate the life can be shorter) FEMP estimates a net present value savings (present value savings minus present value costs) of $850. The average manufacturer suggested retail price (MSRP) range for a baseline V-axis machine is $250–450, while the range for a high-performance clothes washer is $600–1,500. FEMP points out that in all cases, significant discounting to the Federal sector can be expected (FEMP 2000a). Therefore, most upgrades are economically justified.

Battelle Pacific Northwest National Labs (PNNL) has recently completed a study on the energy and water use of resource-efficient commercial clothes washers in a real world setting (2000). The study, commissioned by Southern California Edison (SCE), was set in a senior citizens community of 18,000 residents, Leisure World in Laguna Woods, Calif. Water savings ranged from 10.5 gallons/cycle (28%) to 22.5 gallons/cycle (59%) over the baseline washer. Energy use was reduced by 0.35 kWh/cycle (20%) to 1.16 kWh/cycle (67%). The calculated electricity and water savings totaled $47–139 annually with a simple payback of 3.4–4.4 years over the baseline model.

This February, Pacific Gas & Electric finished a study that provides analytical support to the California Energy Commission for the currently proposed California efficiency standards on commercial clothes washers. The study concludes that using California energy and water rates, efficient commercial clothes washers will generate $186/yr in utility bill savings, with an average payback period of 1.5–3.75 years for current incremental costs of $275 and $700, respectively (PG&E 2001). They estimate that across California, once all the washers are replaced after 8 years, the proposed standard will save 150 GWh annually and reduce electricity demand by 30 MW. The standard will also save 26.4 million therms of natural gas and 7.6 billion gallons of water while creating a net present value of $310 million if the entire fleet were converted to meet the proposed standard (PG&E 2001). Extrapolating from California to the nation (based on relative annual sales), a commercial washer standard would save approximately 1TWh of electricity, 170 million therms of natural gas, and nearly 50 billion gallons of water annually while creating a net present value of approximately $1.8 billion if the entire U.S. fleet were converted (adjusted for difference in price of electricity and natural gas between California and U.S. average).

Past and Current Efforts

CEE launched the commercial, family-sized washer initiative in 1998. Currently, 28 utilities nationwide participate in the initiative and almost $2 million is being used to promote efficient washers. The commercial clothes washer initiative encourages the purchase and use of energy

and water-efficient washers for Laundromats, multi-family buildings and institutions. CEE maintains a list of qualified products, which currently totals 61 models (CEE 2001a).[32]

For this program, CEE uses high-efficiency specifications developed for the Residential Clothes Washer Initiative (see Table 3.11.1). CEE is currently in the process of updating these specifications to use a Modified Energy Factor (MEF), which is an updated measure for clothes washers that addresses the energy used by dryers to dry clothes after the washer spin cycle. The lower the remaining moisture content (RMC) after the washer spin, the higher the MEF.

Table 3.11.1 CEE's High-Efficiency Clothes Washer Initiative Specifications

CEE Specification		EF (ft3/kWh/cycle)	WF (gals/ft3)	RMC
Level	Tier			
A	1	2.50	11.0	No requirement
	2	3.25	9.5	No requirement
B	1	2.50	11.0	50%
	2	3.25	9.5	50%
C	1	2.50	11.0	40%
	2	3.25	9.5	40%
Baseline*		1.18	13.3	62%

Source: CEE 2001a
*Baseline EF is the DOE minimum standard implemented in 1994. Baseline WF and RMC are averages for washers sold in 1994, as supplied to DOE by the Association of Home Appliance Manufacturers (AHAM). EF = Energy Factor; WF = Water Factor; RMC = Remaining Moisture Content[33]

On June 1, the ENERGY STAR program added commercial washers to the 31 other labeled products. In the past, only residential washers could qualify for the label but ENERGY STAR has decided to develop a separate label for commercial models with volume of 3.5 cubic feet or less. In order to qualify for the label, washers must meet a minimum MEF requirement of 1.26. A MEF of 1.26 is very similar to an EF of 2.50 with a RMC of about 60% (EPA/DOE 2001i).

The California Energy Commission is currently developing revisions to their appliance efficiency regulations to update existing standards as well as include several new products including commercial clothes washers. The current proposed standard will govern the sale and installation of commercial washers in the state and require a minimum Modified Energy Factor (MEF) of 1.26 and maximum Water Factor (WF) of 9.5 for all family-sized commercial washers. The final comment period began in early May, and the proposal is expected to be adopted late this year. The general regulations would become effective 1 year later and the commercial clothes washer standard would take effect in 2005 (CEC 2001).

[32] See CEE website: http://www.ceeformt.org/com/cwsh/cwsh-main.php3
[33] EF is a measure of the energy used by the clothes washer directly, as well as for water heating. The greater the cubic feet of laundry washed with a kWh, the higher the energy factor and the machine efficiency. WF is a measure of the total water used by the clothes washer. The less water used per cubic foot of laundry, the lower the water factor, and the greater the machine efficiency. RMC is a measure of the moisture extraction of a washer. The lower the remaining moisture content, the less energy used for drying, and the greater the efficiency of the total wash/dry cycle.

Future Steps and Proposed Standard

We recommend that other states adopt the California standard (minimum MEF of 1.26 and a maximum WF of 9.5). Congress should also consider adopting this standard.

3.12 Commercial Ice-Makers

Overview

An estimated 1.2 million automatic commercial ice-makers in service in the United States consume an estimated 9.4 billion kWh annually and cost American businesses more than $700 million in electricity (ADL 1996). Ice-makers are commonly used in hospitals, hotels, food service, and food preservation. The five major manufacturers are all members of the Air-Conditioning and Refrigeration Institute, which certifies models based on accepted testing standards and publishes the "Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins" which is updated every 6 months. As a result of this ARI initiative, ice-makers stand out among commercial refrigeration systems as the only equipment with comprehensive data on comparative energy usage of different models.

The annual energy cost for a 800 pounds of ice per 24 hour model is as much as $480. Efficient designs exist that can reduce the energy consumption of ice-makers by approximately 20–40%, with a simple payback of 2 years or less. Since the end-user who owns the ice-maker usually pays the utility bill, ice-maker manufacturers tend to pay more attention to energy efficiency (as well as water-use efficiency) than they do for other refrigeration products. Several manufacturers in fact promote energy efficiency over other manufacturer models. However, the focus on energy efficiency varies widely among manufacturers, and as such, it is very difficult to gain consensus on higher-efficiency standards or voluntary labeling programs. End-users are often unaware of how significant the difference in life-cycle costs can be, and tend to focus on design, size, and additional functions at the time of purchase (Kubo, Nadel, and Suozzo 2000).

Technology Description

A typical ice-maker consists of a case, insulation, refrigeration system, and a water supply system. Some of the smaller models have an integrated ice storage bin, but most ice-makers have only a ice-making system and are installed on top of a separate insulated ice-storage bin. Approximately 80% of ice-makers sold have integrated air-cooled condensers, while others have remote air-cooled or integral water cooled configurations. All rated ice-makers use vapor compression refrigeration to produce ice.

The majority of the energy savings potential exists in the refrigeration system. Energy use for commercial ice-makers can vary considerably from product to product—depending on the machine's capacity, the type of ice produced (e.g., cubes, flakes, chips, nuggets, etc.), and the coolant used– but in general, energy use per pound of ice produced decreases as the capacity of the machine increases.

ARI developed a voluntary energy usage test standard for ice-cube machines, which comprise more than 80% of ice-maker sales. This standard, based on an earlier ASHRAE test method,

measures ice harvest rate, energy use and water use for several different types of ice-cube makers:

- Ice-making head units: standard ice-makers with the ice-making mechanism and the condensing unit in a single package, but with a separate ice storage bin.
- Self-contained units: models in which the ice-making mechanism and storage compartment are in an integral cabinet; and
- Remote condensing units: split-system models in which the ice-making mechanism, the condensing unit, and the ice storage bins are in separate sections.

Ice-making head units and self-contained units are subdivided into models that use air or water as their cooling medium.

Energy Savings Potential and Economics

A DOE-sponsored study estimates that energy savings of 18% can be realized through the use of high-efficiency compressors and fan motors, thicker insulation, and other measures, at an added cost that is expected to pay back in a little over 2 years (ADL 1996). A comparison of the most and least efficient units on the market today also illustrates the potential for cost-effective energy savings. Such an analysis for each type of ice-maker and various harvest rates is summarized in Table 3.12.1, and shows that the best models achieve energy savings of 18–46% over the worst models, with a payback period of 1.1 years or less. In some cases, the more efficient models were listed at a lower first cost than the less efficient models.

Table 3.12.1 Payback Analysis of Worst and Best Energy Efficiency Models

Ice Harvest	Worst Model		Best Model		Energy Savings	Payback
	Energy Use	Market Price	Energy Use	Market Price		
(lbs/24hrs)	(kWh/100 lbs of ice)	($)	(kWh/100 lbs of ice)	($)	(%)	(years)
Air Cooled Ice-making Head Unit						
200	11.1	1,410	7.9	1,463	29%	0.9
500	8.3	1,940	5.8	1,940	30%	0 (instant)
1000	7.8	3,020	5.1	3,285	35%	1.1
Water Cooled Ice-making Head Unit						
500	7.0	2,585	4.6	1,940	34%	0 (instant)
1000	7.1	3,020	3.8	2,820	46%	0 (instant)
Air Cooled Remote Condensing Unit						
500	8.4	1,895	6.1	1,895	27%	0 (instant)
1000	7.6	2,970	4.9	3,235	36%	1.1
Air Cooled Self Contained Unit						
150	13.0	1,565	10.7	1,485	18%	0 (instant)
Water Cooled Self Contained Unit						
250	9.0	1,830	7.2	1,775	20%	0 (instant)

Sources: ACEEE analysis based on data from ARI 1999; catalogs of major manufacturers
Notes: Assumes 50% discount from list price (based on communication with local distributors), 3,000 operating hrs/yr, and an electricity rate of $0.07/kWh.

From the above analysis, 30% of the energy can be saved from replacing the least efficient model with the most efficient model with little or no incremental cost. Assuming that the

weighted average efficiency is somewhere between these models, approximately 15% of the total energy use, or 1.2 TWh of electricity can be saved annually across the country.

Past and Current Efforts

As explained earlier in this section, the first (and most difficult) step in energy efficiency initiatives—establishing a testing standard and collecting data– has been achieved by ARI, which developed a certification program and lists all eligible models in a directory updated every 6 months. Using this database, LBNL developed purchasing recommendations for FEMP. The first recommendations were made in 1996, which they updated in 1999 with input from ACEEE and EPA. FEMP generally recommends the top 15–25% of models on the market, with respect to energy efficiency, but adjusts the criteria so at least two manufacturers have complying models in each category. Using the ARI directory (2000), 19.3% of available models meet FEMP recommendations. Table 3.12.2 shows the current FEMP recommendations. If all ice-makers that currently do not meet the FEMP criteria were replaced with models that are at the FEMP efficiency level, 13–14% of total energy use, or approximately 1.1 TWh of electricity can be saved annually.

Table 3.12.2 FEMP Recommendations for Cube-Ice-Makers

Condenser Type	Ice Harvest Rate (lbs/24 hrs.)	Energy Consumption (kWh/100 lbs. of ice)	
		Recommended	Best Available
Ice-Making Head Units			
Air-Cooled	101–200	9.4 or less	8.6
Air-Cooled	201–300	8.5 or less	7.9
Air-Cooled	301–400	7.2 or less	7.1
Air-Cooled	401–500	6.1 or less	5.8
Air-Cooled	501–1,000	5.8 or less	5.4
Air-Cooled	1,001–1,500	5.5 or less	5.1
Water-Cooled	201–300	6.7 or less	5.9
Water-Cooled	301–500	5.5 or less	4.7
Water-Cooled	501–1,000	4.6 or less	3.8
Water-Cooled	1,001–1,500	4.3 or less	4.1
Water-Cooled	> 1,500	4.0 or less	3.7
Self-Contained Units			
Air-Cooled	101–200	10.7 or less	9.5
Water-Cooled	101–200	9.5 or less	7.5
Water-Cooled	201–300	7.6 or less	7.2
Remote Condensing Units			
Air-Cooled	301–400	8.1 or less	7.9
Air-Cooled	401–500	7.0 or less	6.1
Air-Cooled	501–1,000	6.2 or less	5.4
Air-Cooled	1,001–1,500	5.1 or less	4.6
Air-Cooled	> 1,500	5.3 or less	4.9

Source: FEMP 2000b

The CSA developed its own voluntary standards using the ARI database and later the Canadian Government adopted this as a mandatory standard, effective December 31, 1998 (CSA 1998a). Again using the March 2000 ARI database, 83.7% of available models meet the Canadian standard.

EPA has been working on an ENERGY STAR ice-makers program, but so far negotiations with manufacturers have been progressing slowly. Although some manufacturers who produce the

most efficient models showed initial interest in the program, when ARI declined to support the program, these manufacturers chose to back the association's decision. Difficulty in gaining support from the trade association has led EPA to put the program temporarily on hold (Shmeltz 2001).

Future Steps and Proposed Standards

We recommend that state governments and the federal government adopt the Federal Energy Management Program's recommendations as a mandatory energy efficiency standard. States can act while waiting for Congress to set or direct DOE to set national standards. In Canada, Ontario was the first to set mandatory standards before the Canadian government adopted it across the country. The FEMP guidelines were developed using the ARI listings in 1999. At that point, models at or just above the criteria saved 10–40% over the least efficient models with a simple payback of 0–2 years. Thus it is apparent that significant energy savings opportunities exist with minimum or even no incremental cost and standards at this level are justified.

3.13 Packaged Large Air Conditioners

Overview

This section describes the energy and economic savings potential of large packaged air conditioners that are over 20 tons of cooling capacity (heat pumps will also be addressed; however, this section will focus on cooling efficiency). Federal efficiency standards were established under EPAct for packaged systems up to 20 tons in capacity but not for larger equipment.

Cooling commercial buildings is responsible for approximately one-quarter of commercial building energy consumption and energy costs (EIA 1998). In general, commercial air conditioning (A/C) systems come in two main types– packaged systems and built-up systems. Packaged systems are built up at the factory and shipped as one package to the site. Built-up systems are manufactured in components and assembled on-site. Packaged systems account for approximately 55–60% of commercial building A/C capacity (Houghton et al. 1992). Packaged systems predominate for small cooling loads (up to approximately 50 tons of cooling capacity), while for large loads (100 tons and up), built-up systems predominate. For loads of 50–80 tons, either type of system is commonly used (Nadel 1994). Only limited data exist, but according to a 1987 study, packaged systems larger than 20 tons accounted for approximately 21% of commercial cooling capacity (Chiu and Zaloudek 1987).

Technology Description

Packaged equipment is built in a factory and includes all the components required to deliver heating and/or cooling to a space or building. These components consist of a fan for delivering air to and from the space, an indoor or evaporative cooling coil, a heating coil (for heat pumps) or furnace, air filters, dampers for regulating airflow, refrigeration compressor(s), an outdoor or condensing coil for rejecting heat, and controls for automatically regulating space temperature. Sometimes these components are packaged into two factory-made assemblies and are referred to

as "split systems"—as opposed to the "single packaged" systems explained above. For example, a typical split system may have the fan, evaporative coil, furnace, filters, and dampers in one assembly (indoor unit) and the compressor and condenser coil in another assemble (outdoor unit). Most large packaged units over 20 tons are single packaged systems, and are installed on the building's rooftop.

Energy Savings Potential and Economics

Within each type of equipment, efficiencies can also vary significantly. For example, the EER of 30 ton packaged units now on the market varies from approximately 8.5 to 11.7 (FEMP 2000c). A 10 EER unit may cost $70/ton more than an 8.5 EER unit but has a simple payback of just over 3 years (based on ASHRAE 90.1 analysis and an electricity price of 7 cents/kWh)(ASHRAE 1994). The total national energy savings potential from adopting CEE's Tier 2 level (EER of 10.0) is approximately 1.8 TWh with a cost-benefit ratio of above 1 to 3.5 over the life of the equipment (see Section 2.2).

Past and Current Efforts

Under EPAct, Federal efficiency standards were established for packaged systems up to 20 tons in capacity. As a result of negotiations between equipment manufacturers and energy efficiency organizations, federal standards were not established for larger equipment. The original standard for units under 20 tons in EPAct was based on ASHRAE 90.1-1989, "Energy Efficiency Design of New Buildings except Low-Rise Residential Buildings." Since then, the ASHRAE standard was revised and the new ASHRAE Standard 90.1-1999 was adopted (ASHRAE 1999). For several types of commercial equipment, the revision included improved efficiency requirements, which triggers a DOE process to set new standards for equipment 20 tons or less. As required by EPAct, DOE must revise minimum federal efficiency standards to be at least as stringent as those in the latest version of ASHRAE 90.1. In its initial review of 90.1-1999, DOE determined that higher-efficiency levels than these in 90.1-1999 may be justified (Federal Register 2001). DOE is scheduled to begin this rulemaking shortly with a new standard likely being finalized around 2004 and taking effect 4 years later.

This ASHRAE standard also includes recommended efficiency standards for large capacity packaged systems. It calls for an EER of 9.5 and an IPLV of 9.7 for units over 20 tons and equal or less than 60 tons of cooling capacity (ASHRAE 1999). This standard applies to new construction in states that have adopted the ASHRAE 90.1 standard in their building codes. Even in states incorporating ASHRAE 90.1 in their building codes, these standards do not generally apply to replacement of equipment in existing buildings. An exception is New York state, where the State Energy Code applies to both new construction and equipment replacement (Costello 1994).

A number of other groups have defined more aggressive energy efficiency targets for utilities and federal facility managers to use, including targets for large packaged units. For example, CEE through its High-Efficiency Commercial Air Conditioning Initiative, has established efficiency tiers for packaged air conditioners and heat pumps, which its utility members promote to their customers. And FEMP, in response to regulations directing federal agencies to purchase products that fall in the upper 25% of energy efficiency, has developed purchasing

recommendations for large, water-cooled chillers, commercial unitary air conditioners and heat pumps, and commercial boilers. Table 3.13.1 summarizes the current ASHRAE, CEE, and FEMP standards and recommendations.

Table 3.13.1 CEE (and ASHRAE) Minimum-Efficiencies Specifications for Packaged Air Conditioners and Heat Pumps over 240,000 Btu/hr of Cooling Capacity

Equipment Type	Mode	CEE Tier I (ASHRAE 90.1-1999)	CEE Tier II	FEMP
Air Conditioners, air cooled	Cooling	9.5 EER and 9.7 IPLV	10.0 EER and 10.4 IPLV	10.0 EER
Air Conditioners, water and evaporatively cooled	Cooling	11.0 EER and 10.3 IPLV	14.0 EER	11.0 EER
Heat pump, air cooled	Cooling	9.0 EER and 9.2 IPLV	10.0 EER and 10.4 IPLV	NA
Heat pump, air cooled	Heating	3.1 COP (47 °F db/43 °F wb) 2.0 COP (17 °F db/15 °F wb)	3.3 COP (47 °F db/43 °F wb) 2.2 COP (17 °F db/15 °F wb)	NA

Source: CEE 2001c
Note: EER = energy efficiency ratio; IPLV = integrated part load value; COP = coefficient of performance; db=dry bulb; wb = wet bulb.

Future Steps and Proposed Standard

We recommend that Congress adopt amendments to EPAct to expand the coverage of energy efficiency standards on packaged air conditioning equipment to units over 20 tons of cooling capacity. Congress should adopt the CEE Tier II levels for this equipment.

In the meantime, we recommend that states adopt CEE Tier II levels, or at minimum the current ASHRAE standard for this equipment that applies to both new construction and replacement of equipment in existing buildings. This is best done through state building codes but can also be mandated through an equipment efficiency standard. This would enable states to capture the savings potential from this equipment and also prompt DOE and Congress to adopt a national standard to avoid various state standards.

4. OTHER POSSIBLE OPPORTUNITIES FOR NEW MINIMUM-EFFICIENCY STANDARDS

The following section describes energy savings potential and current status of efforts to increase energy efficiency for products that are not currently "ripe" for mandatory standards. These products have significant room to improve energy efficiency and although we lack information and data to make a recommendation at this time, they should be considered in future revision to NAECA, EPAct, and state standards and building codes.

4.1 Liquid-Filled Utility Distribution Transformers

Electric utilities employ large numbers of low and medium voltage (34.5 kilovolts or less input, less than 600 volts output) distribution transformers. EPAct requires DOE to evaluate standards for distribution transformers, and extensive preliminary analysis has been carried out by Barnes and others at Oak Ridge National Laboratory (Barnes et al. 1997). DOE found such standards to be cost-effective in 1997 (CEE 2001a), but a legally binding standard has not yet been

promulgated. However, a voluntary standard which reduces losses somewhat was published by the National Electric Manufacturers Association (NEMA) (1996). This standard has been adopted as the basis for voluntary programs for dry-type transformers by ENERGY STAR, FEMP, and CEE. However, these programs (and the adoption of mandatory, code-driven programs in Minnesota and Massachusetts, with California and New York in process) have been directed at low-voltage dry-type transformers primarily installed in buildings and not the higher voltage liquid-filled distribution transformers typically purchased by utilities.

About 40 million liquid-filled utility-owned distribution transformers are in service (in addition large end-users own about 10%) (Barnes et al. 1996). Traditionally, utilities carried out life-cycle cost analyses and bought relatively high-efficiency distribution transformers. Because cost-control efforts by utilities have heightened concerns about first costs, a national standard may be useful to lock in and improve efficiency standards for utility applications.

Table 4.1.1 gives the first year and cumulative savings available from adoption of various efficiency levels for liquid-filled transformers for liquid-filled transformers, savings from adoption of TP-1 levels are modest since the vast majority of transformer sales already meet or exceed this standard. At higher-efficiency levels, savings are similar to those from dry-type transformers. However, before such standards can be adopted, specific efficiency levels need to be defined, in the same format as the standards in TP-1 (see Table 4.1.2), but at higher-efficiency levels. Such standards should be developed by DOE, states, or voluntary programs.

The first year savings are comparable to those from LED traffic lights or commercial packaged large HVAC equipment, but smaller than the other technologies considered in this report (see Section 2.2). Similarly, the year 2030 savings for liquid-filled distribution transformers are fairly small relative to the year 2020 savings postulated for other technologies.

Table 4.1.1 Savings from High-Efficiency Liquid Transformers, First Year and 30 Years Cumulative

	TP-1	Lowest TOC	Average Losses	High-Efficiency
First-Year Savings (TWh)				
Liquid, medium-voltage, 1-phase	0.025	0.123	0.229	0.727
Liquid, medium-voltage, 3-phase	0.043	0.094	0.089	0.225
30 Years Cumulative Savings (quads)				
Liquid, medium-voltage, 1-phase	0.14	0.71	1.33	4.22
Liquid, medium-voltage, 3-phase	0.25	0.54	0.51	1.31

Source: Barnes et al. 1997

Notes: "TP-1" refers to NEMA efficient transformers specification. "TOC" means total ownership cost, including purchase price and electrical losses over life of transformer. "Average losses" means the average efficiency of the 3 transformers of each type with the lowest TOC. "High-efficiency" means the highest efficiency available, even if not considered cost-effective at stipulated electricity prices.

Table 4.1.2 NEMA TP-1 Efficiency Levels for Liquid-Filled Distribution Transformers

Single-Phase Efficiency		Three-Phase Efficiency	
kVA	Efficiency (%)	kVA	Efficiency (%)
10	98.3	15	98.0
15	98.5	30	98.3
25	98.7	45	98.5
37.5	98.8	75	98.7
50	98.9	112.5	98.8
75	99.0	150	98.9
100	99.0	225	99.0
167	99.1	300	99.0
250	99.2	500	99.1
333	99.2	750	99.2
500	99.3	1000	99.2
667	99.4	1500	99.3
833	99.4	2000	99.4
		2500	99.4

Source: CEE 2001a

4.2 Fractional and Single-Phase Motors

Motors are used in a wide variety of equipment including residential and commercial refrigerating and HVAC systems, as well as industrial processes of all sorts. Motors account for more than 50% of total electricity use in the United States. The majority of motor energy use is due to integral-horsepower (i.e., 1 hp or greater), polyphase (three-phase), alternating current (AC), induction motors which are regulated by federal efficiency standards since 1997. However, integral-horsepower motors are substantially outnumbered by fractional-horsepower (less than 1 hp) motors. These motors are produced in both single and polyphase configurations, and are ubiquitous in commercial applications from small pumps and fans, to compressors and conveyors (Nadel et al. 2001). In the industrial sector, estimates of the proportion of drive energy represented by fractional-horsepower motors range from 0.5 to 1.5% (EPRI 1992, Rosenberg 1996). On the other hand almost three-fifths of the motor energy use in the residential and commercial sector is by motors of 1 hp or below (ADL 1999). In addition, there are a substantial number of single-phase motors of 1 hp and above, primarily in residential and small commercial buildings. These are also not covered by federal standards.

Knowledge of the efficiency of these motors and their applications are much more limited than for their larger siblings, although we know that individual motors can differ greatly in efficiency, depending on motor type and quality of construction. A recent survey of reported efficiency levels in manufacturers catalogs indicate that efficiencies can range from less than 50% to over 80% for 0.5 and 0.75 hp polyphase motors (APT 2000). However, most fractional-horsepower and single-phase motors are purchased by original equipment manufacturers who pay little attention to energy efficiency issues. As a result, sales of high-efficiency motors of these types are limited. Other than studies of test methods in Canada in the early 1990s (McKay 1992) and a draft report prepared for DOE in 1996 (LBNL 1996), there has been little focus on efficiency in this class of product from either the efficiency community or from manufacturers.

In 1993, CSA developed a draft test procedure on Energy Efficiency for Single and Three-phase small motors using a market assessment study by the Canadian Electrical Association (CEA) and Ontario Hydro. However, the CSA test procedure lacks reproducibility and is difficult to implement. As a result, there is no widely accepted test procedure that compares with that for integral motors (NEMA 1999). IEEE is currently attempting to develop a new test method for fractional single-phase motors, though its adoption and the testing necessary to build confidence in the test may be several years off (Stricklett 2001). One obstacle is that the cost of performing a test is many multiples of the cost of the motor.

Recently, some energy efficiency programs have begun to express interest in these motors. For example, in 2000 Southern California Edison commissioned some initial market analysis and testing (Benkhart, Elliott and Grimm 2001). A better understanding of both product efficiency and markets will be needed if standards or other strategies are to be developed to capture this efficiency potential. For fractional polyphase motors, it may be possible to extend the existing NEMA MG-1 testing and labeling standard. For single-phase motors, more extensive work is needed including refining existing or developing new test procedures and collecting additional data to better understand the market. Since a dramatic difference in efficiency exists between the different types of motors, one strategy may be to discourage use of less efficient motor types (e.g., shaded-pole designs), while encouraging more efficient designs (e.g., capacitor-start motors) through a performance or prescriptive standard. However such an approach will need additional research since the more efficient motor types are not drop-in" replacements– they have a different physical size that may not fit in some existing equipment. Also, there are thousands of motor types and applications, and it is not clear without further research which motor types and applications are numerous enough to lend themselves to standards or other programs.

In the Energy Policy Act of 1992, Congress directed DOE to investigate opportunities for setting standards on fractional and single-phase motors. DOE is now beginning to focus on this work and is planning a broad study to look at opportunities for improving the efficiency of fractional and single-phase motors, and looking at a broad range of policies (of which standards is just one) for fostering these changes (Pollock 2001).

4.3 Windows

Windows are responsible for about 25% of heating and cooling requirements in buildings, or approximately 5% of total U.S. energy use (Bevington and Rosenfeld 1990). The energy performance of windows is determined by a combination of glazing materials, frame materials, and window design. Use of double and triple-pane designs, low-emissivity and high shading coefficient coatings, argon gas fill, and low-conductivity window frames and spacers all can contribute towards enhanced window performance.

Presently the majority of states have thermal requirements for windows included in state building codes. These codes generally apply only to new construction, but a few codes apply to retrofits to existing buildings. Most of these codes just address the thermal conductivity of the glass or the entire window assembly; only a few address shading coefficient.

In addition, DOE operates the ENERGY STAR windows program that awards ENERGY STAR label to products meeting specified performance criteria. These criteria vary by climate region (north, central and south) and are summarized in Table 4.3.

Table 4.3.1 ENERGY STAR Window Requirements

	Northern Zone	Central Zone	Southern Zone
Maximum U-factor	0.35	0.40	0.75
Maximum solar heat gain coefficient (SHGC)	No requirement	0.55	0.40
Window features	• Dual panes • Low-e coating • Space between panes may be filled with gas. • Non-metal frames (usually wood or vinyl)	• Dual panes • Low-e coatings • Metal or non-metal frames	• Dual panes • Low-e coatings • Metal or non-metal frames
Design concept	Reduce heat loss	Reduce heat loss and solar gain	Limit amount of solar energy entering home, therefore reducing amount of A/C needed for comfort

Source: EPA/DOE 2001j

An average household spends over 40% of its annual energy costs on heating and cooling. ENERGY STAR-qualified windows can save 15% of the total energy bill (EPA/DOE 2001j). The ENERGY STAR program estimates that if all residential windows in the United States were replaced with ENERGY STAR-qualifying models, consumers would save a total of $7 billion in energy costs over the next 15 years (EPA/DOE 2001j).

Nationwide, ENERGY STAR windows now account for approximately 25–35% of new window sales. In some regions, such as the Pacific Northwest, the ENERGY STAR market share is over 60% (the Northwest ran an ENERGY STAR window promotion program for many years) (Kurtis 2001).

At the state level, window standards are probably most easily adopted through building codes. These codes should specifically apply to replacement windows and for central and southern climates, windows should meet both thermal conductivity and shading coefficient parameters. Generally speaking, the ENERGY STAR levels represent good levels to include in building codes.

At the federal level, the situation is more complicated due to climatic differences between regions of the country. One option at the federal level might be to adopt a simple performance standard that makes sense everywhere. This could perhaps be a maximum U-value requirement of around 0.6–0.75 Btu/hr-ft^{2o}F and a maximum solar heat-gain coefficient (SHGC) of 0.50–0.60, with values determined in accordance with performance rating procedures developed by the National Fenestration Ratings Council (a consensus association of states and the window industry). These levels can be met by new windows with double glazing, a low-emissivity coating, argon fill, and a good quality frame. Under this approach, states should be free to set more stringent requirements that are suitable for their climate. Another alternative would be to

set different standards by region, perhaps along the lines of the ENERGY STAR program. Both of these options should be investigated. Research is needed to determine the energy savings, economics, and practicality of these and other possible approaches.

4.4 Dehumidifiers

Residential dehumidifiers are small, specialized vapor-compression refrigeration devices that work on the same principles as air conditioners, heat pumps, and refrigerators. Approximately 1 million units are sold annually (Census Bureau 2001). EPA observes that dehumidifiers may use over 1000 kWh/yr, twice as much energy as a standard refrigerator complying with the 2001 DOE requirements (EPA/DOE 2001k). Dehumidifiers are typically installed in basements. Basements are generally uninsulated, and tend to cool toward ambient ground temperature, which may vary from 70°F in the deep South to less than 50°F in the far North. During the summer, hot humid outside air drawn into the basement will be cooled to condensing temperature, with deleterious effects: molds will grow on some materials (paper, dirt), tools will rust, etc. Dehumidifiers provide colder surfaces than the basement and its contents, as well as fan flow, so they can remove large amounts of water.

In operation, room air is first drawn through an evaporator coil, where it is cooled below the dew point, so moisture is removed (and collected in a pan or diverted to a drain). The air then passes across a condenser coil, which rewarms it, and is discharged as warmer, dry air, back to the same room. The appropriate metric for dehumidifier efficiency is the amount of water removed per kilowatt-hour of electricity used. Since the electricity used by the device is discharged as heat to the room (with the warm, dry, air), more efficient units also have less "room heater" effect.

We find no current U.S. efficiency standards for residential dehumidifiers. However, there are test procedures for ratings, and an AHAM directory (AHAM 2000).[34] There is a ENERGY STAR program for energy-efficient dehumidifiers, derived in part by reference to a Canadian Standard (CSA 1994). The ENERGY STAR level is about 10% more efficient than the baseline assumed by EPA. The baseline energy consumption assumed is 1114 kWh/yr for each unit. Table 4.4 gives the ENERGY STAR criteria. As of this date, there are 12 listed models from six brands. Assuming a 10-year dehumidifier life, this implies a savings potential of approximately 1.1 TWh of electricity in the year 2020.

Table 4.4.1 Criteria for ENERGY STAR-Qualified Standard Capacity Dehumidifiers

Product Capacity (Liter/day)	Energy Factor Under Test Conditions (L/kWh)
Liter/day < 10	□ 1.20
10 □ Liter/day < 25	□ 1.30
25 □ Liter/day □ 35	□ 1.50

Source: EPA/DOE 2001k

Because the ENERGY STAR program has brought together the elements required for a dehumidifier energy efficiency program, we believe that there is enough information available to

[34]The AHAM directory is only for water removal capacity (pints/day), with no efficiency measure such as kWh/pint.

justify development of a standard. On the other hand, relatively few models have qualified for the ENERGY STAR program, so that time is required before implementing a standard. We recommend that States or DOE develop a standard based on the ENERGY STAR levels but allow several years before the standard takes effect.

4.5 Water Dispensers

Water dispensers are used to provide cold drinking water and some also provide hot water. Water dispensers come free standing (e.g., bottled water dispensers) or can be attached to the building's plumbing system (called pressurized systems). Over one million water dispensers are sold annually in the United States, with approximately half being cold bottled and the rest split between hot/cold and pressurized. The majority of energy use is due to conduction losses when the hot or cold water is being stored but is not being used. Standby energy use varies from approximately 0.13–1.9 kWh/day with hot/cold dispensers generally using more energy than cold only dispensers (DEG et al. 2001).

In September 2000, EPA began an ENERGY STAR program for bottled water coolers. This program sets a standby energy use level of less than 0.16 kWh/day for cold only and less than 1.2 kWh/day for hot and cold units (EPA/DOE 2001l). The current criteria do not apply to pressurized units but it might be possible to use the same criteria for these units. Also, it would be useful at some point to research opportunities for improving the efficiency of the refrigeration system in water dispensers, perhaps for a future version of the ENERGY STAR standard.

Pacific Gas & Electric is now conducting additional research on water dispensers as part of an ongoing effort to identify good products for new minimum-efficiency standards in California. This work is scheduled for completion in late 2001. However, savings from a water dispenser standard may be modest—based on very preliminary estimates for California, savings from a national standard might be on the order of 1.5 TWh/yr once the equipment stock turns over—less than the savings for most of the standards examined in Section 3 of this report. On the other hand, the existing ENERGY STAR specification may make it easy to set and adopt a standard.

4.6 Portable Room Air Cleaners

Room air cleaners are plug-in, portable air cleaners or air purifiers. They are typically designed to clean the air in a 200–450 ft^2 area. These units have become more popular in recent years and ICF Consulting has estimated that about 16 million units are now in use in the United States (DEG et al. 2001).

The Association of Home Appliance Manufacturers (AHAM) has a certification program to test the cleaning performance of these units. This program does not include any tests for energy use. According to Consumer Reports (2000), the annual energy use of air cleaners ranges from 600–1,278 kWh. This is a 53% difference between the highest and lowest energy consumption levels. There appears to be only a modest correlation between energy use and capacity in the Consumer Reports analysis.

EPA with cooperation from manufacturers, has begun to investigate the possibility of establishing an ENERGY STAR labeling program for air cleaners (EPA/DOE 2001m). In addition, PG&E has begun to research air cleaners as part of its efforts to identify good opportunities for minimum-efficiency standards in California (DEG et al. 2000). Based on very preliminary estimates for California, the national energy savings potential for air cleaners could be around 7–8 TWh/yr once the existing stock turns over, and even higher if sales continue to grow.

4.7 Swimming Pool Pumps

Approximately 5.5 million U.S. households have swimming pools, and the pumps used in swimming pool filtering and cleaning systems consume approximately 4.3 billion kWh/yr (EIA 1999). Swimming pool pumps range in size from about 0.5 to 3 hp and are typically operated for an average of about 4 hours daily (more in some cases) (DEG et al. 2001).

PG&E is now researching opportunities for minimum-efficiency standards for pool pumps, with a focus on two-speed pumps (DEG et al. 2001). One study documented a 50% energy use reduction resulting from operating at half speed and doubling hours of filtration (pumping losses generally increase with the cube of the speed, so cutting the speed in half reduces losses substantially). Annual savings ranged from 1,000–1,930 kWh for the five pumps tested (DEG 1994). Applied to the 5.5 million pools in the United States, potential savings could be as high as 6–10 TWh/yr (however, these savings are greater than EIA's estimate of total pool pump energy use as discussed above, meaning more work is needed to review and refine these figures). Alternatively, similar or greater savings are probably possible with variable-speed pumps. In addition, this measure can have large peak demand savings as filtration often occurs during the daytime. The simple payback for a two-speed pump in new and replacement applications is often less than 1 year (DEG et al. 2001).

The PG&E study should be completed by the end of 2001 and if standards look viable, a rulemaking could begin in 2002. California is among the top three states in terms of number of pools (Florida and N.Y. are the other two) so it makes sense for California to take the lead on pool pump standards before other states or the federal government consider this option.

4.8 Residential Portable Spas and Hot Tubs

Portable spas and hot tubs are prefabricated, self-contained spas and hot tubs, as opposed to "in ground" units and other permanently installed residential spas. According to the National Spa and Pool Institute (NSPI), a trade association, there are 3.4 million portable spas in use in the United States. These units are popular in California (e.g., approximately 400,000 units) and in that state all of the units are electrically heated since it is against code to heat portable units with natural gas. There is a standard published by NSPI for residential portable spas that covers certain aspects of spa design, equipment, installation and operation, but this standard does not address energy use. Likewise, to our knowledge there is no energy test procedure for portable spas, although an ANSI/ASHRAE test procedure for spa water heaters may be of some use (DEG et al. 2001).

Given the lack of test procedures, estimates of spa energy use vary widely, from about 1850 to 3600 kWh/yr. At least one manufacturer (Watkins Manufacturing) claims to have units at the lower end of this range and further claims energy savings of up to 50% relative to products from other manufacturers (DEG et al. 2001).

Given the popularity of these units in California, PG&E is now studying whether these products lend themselves to state efficiency standards. Based on their very preliminary estimates, potential national savings could be on the order of 5 TWh/yr, with a simple payback to consumers of about 5 years (DEG et al. 2001). As with swimming pools, given the popularity of spas and hot tubs in California, it makes sense for California to take the lead on researching and setting standards before other states or the federal government consider this option.

5. CONCLUSION

For each of the equipment types discussed in this report, there are substantial opportunities to save energy by promoting more efficient equipment. Use of high-efficiency equipment is cost-effective for most consumers but due to a variety of market imperfections, the majority of consumers are not purchasing the efficient equipment. In order to capture the substantial energy savings that are available from the use of improved-efficiency equipment, state governments and/or the federal government should consider setting minimum-efficiency standards on many of these products. Efficiency standards can make a significant contribution towards bringing U.S. energy supply and demand into better balance, thereby improving the long-term reliability of our electric grid while also helping our environment, our overall economy, and individual consumer pocketbooks.

There are many products among the new batch of “low-hanging fruit” that are ripe for state and federal action. An estimated 1.8 quads of primary energy would be saved in the year 2020 by setting standards for the products described in this report. This amount is well over one-third of the savings from standards established to date since 1987, with a cost-benefit ratio of 5 to 1, better than the 3 to 1 ratio for existing standards.

In some cases, voluntary or state standards have been developed that Congress, DOE, or states can immediately adopt. These products include residential torchiere lamps, consumer electronics, commercial unit heaters, food service refrigerators, ice-makers, exit signs, traffic signals, distribution transformers, large packaged air conditioners, and commercial clothes washers. In other cases, significant energy savings exist but additional research is needed before specific energy efficiency criteria can be set, due to lack of a testing standard and/or comparative data. DOE, state energy offices, and standard-setting organizations should work together to overcome these barriers in order to realize the additional savings from these products.

Finally, this type of research should be repeated in a few years to assess whether there are additional opportunities for standards, including products described in Section 4 as well as new or under-appreciated products not discussed in this report.

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APPENDIX A. DEFINITIONS, TEST METHODS, AND PROPOSED STANDARDS LANGUAGE

A.1 Definitions

Furnace, Air Conditioner, and Heat Pump Fans

"Residential furnace fan" means an electric fan installed as part of a furnace for purposes of circulating air through the system air filters, the heat exchangers or heating elements of the furnace, and the duct work.

"Residential central air conditioner fan" and "heat pump circulation fan" mean an electric fan installed as part of a central air-conditioner or heat pump for purposes of circulating air through the system air filters, the heat exchangers of the air conditioner or heat pump, and the duct work.

Ceiling Fans

"Ceiling fan" means a fan intended to be mounted to a ceiling outlet box, ceiling building structure, or to a vertical rod suspended from the ceiling, and which has blades which rotate below the ceiling and consists of an electric motor, fan blades (which rotate in a direction parallel to the floor), an optional lighting kit, and one or more electrical controls (integral or remote) governing fan speed and lighting operation.

"Light kit" means the equipment used to provide light from a ceiling fan. Light kits can be

a) Integral: the light kit arrives hardwired to the ceiling fan, or
b) Attachable: the light kit is not, at the time of sale, physically attached to the fan. The light kit must be attached to the ceiling fan for the lights to work

"Airflow" means the rate of air movement at a specific fan setting expressed in cubic feet per minute (cfm) as determined using the applicable test method in Section A.2.

"Airflow efficiency" means the ratio of airflow divided by power at a specific residential ceiling fan setting expressed in cubic feet per minute per watt.

Consumer Electronics (Standby Power)

''Covered household appliance" means the following: televisions, video cassette recorders, digital video disk players, audio systems and system components, set-top, microwave ovens, battery chargers, telephone answering machines, cordless telephones and external power supplies.

"Standby mode" means a mode in which a covered household appliance uses household electric current but is not switched to the active (primary operating) mode. For products with more than one such mode, the term 'standby mode' means the mode in which the covered household appliance consumes the least amount of electric energy that the covered household appliance is capable of consuming without user intervention and while still connected to an energized electrical outlet. The [head of implementing agency] may, by rule, develop more detailed

definitions of 'standby mode' for specific classes of products. Such definitions shall consider definitions currently in use, such as those used by the ENERGY STAR program.

"External power supply" means a power supply circuit (typically linear or switching), encased in a sealed casing, that plugs into a wall socket (either directly or through a power cord) and that has an external power cord that connects it to a household product. The power supply is used to convert the line voltage into either DC current or lower-voltage AC current required to operate the household product.

Torchiere Lighting Fixtures

"Torchiere (lighting) fixture" means a portable electric lighting fixture with a reflector bowl giving light directed upward so as to give indirect illumination.

Commercial Unit and Duct Heaters

"Unit heater" means a self-contained fan-type heater designed to be installed within the heated space. Unit heaters include an apparatus or appliance to supply heat, and a fan for circulating air over a heat exchange surface, all enclosed in a common casing. Unit heaters do not include 'warm air furnaces' as specifically defined under the federal Energy Policy Act of 1992.

"Intermittent ignition device" means an ignition source that is automatically ignited or energized when an appliance is called on to operate, and that is off or not energized when the appliance is not operating.

"Power venting" means a system in which combustion air is supplied under pressure to the fuel burning equipment or in which a fan is used to exhaust hot gases from the heat absorbing equipment.

"Automatic flue damper" means a device installed in the vent for exhaust gases of a furnace, boiler, or water heater to limit off-cycle heat losses. The device shall be 'normally closed,'' that is, blocking at least 90% of the cross-section of the flue, when the heater is not firing.

Distribution Transformers

"Transformer" means a device consisting essentially of two or more coils of insulated wire that transfers alternating current by electromagnetic induction from one coil to another in order to change the original voltage or current value.

"Low-voltage dry-type transformer" means a transformer that:

a) has an input voltage of 600 volts or less;
b) is air-cooled; and
c) does not use oil as a coolant.

"Efficiency of distribution transformer" means the ratio of power output to power input, expressed as a percentage, as determined using the applicable test method in Section A.2.

"kVa" means kilovolt-ampere, the designation for the apparent power of a circuit.

Packaged Commercial Food Service Refrigerators and Freezers (including Beverage Merchandisers)

"Packaged commercial food service refrigerator, freezer, or refrigerator-freezer", mean a refrigerator, freezer, or refrigerator-freezer that is not a federally regulated consumer product.

"Pass through cabinet" means a refrigerator or freezer with hinged or sliding doors on both front and rear of the refrigerator or freezer.

"Reach-in cabinet" means a refrigerator, refrigerator-freezer, or freezer with hinged or sliding doors or lids but excluding roll-in or roll-through cabinets, and pass through cabinets.

"Refrigerator" means a cabinet that is designed for the refrigerated storage of food, including but not limited to solid food and wine, beer, and other beverages, at temperatures above 32°F, and that has a source of refrigeration requiring an energy input. It may include a compartment for the freezing and storage of food at temperatures below 32°F, but it does not provide a separate low temperature compartment designed for the freezing and storage of food at temperatures below 8°F.

"Freezer" means a cabinet that is designed as a unit for the freezing and storage of food or ice at temperatures of 0°F or below and that has a source of refrigeration requiring and energy input.

"Refrigerator-freezer" means a cabinet that:
(1) consists of two or more compartments with at least one of the compartments designed for the refrigerated storage of food, including but not limited to solid food and wine, beer and other beverage, at temperatures above 32°F;
(2) has at least one of the compartments designed for the freezing and storage of food or ice at temperatures below 8°F that may be adjusted by the user to a temperature of 0°F or below; and
(3) has a source of refrigeration requiring energy input.

"Roll-in or roll-through cabinet" means a refrigerator or freezer that allows wheeled racks of product to be rolled into or through the refrigerator or freezer.

Refrigerated Beverage Vending Machines

"Vending machine" means a machine that dispenses food, beverages, and other commodities upon payment.

"Refrigerated bottled or canned beverage vending machine" means a vending machine that cools bottled or canned beverages and dispenses them upon payment.

"T8 lamp" means a tubular fluorescent lamp 1 inch in diameter.

Traffic Signals

"Rated power" of a traffic signal means the power consumption, in watts, that the module was designed and tested for at ambient temperatures of 25°C and 74°C.

"Traffic signal" means a device consisting of a set of signal lights operating in sequence, placed at intersections to regulate traffic.

"Traffic signal module" means a standard 8-inch (200mm) or 12-inch (300mm) round traffic signal indication. It consists of a light source, lens and all parts necessary for operation and communicates movement messages to drivers through red, amber and green colors. Arrow modules in the same colors are used to indicate turning movements. Lane control modules indicate whether traffic lanes are open or closed.

"Light emitting diode (LED)" means a solid-state device that emits light when an electric current is applied.

"Luminance" means a measure of the brightness of a luminous surface, measured in candelas per unit area.

"Candela" means a unit of luminous intensity equal to $1/60^{th}$ of one square centimeter of a radiating body at the temperature of the solidification of platinum (1,772°C)

Emergency Lighting (Exit Signs)

"Illuminated exit sign" means an internally illuminated sign that is designed to be permanently fixed in place and used to identify an exit; a light source illuminates the sign or letters from within, and the background of the exit sign is not transparent

"Light emitting capacitor (LEC)" means a solid-state device which produces light when an electric current is passed through a phosphor-impregnated material.

"Light emitting diode (LED)" means a solid-state device that emits light when an electric current is applied.

"Candela" means a unit of luminous intensity equal to $1/60^{th}$ of one square centimeter of a radiating body at the temperature of the solidification of platinum (1,772°C)

"Luminance" means a measure of the brightness of a luminous surface, measured in candelas per unit area.

"Power factor" means the ratio of the real power component to the total (complex) power component.

Commercial Family-Sized Clothes Washers

"Clothes washer" means an appliance designed to clean clothes, utilizing a water solution of soap or detergent and mechanical agitation or other movement.

"Commercial clothes washer" means a soft mount front-loading or top-loading clothes washer that is generally designed for use in applications where the occupants of more than one household will be using it, including multi-family housing common areas and coin laundries or for use in commercial applications where moderate amounts of laundry are generated. Commercial clothes washers may or may not have coin drops, coin boxes, or debit card reader equipment.

"Energy factor" of a clothes washer means ft^3 per kWh per cycle, as determined using the applicable test method in Section A.2.

"Modified energy factor (MEF)" of a clothes washer means the quotient of the ft^3 capacity of the clothes container divided by the total clothes washer energy consumption per cycle, as determined using the applicable test method in Section A.2.

"Water factor" means the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer.

"Soft-mount clothes washer" means a clothes washer that does not require mechanical fastening to a floor for proper operating performance under typical commercial clothes washer applications.

Commercial Ice-Makers

"Automatic commercial ice-maker" means a factory-made assembly (not necessarily shipped in one package) consisting of a condensing unit and ice-making section operating as an integrated unit, with means for making and harvesting ice. It may also include means for storing or dispensing ice, or both.

"Air-cooled" means a condensing unit which utilizes refrigerant-to-air heat transfer means.

"Water-cooled" means a condensing unit which utilizes a refrigerant-to-water heat transfer means.

"Ice-making head" means an automatic commercial ice-making maker that does not include a storage compartment in an integral cabinet.

"Self-contained ice-maker" means an automatic commercial ice-maker in which the ice-making mechanism and storage compartment are in an integral cabinet.

"Remote condensing ice-maker" means an automatic commercial ice-maker in which the ice-making mechanism and condenser or condensing unit are in separate sections.

Large Packaged Air-Conditioning Equipment

"Packaged air conditioning equipment" means an air conditioning equipment that is built as a package and shipped as a whole to end-user sites.

"Large packaged air conditioning equipment" means packaged air conditioning equipment over 20 tons of cooling capacity.

"Cooling capacity" means a measure of the ability of an air conditioner to remove heat from an enclosed space, as determined using the applicable test method.

"Energy efficiency ratio (EER)" means the ratio of the cooling capacity of the air conditioner in Btu per hour, to the total electrical input in watts.

"Coefficient of performance (COP)" of a heat pump means the ratio of the rate of useful heat output delivered by the complete heat pump unit (exclusive of supplementary heating) to the corresponding rate of energy input, both in consistent units and both as determined using the applicable test method.

"Integrated part load value (IPLV)" means a single number part load efficiency calculated using the applicable test method.

A.2 Test Methods

Furnace, Air Conditioner, and Heat Pump Fans

The test method for furnace fans is that developed by the U.S. Department of Energy and published as 10 *Code of Federal Regulations* Part 430, Appendix N except that the static pressures listed in this test procedure shall be doubled prior to conducting the tests. The test method for air conditioner, and heat pump fans is that developed by the U.S. Department of Energy and published as 10 *Code of Federal Regulations* Part 430, Appendix M except that the static pressures listed in this test procedure shall be doubled prior to conducting the tests.

Ceiling Fans

The test method for residential ceiling fans shall be the test method used under the ENERGY STAR program of EPA for residential ceiling fans, as in effect on the date of enactment of this part.

Consumer Electronics (Standby Power)

The test method for standby power consumption of consumer electronics shall be the test method used under EPA's ENERGY STAR program for consumer electronics, as in effect on the date of enactment of this part.

Torchiere Lighting Fixtures

The test method for torchiere fixtures is Underwriters Laboratories (UL) 153, *Standard for Safety: Portable Electric Lamps.*

Commercial Unit and Duct Heaters

[prescriptive standard and thus no need for a test method]

Low Voltage Dry Type Distribution Transformers

The test method for low voltage dry type distribution transformers is NEMA TP 2-1998.

Packaged Commercial Food Service Refrigerators and Freezers, Including Beverage Merchandisers and Refrigerated Beverage Vending Machines

The test methods for refrigerators, refrigerator-freezers, and freezers that are not consumer products are shown in Table A.2.1.

Table A.2.1 Non-Consumer Product Refrigerator, Refrigerator-Freezer, and Freezer Test Methods

Appliance	Test Method
Refrigerating bottled or canned beverage vending machines	ANSI/ASHRAE 32.1-1997
Other refrigerators, refrigerator-freezers, and freezers with doors	ANSI/ASHRAE 117-1992, with the controls adjusted to obtain the following product temperatures: Type — Initial Product Temperature in °F Refrigerator Compartment — 38 ± 2 Freezer Compartment — 0 ± 2 Wine chiller — 45 ± 2 Ice Cream Cabinet — -5 ± 2
Other refrigerators, refrigerator-freezers, and freezers without doors	CSA C657-95

When a refrigerator, refrigerator-freezer, or freezer can be operated using either alternating current electricity or one or more other sources of primary power, the test shall be performed using alternating current electricity only.

Traffic Signals

The test method for traffic signal modules is the CalTrans Traffic Signal Specifications for LED Signal Modules as in effect on the date of enactment of this part.

Exit Signs

The test method for emergency exit signs shall be the test method used under EPA's ENERGY STAR program for illuminated exit signs, as in effect on the date of enactment of this part.

Commercial Family-Sized Clothes Washers

The test methods for commercial clothes washers is 10 Code of Federal Regulations (CFR) Section 430.23(j) (Appendix J1 to Subpart B of Part 430) (2000).

Commercial Ice-Makers

The test method for ice-makers shall be ARI Standard 810-2000 "Automatic Commercial Ice-Makers."

Large Packaged Air Conditioning Equipment

The test method for packaged air-conditioning equipment of 20 tons cooling capacity or more is ARI Standard 340/360-2000.

A.3 Proposed Standard Language

This section describes the proposed mandatory minimum performance levels or prescriptive measures that must be achieved by regulated appliances.

Furnace, Air Conditioner, and Heat Pump Fans

[Note: Current DOE furnace, air conditioner, and heat pump standards likely preempt state standards on furnace, air-conditioner and heat pump fans unless the state successfully petitions DOE for exemption from preemption based on a compelling state interest. Furthermore, as noted in the body of the text, the standard proposed below is preliminary and may need to be modified. States that are not interested in going through this technical process followed by the exemption from preemption process should delete this section from their legislation.]

Furnace, air conditioner, and heat pump fans manufactured on or after the date three years from enactment of this legislation shall not consume more than 0.2 W per cubic feet of air per minute (watts/cfm) at the static pressure specified in Section A.2. The [head of implementing agency] is authorized to modify this standard based on convincing new technical information that becomes available if such a change will either increase energy savings or address any significant technical problems that would likely result if the standard specified above were to be implemented without modification. The [head of implementing agency] shall make a determination on whether or not to modify the furnace, air conditioner and heat pump fan standard no later than one year prior to the effective date of such standard.

Ceiling Fans

The airflow efficiency of ceiling fans that are manufactured on or after the date 3 years from enactment of this legislation shall be no less than the values shown in Table A.3.1.

Table A.3.1 Airflow Efficiency Standards for Ceiling Fans

Fan Speed	Minimum Airflow	Efficiency Requirement
Low	1,250 cfm	155 cfm/W
Medium	2,500 cfm	110 cfm/W
High	5,000 cfm	75 cfm/W

Products shall permit convenient adjustment of fan speed. For those models that accommodate lighting, the lights and the fans must be controllable separately

Ceiling fans with integral or attachable light kits must meet one of the following:

- Pin-based approach: The residential ceiling fan lighting systems shall meet the requirements of the ENERGY STAR specification for residential light fixtures, or
- Screw-based approach: The number of ENERGY STAR qualified screw-based bulbs needed to occupy each standard Edison-based socket shall be included within the residential ceiling fan packaging.

The [head of implementing agency] is directed to review the federal ENERGY STAR ceiling fan specification and if this specification differs in a substantive way from the standard specified above, the [head of implementing agency] may change the standard specified above to conform to the ENERGY STAR specification if such a change will either increase energy savings or address any significant technical problems that would likely result if the standard specified above were to be implemented without modification. The [head of implementing agency] shall make a determination on whether or not to modify the ceiling fan standard no later than one year prior to the effective date of such standard.

Consumer Electronics (Standby Power)

Consumer electronics manufactured on or after the date two years from enactment of this legislation shall not consume more power during standby mode than the values shown in Tier I of Table A.3.2. Consumer electronics manufactured four years from enactment shall not consume more than 1 W during standby mode.

A manufacturer or importer of a covered household appliance, or their designated agent, may submit to the [head of implementing agency] an application for an exemption of the covered household appliance, or class of covered household appliances, from a Tier II standard specified in Table A.3.2.

Table A.3.2 Standards for Standby Power Consumption of Consumer Electronics

Category	Tier I watts	Tier II watts
TV & video		
TV	3	1
VCR	4	1
TV/VCR Combo	6	1
DVD	3	1
Video game	3	1
Set-top boxes		
Category 1	3	1
Category 2	15 (+5 for each additional LNB)	TBD
Category 3	20 (+5 for each additional LNB)	TBD
Audio	2	1
Telephony	1	1
Wall packs	1	1
Microwave	1	1

Notes: TBD = Appropriate level to be decided; LNB = low noise block down converter; Set-top box categories are: Category 1 = analog cable TV, digital TV converter, internet access device, video game console, videophone; Category 2 = digital cable TV, satellite TV, wireless TV, personal video recorder; and Category 3 = multifunction device (a physically integrated device that has the core function of a category 2 set-top box plus one or more additional functionalities.

[Note: ENERGY STAR equipment is widely available, so only two years are needed before standard takes effect.]

The [head of implementing agency] shall grant an exemption for a covered household appliance for which an application is made if the applicant provides convincing evidence showing that, and the [head of implementing agency] determines that—

‘‘(i) it is not technically feasible to modify the covered household appliance to enable the household appliance to meet the standard;

‘‘(ii) the standard is incompatible with an energy efficiency standard applicable to the covered household appliance under another federal or state standard; or

‘‘(iii) the cost of electricity that a typical consumer would save in operating the covered household appliance meeting the standard would not equal the increase in the price of the covered household appliance that would be attributable to the modifications that would be necessary to enable the covered household appliance to meet the standard by the earlier of—

‘‘(I) the date that is 7 years after the date of purchase of the covered household appliance; or
‘‘(II) the end of the useful life of the covered household appliance.

Torchiere Lighting Fixtures

Torchiere fixtures manufactured on or after the date two years from enactment of this legislation shall not consume more than 190 W and shall not be capable of operating with lamps that total more than 190 W.

[Note: Complying equipment is widely available, so only two years are needed before standard takes effect.]

Commercial Unit and Duct Heaters

Commercial unit and duct heaters manufactured on or after the date 3 years from enactment of this legislation shall not have pilot lights and gravity units without automatic flue dampers.

Low Voltage Dry Type Distribution Transformers

The efficiency of all low voltage dry-type distribution transformers manufactured on or after the date two years from enactment of this legislation shall be not less than the values shown in Table A.3.3. For intermediate kVa ratings, efficiency shall be interpolated. There are no efficiency requirements for transformers with kVA ratings beyond the endpoints in Table A.3.3.

Table A.3.3 Standards for Low Voltage Dry-Type Transformers

Single Phase		Three Phase	
kVa	Efficiency	kVa	Efficiency
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
□	□	750	98.8
□	□	1000	98.9

[Note: This standard is already in effect in other states so only two years are needed before standard takes effect.]

Packaged Commercial Food Service Refrigerators and Freezers, Including Beverage Merchandisers

The energy consumption of commercial reach-in, roll-in, roll-through, and pass-through refrigerators, refrigerator-freezers, and freezers that are manufactured on or after the date two years from enactment of this legislation shall be no greater than the values shown in Table A.3.4.

Table A.3.4 Standards for Reach-In, Roll-In, Roll-Through, and Pass-Through Refrigerators, Refrigerator-Freezers, and Freezers

Appliance	Doors	Daily Energy Consumption (kWh)
Reach-in, roll-in, roll-through, and pass-through, refrigerators	With solid doors	0.125V + 2.76
Reach-in, roll-in, roll-through, and pass-through, refrigerators	With transparent doors	0.172V + 4.77
Reach-in, roll-in, roll-through, and pass-through freezers	With solid doors	0.398V + 2.28
Reach-in, roll-in, roll-through, and pass-through refrigerator-freezers	With solid doors	0.273AV + 1.65

Note: V = total volume (ft^3); AV = Adjusted Volume = [1.63 x freezer volume (ft^3)] + refrigerator volume (ft^3).

Beverage merchandisers shall use electronic ballasts and T8 lamps, or a lighting system with better efficacy.

[Note: This standard is scheduled to take effect in California in early 2003, so only two years are needed before standard takes effect.]

Refrigerated Beverage Vending Machines

Refrigerated Beverage Vending Machines manufactured on or after the date one year from enactment of this legislation shall use T-8 fluorescent lamps with electronic ballasts, or by a lighting system of equal or greater efficacy.

[Note: This standard only requires a lamp and ballast change so only one year is needed before standard takes effect.]

Traffic Signals

The maximum power consumption in watts for traffic signals manufactured on or after the date two years from enactment of this legislation shall be not greater than the values shown in Table A.3.5.

Table A.3.5 Standards for Traffic Signal Modules

Temperature	Red		Green	
	25°C	74°C	25°C	74°C
300 mm circular	11	17	12	12
200 mm circular	8	13	10	10
300 mm arrow	9	12	13	13
Lane Control (X)	9	12	N/A	N/A
Lane Control (Arrow)	N/A	N/A	13	13

[Note: This standard is scheduled to take effect in California in early 2003, so only two years are needed before standard takes effect.]

Exit Signs

The input power, luminance contrast, minimum luminance, average luminance and ratio of maximum luminance to minimum luminance of illuminated exit signs manufactured on or after the date two years from enactment of this legislation shall meet the requirements shown in Table A.3.6.

Table A.3.6 Standards for Exit Signs

Standard	Requirement
Input power	≤ 5 W/face
Luminance contrast	> 0.8
Minimum luminance	> 8.6 candelas/meter^2 measured at normal (0°) and 45° viewing angles
Average luminance	□15 candelas /meter^2 at normal (0°) and 45° viewing angles
Maximum luminance to minimum luminance ratio	< 20:1 measured at normal (0°) and 45° viewing angles

[Note: This standard is scheduled to take effect in California in early 2003, so only two years are needed before standard takes effect.]

Commercial Family-Sized Clothes Washers

The modified energy factor and water factor of commercial front-loading and commercial top-loading automatic clothes washers manufactured on or after January 1, 2005 that are not consumer products shall be not less than the applicable values shown in Table A.3.7.

Table A.3.7 Standards for Commercial Clothes Washers

Appliance	Clothes Container Capacity (ft^3)	Minimum Modified Energy Factor	Minimum Water Factor
Front-loading clothes washer	<3.5 ft^3	1.26	9.5
Top-loading clothes washer	<1.6 ft^3	0.65	9.5
Top-loading clothes washer	≥1.6 ft^3 and <4.0 ft^3	1.26	9.5

[Note: 2005 effective date chosen to coincide with scheduled effective date for California standard.]

Commercial Ice-Makers

The energy consumption of automatic commercial ice-makers that are manufactured on or after the date 3 years from enactment of this legislation shall be no greater than the values shown in Table A.3.8.

Table A.3.8 Standards for Ice-Makers

Condenser Type	Ice Harvest Rate (lbs per 24 hrs.)	Energy Consumption (kWh per 100 lbs. ice)
Ice-Making Head Units		
Air-Cooled	101– 200	9.4 or less
Air-Cooled	201– 300	8.5 or less
Air-Cooled	301– 400	7.2 or less
Air-Cooled	401– 500	6.1 or less
Air-Cooled	501–1000	5.8 or less
Air-Cooled	1,001–1,500	5.5 or less
Water-Cooled	201– 300	6.7 or less
Water-Cooled	301 – 500	5.5 or less
Water-Cooled	501 – 1,000	4.6 or less
Water-Cooled	1,001 – 1,500	4.3 or less
Water-Cooled	> 1,500	4.0 or less
Self-Contained Ice-Makers		
Air-Cooled	101 – 200	10.7 or less
Water-Cooled	101 – 200	9.5 or less
Water-Cooled	201 – 300	7.6 or less
Remote Condensing Ice-Makers		
Air-Cooled	301 – 400	8.1 or less
Air-Cooled	401 – 500	7.0 or less
Air-Cooled	501 – 1,000	6.2 or less
Air-Cooled	1,001 – 1,500	5.1 or less
Air-Cooled	> 1,500	5.3 or less

Large Packaged Air Conditioning Equipment

The energy efficiency of large *packaged air conditioning equipment* that are manufactured on or after the date 3 years from enactment of this legislation shall be no less than the values shown in Table A.3.9.

Table A.3.9 Standards for Large Packaged Air Conditioning Equipment

Equipment Type	Mode	Minimum Efficiency
Air Conditioners, air cooled	Cooling	10.0 EER and 10.4 IPLV
Air Conditioners, water and evaporatively cooled	Cooling	14.0 EER
Heat pump, air cooled	Cooling	10.0 EER and 10.4 IPLV
Heat pump, air cooled	Heating	3.3 COP (47 °F db/43 °F wb) 2.2 COP (17 °F db/15 °F wb)

APPENDIX B. METHODOLOGY, ASSUMPTIONS, AND SOURCES

B.1 Methodology

Overview

We obtained national energy savings from proposed new standards by multiplying annual sales figures for each appliance by per-unit energy savings. We calculated electricity and natural gas savings separately, and then summed to obtain total primary energy savings.[35] To calculate peak generation savings, we multiplied electric generation savings by a peak factor (kilowatt per kilowatt-hour). The peak factor for each appliance is the average coincident power demand of the appliance during peak periods divided by the annual energy consumption of the appliance. We determined the financial savings by multiplying electricity and natural gas rates (residential rates or commercial rates, as appropriate) by the energy savings, while we calculated financial costs by multiplying the per-unit incremental cost for each product by the number of units sold. We derived emission reductions by multiplying emission factors (in metric tons/MWh) to the total primary energy savings. For cumulative costs and savings, we discounted to 2000 using a 5% real discount rate. Cumulative costs and savings cover the period from the effective date of the standard to 2020. The net present value of savings also includes savings after 2020 for equipment sold prior to 2020.

Detailed Methodology

1) Obtaining annual sales figures for each appliance

The analysis is static and we assume equipment sales remain at 2000 levels for all products. We also assume that, in the absence of standards, efficiency levels remain at present levels. In actuality, product sales and efficiency are gradually increasing, even in the absence of standards. Thus, we implicitly assume that these factors counterbalance each other. For source we used to estimate 2000 sales, see Table B.3.

2) Calculating energy savings

We calculate end-use electricity savings in 2010and 2020 using one of the following equations:

(a) End-use electricity savings = annual sales volume H (years from effective date - 0.5)H per-unit elec. savings

(b) End-use electricity savings = annual sales volume H average product life H per-unit elec. savings

Similarly, we calculate end-use natural gas (NG) savings in 2010 and 2020 using one of the following equations:

(a) NG savings = annual sales volume H (years from effective date - 0.5)H per-unit NG savings

[35] Primary energy includes the energy consumed by end-users as well as energy losses associated with the generation, transmission, and distribution of electricity.

(b) NG savings = annual sales volume H average product lifeH per-unit NG savings

In each case, equation (a) is used when the average product lifetime is longer than the number of years from effective date. Otherwise, equation (b) is used in order to avoid double-counting the savings from replacements after 100% saturation. We subtract 0.5 from the number of effective years to account for sales throughout the purchase year, so the *savings* from units installed during the year will be equivalent to only half-year sales times annual savings per unit. Assumptions and sources for equipment life and per-unit energy savings are listed in Tables B.2.1 and B.3.1.

We calculate total primary energy savings using the following equation:

Total primary energy savings = elec. generation savings H heat rate + natural gas savings

For heat rates (primary energy input required to generate a unit of electricity, in Btu/kWh), we use 10,203 Btu/kWh for 2010 and 9,967 Btu/kWh for 2020 (EIA 2000b).We use a 0.93 T&D loss factor (a 7% T&D loss).

Peak capacity savings is calculated as:

Peak capacity savings = end-use electricity savings) T&D loss factor H peak factor H reserve factor

We assume a conservative 10% reserve margin, thus the reserve factor in the formula is 1.1. Historically, a reserve margin of 20% has been used, but utilities have been cutting down their margins with the recent restructuring of the electric utility industry. We obtained peak factors from sources shown in Table B.3.

3) Calculating financial costs and savings

We calculate consumer bill savings using the following formula:

Consumer bill savings = end-use electricity savings H national avg. elec. price+ NG savings H national avg. NG price

For commercial clothes washers, we also calculate savings from water savings. For electricity, natural gas, and water prices used for this analysis, see Section B.2.

Net present value (NPV) is calculated as:

NPV expected investment = 3 {PV(annual sales volume H per-unit incremental cost)}

NPV savings for sales = 3 {PV(installed volume H per-unit energy savings H energy price)}

Present value (PV) calculations are discounted to 2000 assuming a 5% real discount rate. The NPV of expected investment aggregates the present value of annual investments from the effective date of each standard through 2020. The NPV of savings aggregates the present value of annual utility bill savings from the effective date of the standard through the year in which products installed through 2020 die out. Essentially, these two measures give us the cumulative

costs and benefits of standard-complying products installed through 2020. For sources we used to obtain per unit incremental cost, see Table B.3.

4) Calculating emission reductions

We calculate carbon, nitrogen oxides, sulfur dioxide, and particulate emissions reductions from electric products using the following equation:

Emission reductions = end-use electricity savings) T&D loss factor H marginal emission factors

We use marginal emission factors rather than straight emissions factors from the projected generation fuel mix. This gives a more accurate estimate of emissions reductions from new standards. For example, coal-fired power plants are often non-marginal—they are the dirtiest, but also the cheapest, and will most likely remain in operation. Carbon emissions savings for natural gas are based on DOE projections (EIA 2000b). Nitrogen oxides, sulfur dioxide, and particulate emissions reductions are based on data from the EPA Office of Air Quality Planning and Standards (EPA 1998).

Projections from the National Energy Modeling System (NEMS) were used to develop the emissions factors used in the analysis. We calculate emissions factors as the change in total emissions divided by the change in total generation when moving from the NEMS base case to an ACEEE policy case based on upgraded appliance standards and other policies (Geller, Bernow, and Dougherty 1999). For details, see Thorne, Kubo, and Nadel (2000a).

B.2 Assumptions

The estimated savings using the above methodology is shown in Table B.1. Assumptions used to estimate savings for each appliance or equipment are shown in Table B.2. The following lists general assumptions across all products:

T&D loss factor:	0.93 (7% loss)
Reserve factor:	1.1 (10% reserve margin)
Residential electricity rate:	0.08 ($/kWh)
Commercial electricity rate:	0.07 ($/kWh)
Commercial gas rate:	0.5 ($/therm)
Commercial water rate:	3.5 ($/1000 gallon)
Annual discount rate:	5 %
Heat rate for 2010:	10,203 (Btu/kWh)
Heat rate for 2020:	9,967 (Btu/kWh)
Carbon emission factor:	0.177 (MT/MWh) for elec., 14.76 (MMT/Quad) for gas
NOx emission factor:	0.531 (MT/GWh) for elec., 41.80 (1000MT/Quad) for gas
SOx emission factor:	2.449 (MT/GWh) for elec., 0.27 (1000MT/Quad) for gas
PM10 emission factor:	0.027 (MT/GWh) for elec., 3.37 (1000MT/Quad) for gas

Note: MT = metric tons; MMT = million metric tons

B.3 Sources

Sources used for obtaining the assumptions for each product is listed in Table B.3.

NOTE: These tables are available in hard copy. Contact the ACEEE publications office at 202-429-0063 or order online from the aceee.org website.