POWERFUL PRIORITIES:
Updating Energy Efficiency Standards for Residential Furnaces, Commercial Air Conditioners, and Distribution Transformers

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

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ABOUT THE APPLIANCE STANDARDS AWARENESS PROJECT

The Appliance Standards Awareness Project (ASAP) is a coalition group dedicated to advancing cost-effective energy efficiency standards for appliances and equipment. ASAP works at both the state and federal levels and is led by a Steering Committee with representatives from consumer groups, utilities, state government, environmental groups, and energy efficiency groups. ASAP was founded in 1998 by the American Council for an Energy-Efficient Economy, the Alliance to Save Energy, the Natural Resources Defense Council, and the Energy Foundation.

ASAP Steering Committee

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EXECUTIVE SUMMARY

New standards will soon be drawn up by the U.S. Department of Energy (DOE) increasing or establishing new minimum energy efficiency requirements for

- residential furnaces and boilers
- commercial central air conditioning
- distribution transformers

As this report seeks to demonstrate, the stakes are high in DOE's rulemaking process for these priority products. Important opportunities to save energy, reduce energy-related pollution, avoid power outages, and save consumers money will be considered and decided upon during the course of these regulatory proceedings.

Major Benefits from Energy Efficiency

If finalized in 2006, new standards for these products have the potential to provide cumulative energy savings worth **at least $22 *billion* (2004$)** to consumers and businesses. About 22,000 megawatts (MW) of summertime peak demand for electricity could be avoided by 2030, an amount equivalent to the output of over 70 average-size new power plants. Annual natural gas savings will grow steadily as well, reaching about 190 billion cubic feet in 2020 and about 300 billion cubic feet in 2030. These 2030 natural gas savings are equal to about 10% of current U.S. total natural gas imports.

Table ES-1. Energy and Economic Savings of Proposed Standards

Product Category	Annual Energy Savings (All Fuels) in 2030 (T. Btu)*	Summer Peak Electric Capacity Reduction in 2030 (MW)	Net Present Value ($ billion)
Residential Furnaces and Boilers	507	7,000	14.7
Commercial Air Conditioners and Heat Pumps	120	12,600	2.3
Distribution Transformers	186	2,600	5.4
Total—Three Product Categories	813	22,200	22.4

* T. Btu = trillion British thermal units. This measure enables us to combine electricity and natural gas savings into a single figure. For perspective, households in the United States used about 11,000 trillion Btus of energy in 2001, so the total savings estimated here (813 T. Btus) equal about 7% of all energy used in households in 2001.

Tables A-1 through A3 in the appendix show detailed state-by-state and overall national energy, economic, and environmental impacts for each of the three standards. Appendix Table A-4 shows the state-by-state and national impacts of the three priority standards taken together.

These savings are predicated upon prompt action by DOE to set standards that are both ambitious and readily attainable. If the Department opts for unnecessarily weak standards, or delays the standard-setting process further, these savings will be reduced. For example, we estimate that each year of delay locks in increased annual electricity use of 3.3 million megawatt hours (MWh) and increased annual natural gas use of 11 billion cubic feet for at least 15 years. On a cumulative basis (i.e., over the lifetimes of the additional inefficient products sold due to a delay), a year of delay increases energy consumption by 66 billion kilowatt-hours of electricity and 186 billion cubic feet of natural gas. At current prices, this much energy is worth about $7.1 billion.

As substantial as these savings appear to be, the economic benefits estimate is quite conservative. Real economic savings are likely to be greater for several reasons. First, for ease of analysis, energy costs were assumed to hold constant at 2003 levels. The cost of natural gas has already increased somewhat in 2004, and if energy costs were maintained or increased in future years, the monetary savings from efficiency standards would be greater than projected here. Secondly, there has been no attempt to monetize the substantial environmental benefits provided by efficiency standards. Similarly, the monetary benefit resulting from improved electric reliability has not been included in this estimate. Additionally, the savings from efficient commercial air conditioners is understated, since savings estimates are based upon average electricity prices, and the summer rates and demand charges typical for commercial customers were not included. Finally, these projected savings will be higher if the actual costs of achieving any of the standards are lower than forecast, as is likely to be the case.

In addition to saving consumers money, improvements in the energy efficiency of appliances and commercial equipment will aid in the resolution of several key energy-related concerns now facing the United States. For example, reducing peak electricity demand could help relieve overloaded electric grids. Since air conditioning is a leading contributor to peak demand during times of system vulnerability, improved central air conditioning efficiency must be a key part of the solution to reliability problems.

Improved energy efficiency will also help ease the looming natural gas supply problems that are projected to keep consumer gas bills high and threaten manufacturing job losses in the years ahead. Saving peak electricity is one of the fastest ways to reduce natural gas consumption. Because gas is disproportionately used for peak electricity generation, reducing electric cooling loads could have a significant impact on gas usage and price. Additionally, since half of all residential energy use is for space heating and most homes heat with natural gas, efficiency standards for new residential furnaces and boilers will have a positive impact on natural gas supplies.

Air pollution and climate change also remain important national concerns. Some 120 metropolitan areas are in nonattainment status for particulates, sulfur dioxide (SO_2), or ground-level ozone, or some combination of the three. Improving the energy efficiency of appliances and commercial equipment will help reduce these continuing threats to public health from criteria pollutants and will reduce emissions that contribute to global warming as well.

Energy Efficiency Standards Are Key to Energy Savings

Just as energy efficiency is an important tool for addressing current energy-related problems, energy efficiency standards for new appliances and equipment are a key strategy for securing major energy savings. Minimum efficiency standards ensure that energy-saving improvements are incorporated into all newly manufactured products, thereby removing the most inefficient models from the marketplace.

In its *Annual Energy Outlook for 2004*, the U.S. Energy Information Administration (EIA) cited appliance and equipment efficiency standards as one of four key factors that have contributed to slowing growth in electricity use over the past thirty years. Looking ahead, EIA cites the promulgation of additional efficiency standards as a key policy for keeping electricity demand growth in check between now and 2025. Based on analysis of U.S. Department of Energy (DOE) data, the national efficiency standards adopted to date cut U.S. electricity use by 2.5% in 2000, and these savings are predicted to reach 6.5 and 7.8% of total projected electricity use in 2010 and 2020, respectively. Estimates of peak load reductions are similarly impressive, with a 2.8% reduction achieved in 2000 and reductions of 7.6 and 12.6% estimated for 2010 and 2020, respectively. These remarkable savings will be worth about $186 billion to U.S. consumers for products purchased through 2030, or about $1,750 per household.

Support for Efficiency Standards Is Widespread

A broad consensus exists in support of energy efficiency standards for new appliances and commercial equipment. Efficiency standards began as state policy in the 1970s, with numerous states including Arizona, California, Connecticut, Florida, Massachusetts, and New York establishing their own standards. The adoption of standards by these states precipitated the development of national standards. The original statute establishing national energy efficiency standards was signed into law by President Reagan in 1987. New and revised standards have been issued under successive Republican and Democratic administrations. New efficiency standards have also drawn bipartisan support in Congress.

Most recently, the National Association of Regulatory Utility Commissioners (NARUC) adopted resolutions in support of both expanded state efficiency standards and upgraded national efficiency standards. NARUC specifically urged DOE "to expeditiously promulgate and implement new national standards for commercial air conditioners and heat pumps; residential furnaces and boilers; and electric distribution transformers that achieve the greatest level of cost-effective energy savings."

New Efficiency Standards Are Overdue

The current standards for residential furnaces and boilers were originally adopted in 1987 and have been in effect since 1992. Their initial revision was due in 1994, to take effect in 2002. The current standards for commercial air conditioners were contained in the Energy Policy Act of 1992 (EPAct). Subsequently, the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) published revised efficiency standards for commercial air conditioners in 1999, and under the law, DOE is directed to follow with a national standard either affirming the ASHRAE standard or strengthening it. EPAct also called for new standards for distribution transformers to be published by 1996. These statutory calls to action have all come and gone, without even a *draft* standard having been proposed by DOE.

Delays in setting standards for priority products are all the more unacceptable when viewed in the context of commercially available technology. None of the standards proposed here will require additional research and development to achieve or new technological breakthroughs to bring to market. To the contrary, products from most major manufacturers are on the market today that will meet the standards proposed here to take effect five years from now, at the earliest.

The recommendations and energy savings estimates contained in this report anticipate final efficiency standards for all three priority products in 2006, with effective dates of 2009 for distribution transformers, 2010 for commercial air conditioners, and 2011 for residential furnaces and boilers. In light of previous delays, these dates represent the most expeditious implementation schedule possible consistent with the terms of the appliance standards laws and regulations.

Key Findings and Recommendations

The following are the key findings and recommendations of this report.

Standards for Residential Furnaces and Boilers

Space heating comprises a large portion of energy use in most American homes. Nationwide, about 50% of residential energy use is devoted to space heating, and altogether, about 70% of U.S. households heat with a furnace or boiler. Each year, over 3 million new furnaces and boilers are sold. Furnaces sold today can be expected to remain in service for an average of 18 years, and boilers last 25 years on average. Prompt action to strengthen efficiency standards for residential furnaces and boilers will quickly bring savings to millions of households. And since the vast majority (about 85%) of furnaces and boilers sold use natural gas or propane, stronger standards for these products will help temper future fluctuations in the supply and price of natural gas.

Energy efficiency standards for new residential furnaces and boilers should be set as follows:

- Raise the minimum efficiency for most types of furnaces and boilers by 4 to 9% (to 81 to 86% AFUE), varying by product type as noted in Table 3 (p. 22).
- Set a 90% AFUE standard (a 15% improvement that is readily achieved by condensing furnaces on the market today) for all gas and propane furnaces sold in 30 cold-weather states, as illustrated in Figure 3 (p. 21).
- Set a national standard for furnace fans that will reduce fan energy use by an average of about 60%.

Standards for Commercial Air Conditioners

Space cooling has been found to be the largest use of electricity in commercial buildings, comprising over 25% of their electric consumption in 1999. The energy savings potential of the commercial air conditioning market is significant, since there are more than four million commercial buildings in the United States. Over half of all commercial buildings (by square footage) and over two-thirds of all buildings with electric space cooling were served by packaged air conditioners in 1999. What's more, commercial air conditioners are a major contributor to peak demand levels. Summer peak demand is currently forecast to continue growing at an average rate of approximately 14,500 MW per year, or about 1.9% annually, through 2012. This *annual* growth is equivalent to the capacity of nearly 50 power plants of 300 MW each.

Energy efficiency standards for new commercial central air conditioners and heat pumps should be set approximately at the minimum life-cycle cost point, as follows.

- Standards for equipment with cooling capacity of 65,000 Btu/hr up to 135,000 Btu/hr should be increased by about 13% over current ASHRAE levels, as follows.
  - Air conditioner only or unit with electric resistance heat—11.7 EER
  - Air conditioner with gas or other heating—11.5 EER
  - Heat pump—11.5 EER

- Standards for equipment with cooling capacity of 135,000 Btu/hr up to 240,000 Btu/hr should be increased by about 19% over current ASHRAE levels, as follows.
  - Air conditioner only or unit with electric resistance heat—11.5 EER
  - Air conditioner with gas or other heating—11.3 EER
  - Heat pump—11.1 EER

Standards for Distribution Transformers

Distribution transformers reduce the voltage of an electric utility's power distribution line to the lower voltages suitable for most of the equipment, lighting, and appliances in businesses and homes. In 1996, an estimated 40 million distribution transformers were located within utilities' electric distribution systems, and about 16 million additional transformers were located on private commercial and industrial premises. More than 1.5 million new distribution transformers are purchased and installed each year, many of them by construction contractors equipping new commercial buildings for which they will never pay the electric bills. Distribution transformers are constantly energized, and they constantly experience some energy losses. Even small changes in transformer efficiency can add up to large energy savings. Improving transformer efficiency means that a larger portion of the power generated in power plants will reach the point in the electric system where it is put to work.

Energy efficiency standards for new distribution transformers should be set at the following efficiency levels.

- Low-voltage dry-type (single-phase and three-phase): levels in NEMA standard TP-1
- Medium-voltage dry-type (three-phase): levels of NEMA TP-1 plus 0.3%
- Medium-voltage liquid-immersed (three-phase): levels of NEMA TP-1 plus 0.2%
- Medium-voltage liquid-immersed (single-phase): levels of NEMA TP-1 plus 0.1%.

Other Products and Standards

In addition to the three product categories featured in this report, there are several other existing federal efficiency standards that should be upgraded without delay. Opportunities and recommendations for residential refrigerators and dishwashers, reflector incandescent lamps, commercial boilers, packaged terminal air conditioners, and small commercial central air conditioners are discussed in the final section of this report.

INTRODUCTION

Since the enactment of the National Appliance Energy Conservation Act of 1987 (Public Law 100-12), the U.S. Department of Energy (DOE) has had the authority and the responsibility to establish minimum energy efficiency standards for a wide variety of consumer products and commercial equipment. To date, standards have been set for eleven types of consumer products and ten types of commercial equipment. Under the law, DOE's existing standards are to be revised and strengthened to maximize energy efficiency where technically feasible and economically justified (DOE 2004a).

In each of the past three years, DOE has designated three product categories as "high priority" for the establishment of new or revised energy efficiency standards (DOE 2003a). These three product categories are

- residential furnaces and boilers
- commercial central air conditioning
- distribution transformers

As this report seeks to demonstrate, the stakes are high in DOE's rulemaking process for these priority products.

Major Benefits from Energy Efficiency

New energy efficiency standards will soon be drawn for residential furnaces and boilers, commercial air conditioners, and distribution transformers. These standards may bring greater or lesser value to consumers and society, depending on the final regulatory decisions made by DOE. Important opportunities to save energy, reduce energy-related pollution, avoid power outages, and save consumers money will be considered and decided upon during the course of these three arcane regulatory proceedings at DOE.

If finalized in 2006, these three new rules taken together have the potential to provide cumulative energy savings worth **at least $22 *billion* (2004$)** to consumers and businesses.[1] About 22,000 MW of summertime peak demand for electricity could be avoided by 2030, an amount equivalent to the output of over 70 average-size new power plants. Annual natural gas savings will grow steadily as well, reaching about 190 billion cubic feet in 2020 and about 300 billion cubic feet in 2030.[2] These 2030 natural gas savings are equal to about 10% of current U.S. total natural gas imports or about double current imports of liquefied natural gas (LNG).

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[1] These savings are net of (or in excess of) the estimated costs of the incremental product improvements needed to achieve the proposed efficiency standards.

[2] Natural gas savings estimates include savings directly from reduced use in furnaces and boilers and also savings from reduced use to generate electricity. We calculate the natural gas portion of electricity savings based on the midpoint of U.S. Energy Information Administration projections for the natural gas portion of electric generation mix and the natural gas portion of electric system capacity additions. For 2030, we use 2025 projections since EIA projections for 2030 are not available.

Tables 1 and 2 below summarize the impacts of the standards recommended by this report. Tables A-1 through A-3 in the appendix show detailed state-by-state and overall national energy, economic, and environmental impacts for each of the three standards. Table A-4 shows the impacts of the three priority standards taken together.

Table 1. National Energy and Economic Savings from New Standards

	Annual Savings in 2030			Cumulative for Products Sold Through 2030	
	Natural Gas Savings[a] (cubic feet)	Electricity Savings (kWh)	Peak Electricity Demand Savings	Net Present Value (2004$)	Benefit-Cost Ratio
Residential Furnaces and Boilers					
• *Increase minimum thermal efficiency (i.e., AFUE rating)*	*41 billion*	*NA*	*NA*	*$2.4 billion*	*3.2*
• *Set stronger gas furnace standard for "cold" states*	*146 billion*	*NA*	*NA*	*$3.5 billion*	*1.9*
• *Set furnace fan efficiency standard*	*NA*	*30 billion*	*7,000 MW*	*$8.7 billion*	*4.2*
Residential Furnaces and Boilers (Subtotal)	187 billion	30 billion	7,000 MW	$14.6 billion	2.9
Commercial Air Conditioners	NA	12 billion	12,600 MW	$2.3 billion	2.1
Distribution Transformers	NA	18 billion	2,600 MW	$5.4 billion	3.3
TOTAL: All Products	187 billion	60 billion	22,200 MW	$22.3 billion	

[a] Natural gas savings reported in this table include direct savings in furnaces and boilers only.
NA = not applicable

These savings are predicated upon prompt action by DOE to set standards that are both ambitious and readily attainable. If the Department opts for unnecessarily weak standards, or delays the standard-setting process further, these savings will be reduced.

As substantial as these savings appear to be, this estimate is quite conservative. Real economic savings are likely to be greater for several reasons. First, for ease of analysis, energy costs were assumed to hold constant at 2003 levels. The cost of natural gas has already increased somewhat in 2004, and if energy costs were maintained or increased in future years, the monetary savings from efficiency standards would be greater than projected here. Secondly, there has been no attempt to monetize the substantial environmental benefits provided by efficiency standards. The avoidance of emissions certainly has value, but has not been quantified here. Similarly, the monetary benefit resulting from improved electric reliability has not been included in this estimate, although California's recent experience suggests a multi-billion dollar benefit from avoidance of blackouts (Bachrach, Ardema & Leupp 2003). Additionally, the savings from efficient commercial air conditioners is understated, since savings estimates are based upon average electricity prices, and the summer rates and demand charges typical for commercial customers were not included. Finally, these projected savings will be higher if the actual costs of achieving any of the standards are lower than forecast, as is likely to be the case. There is a lengthy record of both DOE and product manufacturers significantly overstating the cost of standards compliance.[3]

In addition to saving consumers money, improvements in the energy efficiency of appliances and commercial equipment will aid in the resolution of several key energy-related concerns now facing the United States. For example, reducing electricity demand could help relieve overloaded electric grids. On August 14, 2003, heavy air conditioning loads in northern Ohio caused electric transmission lines to sag, coming into contact with trees and setting off the largest power blackout in U.S. history (U.S.-Canada Power System Outage Task Force 2003). Increased peak demand is at the heart of electric reliability problems, so efficiency standards designed to reduce peak demand are an important part of any strategy to improve electric system reliability. Since air conditioning is a leading contributor to peak demand during times of system vulnerability, improved central air conditioning efficiency must be a key part of the solution to our reliability problems.

Electric efficiency will also help ease the looming natural gas supply problems that are projected to keep consumer gas bills high and threaten manufacturing job losses in the years ahead (Elliott et al. 2003). Over the past 15 years, natural gas has assumed an increasingly significant role in domestic electricity markets, now generating around 15% of the nation's power. Electric power generation accounted for 22.5% of total U.S. natural gas consumption in 2003, compared with 16.2% in 1989 (EIA 2004g). As available supplies of natural gas have leveled off in North America, some have called for increasing imports of liquefied natural gas (Greenspan 2003). However, saving peak electricity is one of the fastest ways to reduce natural gas consumption. Because gas is disproportionately used for peak electricity generation, reducing electricity used for cooling could have a significant impact on gas usage and price.

Air pollution also remains an important national concern. Some 120 metropolitan areas are in nonattainment status regarding national air quality standards for either particulates, sulfur dioxide, or ground-level ozone, or some combination of the three (EPA 2004). Emissions from electric power plants, particularly the nation's aging coal-fired power plants grandfathered under the Clean Air Act, are a major contributor to each of these pollutants. Fine particle pollution attributable to U.S. power plants results in an estimated 30,000 premature deaths each year (Clean Air Task Force 2000). Improving the energy efficiency of appliances and commercial equipment is a cost-effective way to reduce these continuing threats to public health.

An additional dividend of energy efficiency standards is a predictable reduction in carbon dioxide emissions, a principal contributor to global warming. These reductions are achieved essentially without cost when standards are adopted on the basis of energy cost savings alone. These emission reductions will become increasingly important in any US strategy to reduce CO_2 emissions.

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[3] See the sidebar on pages. 32–33 for further discussion of the record of overstated compliance costs.

Table 2. National Pollutant Emission Reductions from New Standards (Annual Reductions in 2030)

	Carbon[a] (million metric tons)	Nitrogen Oxides (metric tons)	Sulfur Dioxide (metric tons)	PM10 (particulates) (metric tons)
Residential Furnaces and Boilers (All Three Standard Components)	8.8	29,000	79,100	15,000
Commercial Air Conditioners	2.3	5,800	28,000	340
Distribution Transformers	3.6	10,600	45,800	560
TOTAL: All Products	14.4	45,400	152,900	16,000

[a] To convert carbon to carbon dioxide, multiply by 3.67.

Energy Efficiency Standards Are Key to Energy Savings

Just as energy efficiency is an important tool for addressing current energy-related problems, energy efficiency standards for new appliances and equipment are a key strategy for securing major energy savings. Minimum efficiency standards ensure that energy-saving improvements are incorporated into all newly manufactured products, thereby removing the most inefficient models from the marketplace.

New or revised efficiency standards make sense when products with improved efficiency are available and cost-effective for consumers, but where sales of inefficient products persist due to any of several barriers or imperfections in the marketplace. These barriers most often consist of a lack of knowledge of the cost-saving potential of energy-efficient models; financial accounting and management procedures that overlook life-cycle cost comparisons by focusing purchasing decisions on first costs; and division of responsibility between those who make purchasing decisions—e.g., landlords—and those who pay the utility bills—e.g., tenants (Kubo, Sachs & Nadel 2001). Each of these market barriers to more widespread use of efficient products can be overcome with the adoption of energy efficiency standards.

The national efficiency standards adopted to date have accomplished much, and their benefits will grow substantially as inefficient products are gradually replaced by more efficient products meeting the standards. In its *Annual Energy Outlook for 2004*, the U.S. Energy Information Administration (EIA) cites appliance and equipment efficiency standards as one of four key factors that have contributed to slowing growth in electricity use over the past thirty years. Looking ahead, EIA cites the promulgation of additional efficiency standards as a key policy for keeping electricity demand growth in check between now and 2025 (EIA 2003a).

A recent estimate of the effects of appliance standards adopted from 1987 through 2001 found that standards had already cut U.S. electricity use by 2.5% in 2000, and that these savings would reach 6.5 and 7.8% of total projected electricity use in 2010 and 2020, respectively. Estimates of peak load reductions were similarly impressive, with a 2.8% reduction achieved in 2000 and reductions of 7.6 and 12.6% estimated for 2010 and 2020, respectively. These remarkable savings will be worth about $186 billion to U.S. consumers for products purchased through 2030, or about $1,750 per household (Geller, Kubo & Nadel 2001).

Support for Efficiency Standards Is Widespread

Notwithstanding the occasional controversy over a specific product or efficiency level, a broad consensus remains in support of energy efficiency standards for new appliances and commercial equipment. Efficiency standards began as state policy in the 1970s, with numerous states including Arizona, California, Connecticut, Florida, Massachusetts, and New York establishing their own standards.[4] The adoption of standards by these states encouraged the development of national standards. The original statute establishing national energy efficiency standards was signed into law by President Reagan in 1987. New and revised standards have been issued under successive Republican and Democratic administrations. Policy support for these decisions has come from groups as diverse as the Interlaboratory Working Group (2000), the National Petroleum Council (2003), the State Public Interest Research Groups (2001), and the National Energy Policy Development Group (2001)—the so-called "Cheney Task Force." New efficiency standards have also drawn bipartisan support in Congress. One of the least controversial elements of the pending Energy Policy Act of 2003, which has stalled in Congress due to a variety of highly controversial provisions, would specify new efficiency standards for six categories of consumer and commercial products and would direct DOE to undertake rulemakings on four additional products (U.S. House of Representatives 2003).

Most recently, the National Association of Regulatory Utility Commissioners (NARUC) adopted resolutions in support of both expanded state efficiency standards and upgraded national efficiency standards. NARUC specifically urged DOE "to expeditiously promulgate and implement new national standards for commercial air conditioners and heat pumps; residential furnaces and boilers; and electric distribution transformers that achieve the greatest level of cost-effective energy savings" (NARUC 2004).

New Efficiency Standards Are Overdue

NARUC's concern for "expeditious" action by DOE is well placed. The current standards for residential furnaces and boilers were originally adopted in 1987 and have been in effect since 1992. Their initial revision was due in 1994, to take effect in 2002. The current standards for commercial air conditioners were contained in EPAct. Subsequently, ASHRAE published revised efficiency standards for commercial air conditioners in 1999, and under the law, DOE is directed to follow with a national standard either affirming the ASHRAE standard or strengthening the ASHRAE standard. EPAct also called for new standards for distribution transformers to be published by 1996. These statutory calls to action have all come and gone, without even a *draft* standard having been proposed by DOE.

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[4] States are once again establishing state standards. In 2002, California created new state standards for products not covered by federal law, and Maryland and Connecticut enacted new efficiency standards laws of their own in 2004. Legislation is actively pending in several other states.

After establishing its priorities for the appliance standards rulemaking process, DOE will take each proposed regulation through three specific steps. These are the Advanced Notice of Proposed Rulemaking (ANOPR), the Notice of Proposed Rulemaking (NOPR), and the Final Rule. The first two of these steps produce documents that are available for public review and comment. Upon publication of the ANOPR, DOE will also release a draft Technical Support Document (TSD) laying out potential energy efficiency levels for a product, the technology configurations that are available to achieve each level, and the benefits and costs of achieving each level. Subsequently, the NOPR will contain a specific proposed efficiency level for the product, i.e., an efficiency standard, and explain the basis for the selection (DOE 1996). ANOPRs and TSDs were belatedly issued for the three priority product categories that are the subject of this report in August of 2004.

Delays in setting these standards are all the more unacceptable when viewed in the context of commercially available technology. The standards proposed here will not require additional research and development to achieve nor further technological breakthroughs to bring to market. To the contrary, products from most major manufacturers are on the market today that will meet

DOE's Costly Delays

Each of the standards evaluated for this report are overdue. DOE missed legal deadlines for two of the three standards in the 1990s, and since 2001, when the agency designated these three products its “high priorities,” DOE has repeatedly missed self-imposed deadlines. These delays are costly. Each year that new standards are delayed means that millions more inefficient furnaces, commercial air conditioners, and electric distribution transformers that will stay in use for decades are sold and installed. Based on the analysis for this report, we estimate that each year of delay locks in increased annual electricity use of 3.3 million MWh and increased annual natural gas use of 11 billion cubic feet for at least 15 years. (We assume that each year of delay in the rulemaking delays a new standard’s implementation and the onset of benefits resulting from that standard by one year. The effect of a delay lingers for the life of the equipment purchased during the delay period—15 to 30 years for the products covered by this report. Note that the effect is cumulative. For example, after three years of delay, the total cumulative electricity savings forgone is six times the savings forgone in just the first year.) On a cumulative basis (i.e., over the lifetimes of the additional inefficient products sold due to a delay), a year of delay increases energy consumption by 66 billion kilowatt-hours of electricity and 186 billion cubic feet of natural gas. At current prices, this much energy is worth about $7.1 billion.

When Congress created efficiency standards for products in 1987, it required DOE to review most standards on a set schedule. Based upon these reviews, DOE is required by statute to set new standards at levels that “achieve the maximum improvement in energy efficiency ….which the Secretary determines is technologically feasible and economically justified” [42 U.S.C. 6295(o)2(a)].

By the mid-1990s, DOE had already fallen behind the schedule set by law. In 1996, DOE established a formal set of procedures for reviewing and upgrading standards. Under the procedures, the Department prioritizes among its various potential standard rulemakings subject to certain criteria. In essence, these criteria require the agency to grant highest priority to those proceedings that offer the greatest potential energy and economic benefits. Once DOE initiates a rulemaking, the appliance standards laws and DOE procedures require three official steps: an Advanced Notice of Proposed Rulemaking (ANOPR) provides initial technical and economic analysis and lays out options for different possible standard levels;

the standards proposed here to take effect five years from now, at the earliest.

the Notice of Proposed Rulemaking (NOPR) proposes a new standard for public comment based on the Department's economic and technical analyses; and the final rule establishes the new standard. Typically, the new standard goes into effect three to five years later. According to the Department's procedures, the entire process should take three years—18 months to publish the ANOPR and another 18 months for the NOPR and final rule publication.

In 2001, DOE determined that the three standards evaluated for this report—those for residential furnaces and boilers, commercial air conditioners, and electric distribution transformers—would be its "high priority" standards. That year, DOE published a schedule that called for completing the standards within the three-year timeframe required by the agency's procedures (i.e., by the fall of 2004). Each year since 2001, DOE has reiterated the "high priority" status of these standards. But, instead of getting the ANOPRs completed, for each year that has gone by, DOE simply has pushed its deadlines six months to one year into the future. Since 2001, DOE has missed eighteen self-imposed deadlines for advancing these standards and has not met one.

DOE's failure to stick to its own schedule for advancing these standards means that the agency has fallen even further behind the original legal deadlines set by Congress. The appliance standards law requires DOE to complete the furnace standard review by January 1994 and requires DOE to establish the standard for electric distribution transformers by 1996. DOE's revision of the commercial air conditioner standard was triggered by the agency's January 2001 determination that the voluntary standard established by the American Society of Heating, Refrigeration and Air-conditioning Engineers in 1999 fell short of legislated requirements. This standard is not subject to a specific deadline, but a timely review would suggest that it should be completed within three years of the 1999 change to the ASHRAE standard.

The costs imposed by the delays on the high priority rules are compounded since other standards revisions required by law are pushed even further off into the future. Altogether, as of June 2004, DOE has missed legally required deadlines for reviewing and upgrading twelve standards in addition to those evaluated for this report. For many of these products, DOE has already missed two legal deadlines.

Delays in completing standards for priority products further compound themselves into delays in setting standards for other products that are ready for attention. Good opportunities now exist for savings in residential refrigerators and dishwashers, reflector incandescent lamps, commercial boilers, packaged terminal air conditioners, and small commercial central air conditioners; and recommendations for these products are made in the final section of this report.

The recommendations and energy savings estimates contained in this report anticipate the publication of final efficiency standards for all three priority products in 2006, with effective dates of 2009 for distribution transformers, 2010 for commercial air conditioners, and 2011 for residential furnaces and boilers. In light of previous delays, these dates represent the most expeditious implementation schedule possible consistent with the terms of NAECA.

RESIDENTIAL FURNACES AND BOILERS

Space heating comprises a large portion of energy use in most American homes. Nationwide, about 50% of residential energy use is devoted to space heating, and altogether, about 70% of U.S. households heat with a furnace or boiler (EIA 2004a).[5] Each year, over 3

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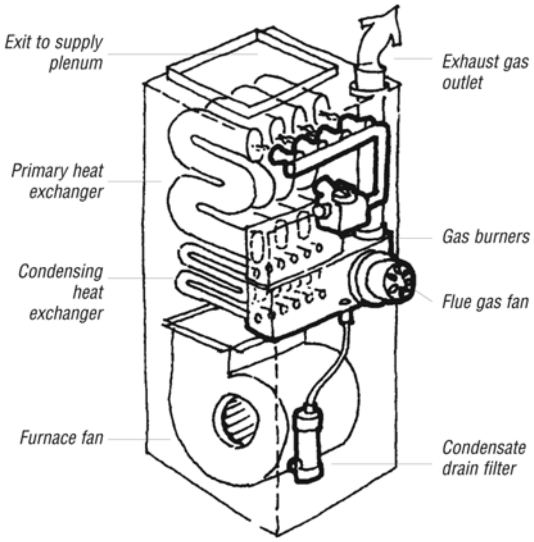
[5] The remainder may use an electric heat pump, electric resistance baseboard heating, or room heaters.

million new furnaces and boilers are sold (Kendall 2002). Furnaces sold today can be expected to remain in service for an average of 18 years, and boilers last 25 years on average (DOE 2001). Prompt action to strengthen efficiency standards for residential furnaces and boilers will quickly bring savings to millions of households. And since the vast majority (about 85%) of furnaces and boilers sold use natural gas or propane,[6] stronger standards for these products will help temper the effects of future fluctuations in the supply and price of natural gas.

Technology Description: Basic Furnaces and Boilers vs. Efficient Technology

Furnaces and boilers contain a gas, oil, or propane burner; a combustion chamber where the fuel is burned; a heat exchanger where the heat from combustion is transferred to water or air that is circulated into the living space; an electric fan or pump to circulate air or water through the heat exchanger and throughout the house; and a flue to exhaust combustion gases. The majority of houses in the United States use fans and ducts to circulate warm air around the house—*furnaces* heat this air. Figure 1 shows the various parts of a typical high-efficiency furnace. Some houses circulate hot water or steam through radiators or baseboard heaters—*boilers* heat this water (see Figure 2).

Figure 1. A High-Efficiency Residential Furnace



Furnaces and boilers now being sold in the United States are subject to federal efficiency standards enacted by Congress in 1987. As a result of the 1987 standard, furnaces and boilers available today generally include an electronic ignition (instead of a pilot light), fan-induced draft (which gives better combustion and limits the amount of warm air that escapes up the flue), and more efficient heat exchangers than were previously used. However, the efficiency of furnaces and boilers can be improved even further, primarily by adding a second heat exchanger to collect even more heat. In addition, with furnaces, a high-

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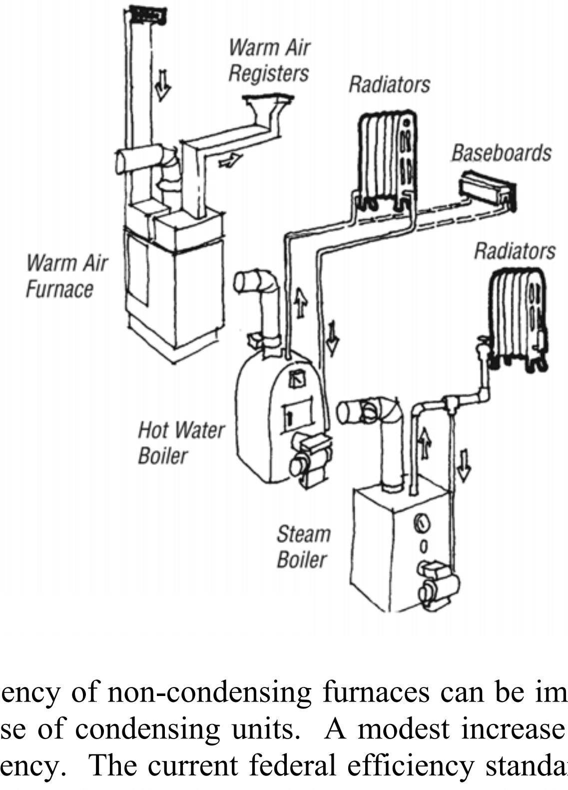
[6] Another 6% of residential furnace and boiler sales are oil-fired units, mostly in the Northeast. Remaining units are mostly electric furnaces, with an electric resistance heater in place of the burner (Kendall 2002).

efficiency fan can be used to move the warmed air through a home's duct system, since the fans that now come with most new furnaces are not very efficient.

Furnaces and boilers generally fall into two classes—condensing and non-condensing. Condensing furnaces and boilers add a secondary heat exchanger to cool the exhaust gases to less than 140°F. This leads the water vapor in the exhaust, a normal product of combustion, to condense out and yield additional heat to help heat a house. The condensed water is drained or pumped to a suitable disposal such as a drain. Condensing furnaces generally have an efficiency of 90 to 95%, meaning around 90 to 95% of the heat in the fuel is used to heat a home and only 5 to 10% is exhausted out the flue. This is much better than a conventional new furnace or boiler, which typically has an efficiency of 80%. However, adding the extra heat exchanger raises the cost of the unit. In addition, the condensed water vapor is somewhat corrosive, due to various elements in the fuel, so special steels and plastics must be used where the condensate gathers. As a result, condensing furnaces and boilers cost more, but this cost is generally paid back in a few years in parts of the country that have cold winters. In warm regions, condensing furnaces and boilers are generally not cost-effective, as the heating season is too short to justify the added expense of a condensing unit.

Figure 2. Residential Furnaces and Boilers



Even the efficiency of non-condensing furnaces can be improved somewhat, without getting into the expense of condensing units. A modest increase in the heat exchange area yields improved efficiency. The current federal efficiency standard for gas and oil furnaces is 78% AFUE (annual fuel utilization efficiency—a standardized measure of efficiency averaged throughout the heating season). However, according to manufacturer data, very few units are sold with AFUE below 80%. The efficiency standard can be raised slightly, to 81% for gas furnaces and to 84% for oil furnaces without getting into condensing operation.

Likewise, the current federal efficiency standard for gas and oil-fired hot water boilers is 80%. Based on recent sales data, it appears that this efficiency can be raised to about 86% for oil boilers and 84% for gas boilers.[7] Levels for steam boilers will need to be set slightly lower.

As noted above, there is also a major opportunity to improve the efficiency of fans that come with furnaces. Although there have been numerous advances in electric motors in recent years, the typical furnace fan sold today is not very efficient. A large one may use more than 1,000 kWh per year just for heating—nearly twice as much electricity as is used by a typical new refrigerator—plus additional electricity in the cooling season in homes with central air conditioning. (A house with a furnace and a central air conditioner uses the same air handling system—fan and ducts—for heating and cooling, but the fan is typically a component of the furnace.) In particular, these fans waste a lot of energy when they are not operated at full-speed, as is common during the heating season. Fans generally operate at full speed only when used in conjunction with air conditioners, due to the need to circulate greater quantities of air during the cooling season to maintain comfortable temperatures.

High efficiency fans generally use advanced designs such as permanent magnet motors, which offer very high efficiency at full speed, but more importantly, have only modest efficiency losses at the lower speeds where furnace fans often operate. Such fans are now on the market and reduce heating season fan energy use by about 65%, saving about 500 kWh/year on average. These same fans reduce cooling season fan energy use by about 200 kWh/year in homes with air conditioning (Sachs & Smith 2003).[8,9] Industry experts estimate that high efficiency fans are now included with about 5% of furnace sales, mostly in high-end condensing furnaces.

Proposed National Standards for Residential Furnaces and Boilers

The current federal efficiency standard for furnaces and boilers does not cover electrical energy used by the furnace fan or boiler pump that moves the warmed air (or in the case of boiler pumps, warmed water) to where heat is needed. As noted above, electrical energy consumption of furnace fans can exceed 1,000 kWh per year, making the furnace fan one of the largest electricity users in most homes. Since DOE has the authority to set efficiency standards for all types of residential furnaces, it may set an efficiency standard that is specific to the fan component of a residential furnace.

Additionally, the superior performance of condensing furnaces in cold climates supports establishing an efficiency standard *specifically for products offered for sale and installation in cold weather states*. While this would be a new approach to federal standard-

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[7] According to GAMA data, units with AFUEs of 86 and 87% accounted for 14% of oil boiler sales in 2000. For gas boilers, units with AFUEs of 84 and 85% accounted for 9% of gas boiler sales in 2000 (Kendall 2002).

[8] Savings are even greater in homes that run their furnace fans continuously to ventilate their homes, although for most homes, continuous ventilation is not needed.

[9] In the case of electric furnaces, high efficiency fans primarily save during the cooling season, since during the heating season an inefficient fan produces the same amount of heat per kWh used as an electric resistance heater.

setting, efficiency criteria for several weather-sensitive products, such as residential windows, doors, and skylights, are already set on a geographically specific basis by ENERGY STAR®. Currently, the federal furnace standards include special classes for mobile home furnaces and furnaces below a certain size. One approach for establishing a standard for cold weather states would be to recognize that furnaces sold in these states constitute a class of products deserving of its own efficiency standard.

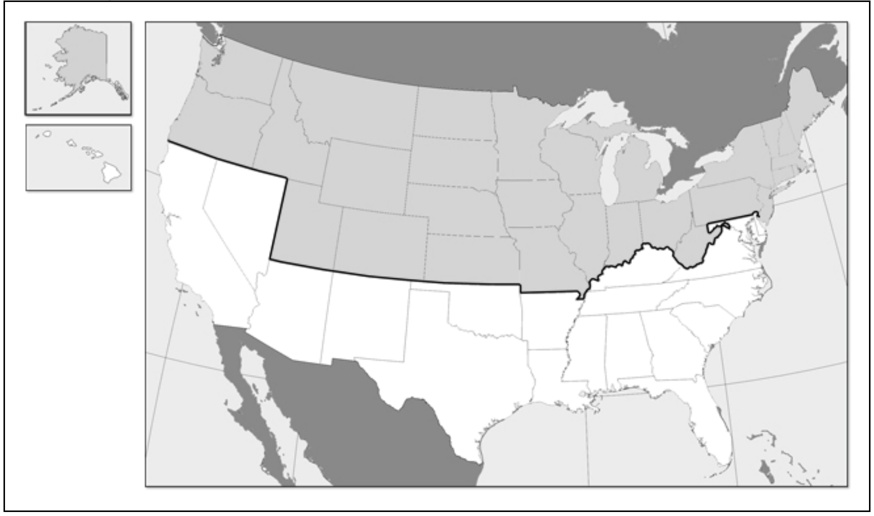
Accordingly, we recommend that a new federal efficiency for residential furnaces and boilers standard contain three components as follows:

- Raise the minimum efficiency for furnaces and boilers to 81 to 86% AFUE (varying by product type—specific recommendations are provided in Table 3 below) in order to capture the additional savings available from improved, non-condensing operation.

- Set a 90% AFUE standard, a level that is readily achieved by condensing furnaces on the market today, for all gas and propane furnaces sold in 30 cold-weather states (i.e., states with more than 5,000 average heating degree days).[10] See Figure 3 below.

- Set a national standard for furnace fans that will reduce fan energy use by an average of about 60%. One (but not the only) possible approach is provided in a report prepared for the California Energy Commission (DEG/ACEEE 2004). Such a standard would reduce typical fan energy use in homes with heating and cooling from roughly 1,300 kWh to about 600 kWh.

Figure 3. Cold Weather States:
Geographic Scope of Proposed 90% AFUE Furnace Standard



Note: 30 states with more than 5,000 average heating degree days

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[10] DOE's Building America program classifies climates of 4,500 heating degree days (HDD) or more as "cold" (see www.eere.energy.gov/buildings/building_america/climate_zones.html). Using a more conservative 5,000 HDD ensures cost-effectiveness in each state, as well as for the proposal as a whole. The 30 states so classified on a population-weighted basis include CO, ID, IN, IL, KS, MO, NJ, OH, OR, PA, UT, WV, and those more northerly. The 20 states that fall outside this classification include AR, AZ, CA, DE, KY, MD, NM, NV, OK, VA, and those more southerly (NOAA 2002a).

The proposed standards listed below are based on products now on the market that already have significant sales, according to sales data provided to DOE by the Gas Appliance Manufacturers Association (Kendall 2002).

Table 3. Current and Proposed Residential Furnace and Boiler Efficiency Standards

Product Type	Current Standard (AFUE)	Proposed Standard (AFUE)
Gas & propane furnaces	78%	81% (90% for cold weather states)
Oil furnaces	78%	84%
Gas & propane hot water boilers	80%	84%
Oil-fired hot water boilers	80%	86%
Gas & propane steam boilers	75%	82%
Oil-fired steam boilers	80%	84%
Furnace fans	none	6.8%[a,b]

[a] The proposed furnace fan standard is expressed as the percentage of the total annual furnace gas and electricity use (with electricity use calculated on a primary basis) that is attributable to furnace electricity use alone—primarily the fan. Today's typical product uses 9.2% of the total annual energy consumption of the appliance, while a typical product meeting this standard uses 4%.

[b] Alternative levels are appropriate for very small and very large equipment.

Pros and Cons of Efficient Furnaces and Boilers

In its recently published Advanced Notice of Proposed Rulemaking, DOE stated that it lacks authority to set separate standards for furnaces in cold and warm states and to set a performance standard for furnace fans (DOE 2004d). We disagree. DOE bases its argument on narrow semantic grounds while ignoring other relevant parts of the law. For example, one section of the law directs the Secretary of Energy to set standards that are "designed to achieve the maximum improvement in energy efficiency ... which the Secretary determines is technologically feasible and economically justified." [42 USC 6297(2)(A)]. If separate standards for cold and warm states allow maximum savings that are economically justified, as determined by the Secretary, then the Secretary has the discretion to do so. Another section permits the Secretary to amend test procedures, "if the Secretary determines that amended procedures would more accurately or fully ... produce results which measure energy efficiency, energy use ... or estimated annual operating cost of a covered product during a representative average use cycle or period of use, as determined by the Secretary ..." (42 USC 6293). Since the current test procedure ignores furnace electricity use, it underestimates furnace energy use and a new test procedure that includes this energy use would produce more accurate results. Such an amended test procedure is clearly within the Secretary's discretion.

Efficient furnaces and boilers can save an enormous amount of energy and, by extension, reduce gas and electricity bills for consumers. If the AFUE values recommended above are adopted, simple payback periods to the consumer would range from about 1.5–8.0 years. Details are provided in Table 4. More efficient furnace fans have a simple payback of about 2.9 years.

Table 4. Economics of Heating System Improvements

System Type & Efficiency	Annual Fuel Savings	Annual Energy Bill Savings	Typical Incremental Product Cost	Simple Payback (years)
Gas furnace (81% AFUE)	8 therms	$8	$30	3.8
Gas furnace (90% AFUE)	79 therms (in colder than average climates[11])	$75	$450	6.0
Gas boiler (84% AFUE)	32 therms	$31	$249	8.0
Oil furnace (84% AFUE)	30 gallons	$41	$202	4.9
Oil boiler (86% AFUE)	44 gallons	$60	$91	1.5
Efficient furnace fan	625 kWh (but uses 20 more therms of gas)	$35	$100	2.9

Based on average U.S. residential prices of $0.087/kWh (EIA 2004d), $0.95/therm of gas (EIA 2004e), and $1.53/gallon of oil (EIA 2004f). Savings and costs are ACEEE estimates based on data in RECS 97 (EIA 1999b), DOE furnace spreadsheet (DOE 2002), and Sachs & Smith (2003).

In addition to direct energy and monetary savings, the more efficient furnace fans tend to be quieter and to distribute heat throughout a home more evenly. Today's typical fans tend to start and stop frequently, as they have only three operating modes—medium speed (used when the thermostat is set to "heat"), high speed (used when the thermostat is set to "cool"), and off. The more efficient fans tend to vary their speed (either continuously or in steps) as a function of the need for heating (or cooling) and will operate at low speed for long periods of time, providing relatively quiet and even heat distribution.

Achieving these improvements will require a modest increase in the initial cost of a new furnace or boiler. Currently a new furnace generally costs about $3,285 installed (DOE 2002). For a non-condensing furnace with an efficient fan, the cost premium will typically be around $130 in a market that is fully price-competitive, a price increase of about 4% relative to a typical furnace sold today.[12] Once established as a required standard in cold weather states, a condensing furnace meeting the 90% AFUE standard will show a likely price increase of around $550 ($450 to meet the higher AFUE standard and about $100 for the more efficient fan), a roughly 17% price increase. While this price increase is substantial, the simple payback period in cold climates is about five years including both the higher AFUE and the better fan. For other types of equipment, the price increase ranges from 3% (for an oil boiler) to 6% (for an oil furnace) to 9% (for a gas boiler).

Another possible drawback from the manufacturers' perspective is that currently condensing furnaces with quiet, efficient fans are marketed as premium, highly profitable products. Manufacturers often charge large price premiums for these premium units—well in excess of production costs. Manufacturers earn a disproportionate share of their profits on such premium products, while low-cost, low-efficiency models sold to the most price-sensitive buyers earn relatively little profit. Once high efficiency products are the minimum

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[11] Based on average consumption in areas with more than 5,000 HDD (EIA 1999b).

[12] See the sidebar on pages 24–25 for further discussion of how standards tend to bring down the costs of high efficiency equipment.

required by law, increased competition between manufacturers to provide these units to price sensitive consumers combined with economies of scale will likely drive the price down. This trend can already be seen in northern states with high sales of condensing units. For example, incremental costs of condensing furnaces declined from about $1,000 to $465 in Wisconsin as market share increased due to competition among suppliers and manufacturers and to growing contractor familiarity with equipment and installation practices (Hewitt 2000). In our opinion, manufacturers can address this problem by identifying new ways to differentiate high quality units in the market and charge a price premium for those units. For example, units with an efficiency of 95% or other features that consumers value (such as humidistats, zoning, and premium air filtering systems) could become the new premium products.

Condensate in the flue and chimney is a potentially important issue. The condensing furnace and its flue are designed to handle condensed water vapor. The furnace incorporates a stainless steel heat exchanger in the condensing section and is installed with a condensate drain and through-the-wall vent pipe. These elements are

Low-Income Households Are Big Winners with More Efficient Heating Equipment

All consumers benefit if government requires the cost-effective installation of more efficient furnaces and boilers. Low-income consumers especially benefit. Average home heating expenditures were $800 (gas heat) to $990 (oil heat) during the winter of 2002–03 (EIA 2004c). Yet median income for the poorest 20% of U.S. households (22 million households) is only $10,136. These households spend 8 to 10% of their entire income on heating bills and 15% on all home energy costs (heating, hot water, lights, and appliances) (Census YEAR). (Note that the median income of the next quintile—that is, the 20% of households with incomes just higher than the poorest 20%—is only $25,468.) Several hundred thousand families lose heat during the winter due to terminations for non-payment (gas systems) or inability to purchase fuel (oil systems).

Low-income tenants have the most to gain from mandated standards. They generally pay the heating bills but have no control over the efficiency of their heating units. Sixty percent of the lowest-income households (< $15K/yr.) rent. They rely on the owner to replace old and inefficient heating systems. But in rentals, owners face financial *disincentives* for installing units that are more efficient than the minimum allowed by law, since owners usually pay only the initial cost, and not the ongoing fuel costs.

Low-income households will save an estimated $700 million (discounted net present value savings minus costs) from adoption of the improved furnace and boiler standards of 81–86% (see Table 3, above). Low-income households will additionally reap $1 billion in net economic benefits from adoption of the 90% AFUE standard in cold-climate states. Finally, low-income households will gain $2.6 billion in net economic savings from the proposed new standards for furnace fans. These estimates are based on the assumption that the family residing in the heated unit pays for installation of the new heating system. In fact, a disproportionate percentage of low-income households are renters, who do not make the initial outlay for heating systems. Therefore, the savings estimates for low-income households are somewhat conservative, since these low-income renter households (the majority of all low-income households) immediately begin reaping the savings from newly installed, efficient heating systems but only pay for the costs of these systems over the course of years (to the extent the landlord chooses to raise rents to recapture the modest annual cost of a new heating system.)

Many low-income homeowners and tenants receive assistance from the federal Weatherization Assistance Program (WAP) to replace inoperative or inefficient units. A key WAP goal is to increase energy efficiency. These included in the cost estimates above. Condensing furnaces are safe: they now account for over 20% of U.S. annual sales, and over 50% in some states (Kendall 2002).

programs also can assist landlords who rent to low-income tenants, if they agree to install more efficient units. Art Wilcox, who oversees weatherization programs that annually serve 2,000 low-income households in Massachusetts, explains how higher standards help the poor:

> The typical low-income homeowner or tenant who is faced with replacement of a failing heating system is going to install a unit that is low end in price. This lower-efficiency unit will be an ongoing drain on the customer's limited resources. The customer may not even realize that this unit is less efficient when making this technically involved choice. In fact, the customer can end up with a "total payment plan" monthly bill for the heating system that exceeds the cost of a high efficiency unit due to the higher fuel consumption. By contrast, our goal is to support the installation of the highest efficiency units we can. We screen our clients for greatest need and make installations only after conducting an individualized cost/benefit analysis. We require ENERGY STAR certification or higher ratings. We often install high-efficiency units that command a premium price. Increasing the federal standard would almost certainly provide much-needed relief to my agency, by shifting production to the more-efficient end of the range and bringing down the price of these units. This will allow us to serve even more needy clients with the best product and service possible.

Higher efficiency standards will also help reduce the pressure on the federal fuel assistance program (LIHEAP), which is funded in the range of $2 billion annually. Because heating bills are so high, LIHEAP reaches only about 15% of the eligible households each year. With more efficient heating systems in place, expenditures per household would decline and more people would be served.—*Charlie Harak*

For non-condensing furnaces and boilers, *transient* condensate (as during start-up of a cold system) in the unit or its flue system is not generally considered a threat to equipment life or system safety, but *persistent* condensate (several hours per day) in either subsystem causes substantial concern. The efficiency levels we recommend for non-condensing furnaces and boilers should not generally result in additional condensation in the units (i.e., the problems will be no worse than with the existing typical 80% AFUE products). However, with both existing and future non-condensing products, particularly those installed with external masonry chimneys in cold climates, careful attention must be paid to system, flue, and chimney sizing and materials (Philips et al. 1994). Therefore, regardless of the level of the future efficiency standard, furnace and boiler manufacturers should make sure that installers are properly trained to avoid condensation problems. In addition, programs and building codes that have equipment sizing requirements should adopt appropriate venting requirements.

Finally, some people have alleged that requiring condensing furnaces in cold climates will promote the use of electric resistance heating. We think this is very unlikely, because electric resistance heating is very expensive to operate in cold climates. Support for this view is provided by recent market data that shows that in cold climates, the market share for electric resistance heat is now quite low, while the share of condensing furnaces is substantial. For example, a 2001 field study of 186 new homes in Massachusetts found no new homes with electric resistance heat and 63 homes with gas or propane furnaces, of which about half were condensing. (The remaining homes mostly used oil, gas-boilers, or non-condensing gas furnaces) (XENERGY 2001).

Energy, Economic, and Environmental Benefits of the Proposed Standard

Improved furnace and boiler standards along the lines we suggest above will have large energy, economic, and environmental benefits. We estimate that upgrading equipment efficiency to the 81–86% range (varying by equipment as outlined in Table 3) will reduce U.S. oil and natural gas use by about 60 trillion Btu's annually by 2030, which is enough to provide space heating to more than 1.1 million typical American households. These changes will result in net economic benefits to consumers (discounted net present value savings minus costs) of about $2.4 billion.[13]

Establishing a 90% AFUE requirement for furnaces used in cold-climate states will yield substantially increased savings. We estimate that such a standard will save 150 trillion Btu annually by 2030, which is more than the entire statewide residential use of natural gas in Georgia, Minnesota, or Wisconsin in 2000 (EIA 2003d). Such a standard will result in net economic benefits to consumers of $3.5 billion.

Requiring furnace fans to meet specific efficiency standards will also result in large electricity savings. We estimate that such a standard will save about 30 billion kWh of electricity annually by 2030, enough to meet the total annual electricity needs of nearly three million American households (EIA 1999b). In addition, such a standard will reduce peak electricity demand by about 7,000 MW in 2030, equivalent to the output of 23 new power plants of 300 MW each. These standards will result in net consumer economic benefits of nearly $9 billion.

Taken together, these standards will reduce U.S. energy use by about 507 trillion Btu annually by 2030, which is more than the entire residential sector energy consumption of such states as Virginia, Indiana, or Tennessee in 2000, and nearly equal to the residential energy consumption of New Jersey (EIA 2003d). Such standards will save consumers nearly $15 billion on a net present value basis. The average benefit-cost ratio for these standards is 2.9:1, meaning that benefits are nearly triple the costs. Emissions reductions are also significant, including 29,100 metric tons of nitrogen oxides, 79,100 metric tons of sulfur dioxide, and 8.8 million metric tons of carbon per year by 2030. Achieving such carbon reductions in the U.S. today would be the equivalent of taking 6.2 million cars off the road.

See Appendix A for state-by-state savings achievable by this standard.

COMMERCIAL AIR CONDITIONERS

Power outages and other reliability problems often relate to high levels of peak power demand. Much of this peak demand comes from the air conditioning load in commercial and residential buildings. Historically, electricity demand in the U.S. peaked in the winter when

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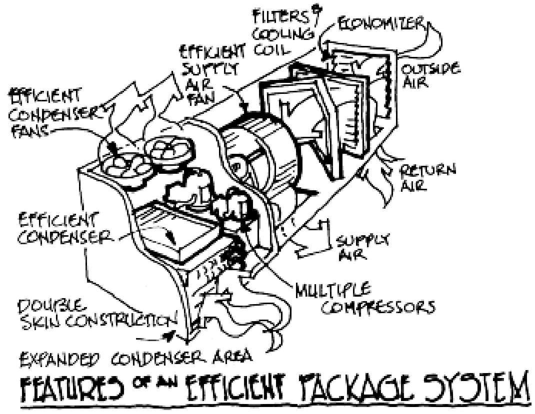
[13] For all net present value calculations in this report, we use a real discount rate of 5% and account for equipment sold between the date the standard would become effective and 2030.

power was needed in factories and cities in the industrial north. However, as air conditioning has become more common and as population and commercial and industrial activity have increased in the Sun Belt states, this pattern has changed. Electricity demand in the U.S. now peaks in the summer, when extra power is needed to provide cooling for industries, offices, and homes. From 1989 to 2002, national summer peak demand grew from 524,000 MW to 715,000 MW, an average annual growth of 14,650 MW, or 2.4%. Summer peak demand is currently forecast to continue growing at an average of approximately 14,500 MW per year, or about 1.9% per year through 2012 (NERC 2003). This *annual* growth is equivalent to the capacity of nearly 50 power plants of 300 MW each.

Commercial air conditioners are a major contributor to peak demand levels. For example, the California Energy Commission estimates that 15% of statewide load in California on a hot summer day is due to commercial air conditioning (CEC 2001). And in New Jersey, this figure is about 25% (XENERGY 1999).

Space cooling has been found to be the largest use of electricity in commercial buildings, comprising over 25% of such electric consumption in 1999 (EIA 2003a). The energy savings potential of the commercial air conditioning market is significant, since there are more than 4 million commercial buildings in the United States. Over half of all commercial buildings (by square footage) and over two-thirds of all buildings with electric space cooling were served by packaged air conditioners in 1999 (EIA 2003c). This percentage is growing because packaged equipment is inexpensive to purchase and install.

Figure 4. Typical Air-Cooled Commercial Air Conditioner



Technology Description: Basic Air Conditioners vs. Efficient Technology

Packaged commercial air conditioners and heat pumps (sometimes also called "unitary" air conditioners and heat pumps) are factory-made cooling equipment shipped to the building site ready for installation. This equipment is typically used to cool small- to medium-sized commercial buildings such as small office buildings or shopping centers. The most common commercial units contain a compressor, blower, and heat exchangers in a single package, which is usually mounted on the roof (hence, these are commonly called "rooftop" units). Some units are split into two pieces, just like a typical residential central air conditioner, with the compressor and condenser located outside and the evaporator and circulating fan installed inside. Packaged equipment differs from the large chilled water systems used in very large buildings. These “chiller systems” are generally custom-designed for a particular application and built up from multiple components on-site.

Nearly all packaged commercial air conditioners use a vapor-compression cycle to cool the air—the same cycle used in a household refrigerator. The vapor-compression cycle converts a liquid refrigerant to a gas, and back again, and in the process provides cold refrigerant plus waste heat. In addition, some units—called *heat pumps*—can operate in reverse and concentrate heat from the outside to provide heat inside buildings during the heating season (these generate hot refrigerant and cold exhaust air). Approximately 12% of commercial packaged air conditioners are heat pumps (Census 2003a). Others, called “year-rounds” or “gas-packs” include rather moderate-efficiency gas furnaces (~80% efficient) in the rooftop package. ASHRAE and DOE recently set commercial furnace standards, so the efficiency of the furnace is not part of the current air conditioner rulemaking. However, the manufacturer's selection of heating elements can have an effect on the cooling efficiency of packaged systems, since electric heat and gas heat impose different design requirements on the airways that are common to both heating and cooling. A small allowance may be made in cooling efficiency standards to account for this difference.

Packaged commercial air conditioners may be either air-cooled or water-cooled. DOE recently set efficiency standards for water-cooled packaged equipment, so the current rulemaking will apply only to air-cooled equipment, which constitutes the predominant segment of the market.

Packaged commercial air conditioners can be made more efficient in several ways. First, more efficient compressors can be used. Second, heat exchangers can be improved, either by making them larger (more heat exchange area) or more efficient (better heat transfer within a given amount of space). Improved controls can also save energy, although controls are more likely to affect off-peak performance than on-peak performance. For example, in climates with hot days and cool nights, *economizer* controls can bring in cool outside air in the evening instead of operating the compressor.

Current federal efficiency standards regulate the efficiency of commercial packaged air conditioners with a cooling capacity of 65,000 to 240,000 Btu's per hour. Cooling capacity is commonly referred to in “tons,” which is the equivalent cooling capacity to a ton of ice. Melting one ton of ice takes 12,000 Btu's, so the equipment now covered by federal standards ranges from 5 to 20 tons capacity. Such a system can cool a commercial building of around 2,000–10,000 square feet in a typical U.S. climate (more in cool climates, less in warm climates). Commonly, multiple rooftop units are used in a commercial building, permitting even large buildings (of up to about five or six stories) to use rooftop units. Often, a building owner chooses to install a series of packaged rooftop units rather than going to a more efficient, but more expensive chiller system.

The peak efficiency performance (i.e., performance at high ambient temperatures) of a commercial air conditioner is expressed as its Energy Efficiency Ratio (EER). EER measures the amount of cooling produced (in Btus) per Watt of electricity consumed under specified conditions, in this case an outdoor temperature of 95 degrees F. In addition to raising the EER requirement for the forthcoming standard, DOE also should specify an Integrated Part Load Value (IPLV)—a measure of average efficiency over a range of operating conditions—and Coefficient of Performance at 17 degrees F (COP_{17})—a measure of heat pump efficiency. These additional parameters will help ensure that EER is not improved at the expense of these other important performance indicators.

Proposed National Standards for Commercial Air Conditioners

The current national standard for the most common sizes of commercial packaged equipment is an EER of 8.9. The required EER for equipment larger than 11 tons is 8.5. This standard was set in 1992 with the passage of the Energy Policy Act, but since then higher efficiency equipment has become much more common. At present, the majority of equipment on the market is designed to meet ASHRAE Standard 90.1-1999, a voluntary standard that is frequently incorporated into state building codes. ASHRAE 90.1-1999 calls for EERs of 10.1 to 10.3 for equipment of 11 tons and below, and EERs of 9.3 to 9.7 for equipment larger than 11 tons (see Table 5). In addition, most manufacturers market a "high-efficiency" line of equipment with an EER of 11 or more, and equipment is now on the market with EERs as high as 13.

EER 10.8 to 11 is the level of performance now recommended by the Consortium for Energy Efficiency (CEE), a non-profit group of energy-efficiency program operators. CEE established its voluntary performance levels in the 1990s and they have since been widely promoted by utilities and other energy efficiency programs sponsors.[14] ENERGY STAR has recently adopted most of the CEE levels. EER 11.5 is also met by many units on the market and is the level found to be the minimum life-cycle cost point in a preliminary analysis by DOE (LBNL 2003).

In recent years, many utilities and other energy-efficiency program operators have promoted packaged commercial air conditioners with an EER of 11 or more. Based on discussion with industry experts, such equipment accounts for at least a 15% share of the U.S. market. For example, equipment of EER 11 or more has been successfully promoted in New England for several years based on studies by the utilities that such equipment is cost-effective to the utility and to consumers. If these efficiency levels can be cost-effective in the relatively cool climate of New England, then they certainly make sense for a national minimum efficiency standard.

Accordingly, we recommend that the new national standard for commercial air conditioners be set in the range of 11.1 to 11.7 EER, depending on the type of equipment. The new standard will need to be tiered as a function of unit size, and allow slightly lower levels for heat pumps. Specific recommendations are provided in Table 5 below. Overall, this approach will result in an average EER of about 11.4. By way of comparison, the new residential central air conditioner energy efficiency standard of SEER 13 will generally result

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[14] Originally CEE had two efficiency tiers—Tier 1 (10.3 EER for the most common products) and Tier 2 (EER 11). In recent years, as the market share of Tier 1 products has grown, CEE has stopped promoting Tier 1 and now emphasizes Tier 2.

in EERs of 11 to 12 (DOE 2000a). Such a standard level will save a substantial amount of energy (as discussed below), yet it still provides room for manufacturers to produce, and utilities to promote, even higher efficiency levels.

Table 5. Current and Proposed Standards for Commercial Packaged Air Conditioners and Heat Pumps

Product Size and Type	Efficiency (EER)		
	Current Federal Standard	ASHRAE 90.1-1999 (approx. current baseline)	Proposed New Federal Standard
Cooling Capacity 65 to <135 kBtu/hr			
Air conditioner only or unit w/ electric resistance heat	8.9	10.3	11.7
Air conditioner w/ gas or other heating	8.9	10.1	11.5
Heat pump	8.9	10.1	11.5
Cooling Capacity 135 to <240 kBtu/hr			
Air conditioner only or unit w/ electric resistance heat	8.5	9.7	11.5
Air conditioner w/ gas or other heating	8.5	9.5	11.3
Heat pump	8.5	9.3	11.1

Notes:

- Proposed efficiency levels are based on DOE minimum life-cycle cost point for a 90,000 Btu/hr unit with gas heating. Recommended efficiencies for other categories are based on this level plus appropriate allowances for larger capacity equipment (from CEE Tier 2) and for heat pumps, cooling-only units, and units with electric resistance heat (from 90.1-1999).
- In addition to EER requirements, we recommend that efficiency standards be established at comparable efficiency levels for multi-capacity equipment (efficiency specified in terms of IPLV) and for heat pumps in heating mode (efficiency specified in terms of COP).

Pros and Cons of Efficient Commercial Air Conditioners

More efficient packaged commercial air conditioners reduce energy use, save money, and reduce peak electric demand. Relative to a unit just meeting the current 8.9 EER standard, an EER 11.5 unit reduces energy use by about 23%. However, if we estimate the average unit being sold today as one just meeting the ASHRAE standard (i.e., EER = 10.1 for an air conditioner with gas heating equipment), for an average size unit (11 tons cooling capacity) in an average climate, an 11.5 EER standard would reduce electricity use by about 2,500 kWh each year, saving $205 annually at the average commercial electricity price for 2003 ($0.0813/kWh) (EIA 2004d). Prices of the more efficient units vary from manufacturer to manufacturer and supplier to supplier, but a detailed investigation by Northeast Utilities for Northeast Energy Efficiency Partnerships found an average cost increase of about $68/ton of capacity to raise efficiency to EER 11 (Northeast Utilities 1998). An analysis for DOE estimated an average incremental cost of about $74 per ton to go to EER 11.5 from the ASHRAE 90.1-1999 efficiency levels. Based on the DOE cost estimates, an 11 ton unit would increase in price by $814, but yield energy savings that cover this additional cost in about four years on average.

In addition, the projected payback is likely to be even more rapid, since air conditioners run more in the summer when electricity prices are highest. For example, in July 2003, electricity prices nationally were 6% higher than the average for the year (EIA

2004d). Demand charges (additional charges for most commercial and industrial customers based on monthly peak demand) generally add further to the cost of air-conditioning, and thus to the value of energy savings. The value of demand savings varies from utility to utility, but averages around 10%. Table 6 shows the savings, incremental costs, and simple pay-back periods that result from increasing efficiency levels from the current ASHRAE standard (EER 10.1 and 9.5 respectively) to our proposed new national standard for two typically-sized units.

Table 6. Economics of Efficient Commercial Air Conditioners

Illustrative System Size	Annual Electricity Savings (kWh)	Annual Electricity Cost Savings ($)	Typical Incremental Product Cost	Simple Payback (years)
7.5 tons (108,000 Btu/hr)	1,723	$140	$555	4.0
15 tons (180,000 Btu/hr)	5,233	$425	$1,357	3.2

Note: Savings are for average climates (1,588 hours of operation). Cost savings are computed on the basis of average electricity prices only. Savings in summer surcharges and customer demand charges will often add to these savings and reduce payback periods accordingly. Incremental costs are based on DOE analysis (LBNL 2003).

In today's utility environment, the reliability and economic benefits of reduced peak electric demand are often as important as the energy savings. More efficient packaged commercial air conditioners will significantly reduce peak electric demand, thereby helping to make the electric system more reliable. The improvement from 8.9 or 10.1 to 11.5 EER results in a 12–23% reduction in air conditioner peak demand. Nationwide, peak electricity demand savings from this new standard will reach more than 8,000 MW by the summer of 2020, comparable to the output of more than two dozen power plants of 300 MW each, making brownouts and rolling blackouts less likely.

While the benefits of EERs above 11 are substantial, there are a few drawbacks. As noted above, the more efficient units cost more—about 15% more on average according to Northeast Utilities (1998), but DOE (2003c) predicts that if a standard is set, this will decline to 4–7% for EER 11, and 9–12% for EER 11.5. This cost is recovered in a few years. As with furnaces, manufacturers often charge large price-premiums for high-efficiency equipment. If the standard becomes EER 11 or 11.5, then manufacturers are likely to introduce units that are differentiated by even higher efficiency (e.g., EER 12 and 13) and/or other features (e.g., integrated controls and economizers) to justify price premiums. Finally, more efficient packaged air conditioners are generally a little larger than less efficient units. When an old inefficient air conditioner is replaced, some building modifications, such as a larger roof opening, may be required to fit the new unit in the same place where the old unit was. This is sometimes an issue when installing EER 8.9 or 10.3 units in place of older units, but with EER 11 or 11.5 these issues will probably become a little more common. Contractors deal with these issues daily already, so they can and will be dealt with.

Energy, Economic, and Environmental Benefits of the Proposed Standard

A commercial air conditioner standard as proposed here would result in substantial energy and peak demand savings and provide large economic and emissions-reduction benefits. We estimate that raising the standard to an average of EER 11.4 will result in annual energy savings of about 12 billion kWh by 2030. By way of comparison, this savings is nearly equal to the total 2000 commercial sector statewide electricity use in Connecticut or Minnesota (EIA 2003d). Peak electric demand will be reduced by about 12,600 MW in 2030, equivalent to the output of 42 new power plants of 300 MW each, or about 1.7% of total U.S. summer peak demand in 2002 (NERC 2003). Net economic benefits to consumers (discounted benefits minus costs) total approximately $2.2 billion. The benefit-cost ratio is 2.1:1—benefits are more than double the costs. Emissions reductions are also significant, including 5,800 metric tons of nitrogen oxides, 28,000 metric tons of sulfur dioxide, and over 2.3 million metric tons of carbon per year by 2030. Achieving such carbon reductions in the U.S. today would be the equivalent of taking nearly 1.6 million cars off the road.

See Appendix A for state-by-state savings achievable by this standard.

DOE and Manufacturers Overestimate the Cost of Standards During Rulemakings

Across a range of products, DOE's and manufacturers' estimates of the price of efficiency improvements caused by standards have generally been too high. DOE and manufacturers often examine current costs of high efficiency products and/or look at current technologies for meeting efficiency levels. But such analyses ignore innovation and the ability of manufacturers to find less expensive ways to meet new efficiency standards than DOE predicts. For this analysis, DOE and ACEEE cost estimates are for the year the standards took effect but are expressed in dollars from several years earlier (e.g., costs are typically expressed in terms of current-year dollars at or just before the time of the final rule). The Census Bureau figures are in nominal dollars, e.g., 2001$ for 2001 numbers, 2002$ for 2002 numbers, etc. Some specific examples:

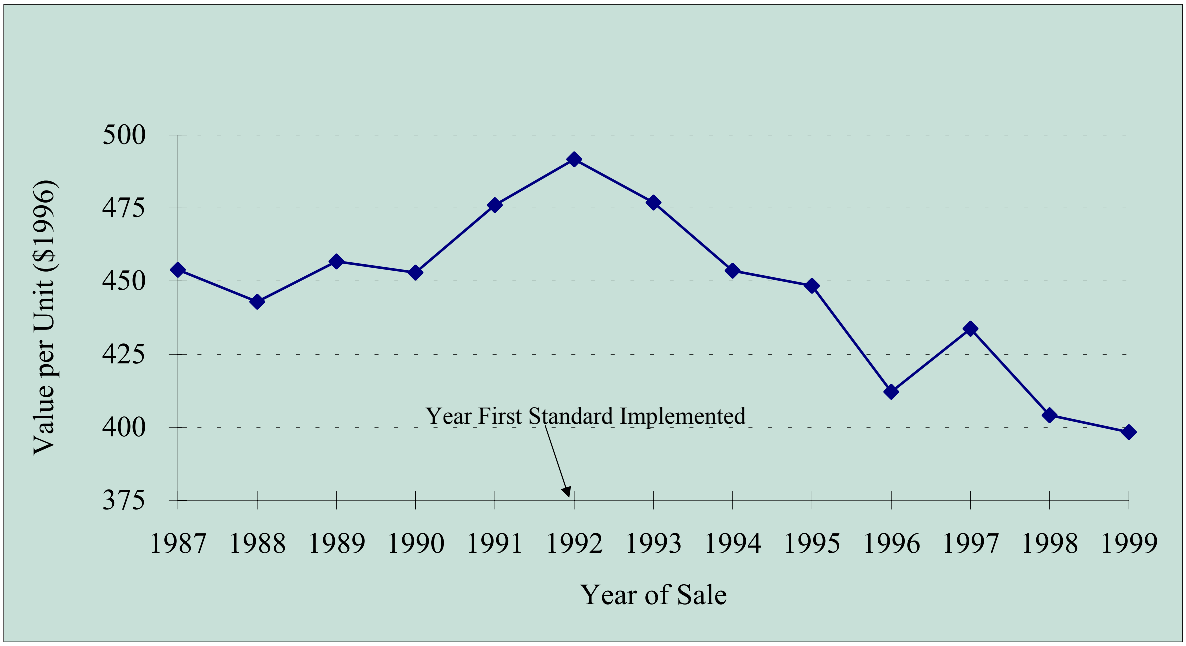
In the very first DOE analysis for furnace standards, the agency predicted that increasing the efficiency of a new furnace from 64.8 to 81% would raise manufacturing costs from $435 to $655 per furnace (DOE 1982). Because manufacturer, wholesaler and contractor markups typically double the manufacturing cost in this market, this $220 increase in manufacturing costs would yield an estimated $440 increase in the consumer price. At the time, ACEEE predicted a $156 incremental price to the consumer (Geller 1987). This standard was implemented in 1992. Data collected by the U.S. Census Bureau (2004) found that value of shipments per unit by the manufacturer increased only $38 from 1990–1992 (thus approximately $76 to the consumer when markups are included), substantially less than predicted by DOE or ACEEE. These trends are illustrated in Figure 5. Thus, DOE overestimated costs by a factor of six and ACEEE overestimated costs by a factor of two.

For residential central air conditioners, during the first DOE rulemaking the manufacturer trade association (ARI) predicted a $762 consumer price increase (roughly $381 to the manufacturer) and DOE predicted $349 (about $174 to the manufacturer) to raise efficiency to about SEER 10 (CEC 1984; DOE 1982). A SEER 10 minimum standard took effect in 1992 and 1993. According to the Census Bureau (2004), the manufacturer value per unit for central air conditioners declined from $700 in 1990 to about $570 in 1998 (a 23% decrease), and then was fairly constant through 2000. Standards adopted in 1992 and 1993 did not significantly alter the trend, although manufacturer value per unit rose $18 in 1993—and then fell more than $40 the next year. Even ignoring the price *decline* in 1994 and subsequent years, the price change in 1993 was about 5% of the increase predicted by ARI and 10% of that predicted by DOE.

Consider refrigerators, another relatively complex and expensive consumer product. For the most recent standards, which took effect in July, 2001, DOE predicted a $50 consumer price increase (DOE 1995). Census Bureau data (2004) indicate that the average value per unit to manufacturers increased $19 over the 2000–2001 period and then declined $16 in 2002, resulting in a net manufacturer increase of about $3 per unit over the period when manufacturers adjusted to the new standard. Consumer costs are roughly double this or $6 per unit, which is only 12% of the consumer cost increase predicted by DOE.

In a retrospective analysis of price trends and efficiency of room air conditioners, central air conditioners, refrigerators, and clothes washers, Dale et al. (2002) found that DOE's Technical Support Documents generally overestimated the impact of new standards on consumer prices. The authors conclude that "[C]urrent methods for forecasting post-standard equipment prices may insufficiently represent real-world industry trends." —*Steven Nadel*

Figure 5. Value per Unit of New Gas Furnaces under 150,000 Btu/hr by Year of Sale



Distribution Transformers

Distribution transformers reduce the voltage of an electric utility's power distribution line to the lower voltages suitable for most of the equipment, lighting, and appliances in businesses and homes. In 1996 it was estimated that about 40 million distribution transformers were located within U.S. utilities' electric distribution system, and about 16 million additional transformers were located on private commercial and industrial premises. A typical medium-sized office building (100,000 sq. ft.) might require 600 kVA of transformer capacity. Industrial use of transformers will vary by industrial process and the type and size of electrical equipment. Distribution transformers generally last a long time (around 30 years), so most new transformers are used in new construction. More than 1.5 million new distribution transformers are purchased and installed each year, many of them by construction contractors equipping new commercial buildings (for which they will never pay the electric bills) (Barnes et al. 1996). [15]

While distribution transformers are relatively efficient devices—generally delivering well over 90% of their input power as usable power output—they are constantly energized, and they constantly experience some energy losses. As a result, even small changes in transformer efficiency can add up to large energy savings. In addition, transformer inefficiency imposes a penalty on nearly all electric power produced, since virtually all power flows through one or more transformers. In effect, improving transformer efficiency means that a larger portion of the power generated in power plants will reach the point in the electric system where it is put to work. As shown below, the overall savings achievable from more efficient transformers are substantial.

Figure 6. Typical Distribution Transformers

Pictured from left to right are a pad-mounted medium-voltage dry-type transformer (commonly used in industrial facilities), a small pole-mounted liquid-immersed transformer (typically-mounted on utility poles; larger liquid-immersed transformers are commonly pad-mounted), and low-voltage dry-type transformers of the type used to serve commercial buildings.

Technology Description: Basic Distribution Transformers vs. Efficient Technology

Transformer efficiency is the outcome of several design and operating characteristics. Distribution transformers are composed of two basic parts: a core made of magnetically responsive material (such as steel), and a conductor for windings (wires), typically made of low resistance material such as aluminum or copper. Energy losses in distribution transformers arise from both of these components. Core or "no load" losses occur continuously as the transformer stands by ready to serve a demand. Winding losses or "load losses" result from resistance in the windings when there is a load on the transformer.

Distribution transformers can be broadly divided between the liquid-immersed type and the dry type. As the name implies, liquid-immersed transformers use a liquid (oil) bath around the transformer core and coil for insulation and to dissipate heat. In most dry-type transformer applications, no-load losses are larger than load losses because average loads are very low. In liquid-immersed transformers, both load and no-load losses are significant.

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[15] Many types of equipment and appliances contain their own transformers within their electrical circuitry, but these are not distribution transformers. Distribution transformers are constantly energized as part of the electrical distribution system, whether owned by utilities or by utility customers.

Most liquid-immersed transformers are owned by utilities and used in outdoor applications. Such utility-owned, liquid-immersed transformers are commonly seen attached to telephone poles or, in their larger forms, located on concrete pads behind chain link fences in small lots throughout a utility's service area. Some large industrial customers and large office and institutional buildings also use these transformers, as may be found in grated vaults below city sidewalks. In contrast, few dry-type transformers are owned by electric utilities. Such business-owned, dry-type transformers tend to be installed indoors, often in utility closets.

Low-voltage distribution transformers work by decreasing the voltage of electricity received from a low voltage source to the levels that are appropriate to power lights, computers, and other electrical equipment. Medium voltage transformers serve the same function, but are used to decrease the voltage provided by a utility to the appropriate level for use within a commercial building or industrial facility.

Distribution transformers are further divided between equipment designed for use on electrical circuits running single-phase or three-phase power. Three-phase power involves three separate, but coordinated, power outputs from a single source of generation. Most residential and some small commercial buildings operate on single-phase power. Three-phase power is used by most large commercial buildings and industrial facilities and by some smaller commercial facilities as well. Common applications for three-phase power include medium and large electric motors (Nadel et al. 2002).

As noted above, there are two types of transformer energy losses—core losses and coil losses. Both types of losses are largely a function of the material used for key components. Amorphous iron can replace steel in transformer cores and reduce losses by 30%. Intermediate grades of steel are also sometimes available. Copper windings are more efficient than aluminum windings. The windings' electrical resistance—a key factor in load losses—is influenced by temperature, and thus insulation designs and materials also affect transformer efficiency. Additionally, careful matching of transformer size to load will provide more efficient operation (Barnes et al. 1996).

Proposed National Standards for Distribution Transformers

Low-Voltage Dry-Type Distribution Transformers

A low-voltage distribution transformer has both the primary and secondary windings designed to operate at system voltages in the low voltage classes (i.e., less than 600V) used within buildings. Historically, little attention has been paid to low-voltage dry-type transformer efficiency. Low-voltage transformers have been commodity items specified and purchased primarily on the basis of first cost. To encourage purchases of more efficient transformers, in 1996 the National Electrical Manufacturers Association (NEMA) developed standard TP-1, *Guide to Determining Energy Efficiency for Distribution Transformers*. The current version of this document gives efficiency recommendations for the dry-type distribution transformers that predominate in commercial and industrial building applications.

Two voluntary initiatives promote low-voltage dry-type transformers that meet TP-1 levels. The ENERGY STAR program makes more efficient transformers easy to identify by their labels. A Consortium for Energy Efficiency (CEE) initiative aggregates utility influence in promoting efficient transformers. These efforts are gaining momentum and recognition in the market. Furthermore, regulatory developments in several states (distribution transformer standards in California, Connecticut, Maryland, and Massachusetts and building code requirements in California, Hawaii, Massachusetts, Minnesota, New York, and Oregon) that rely on TP-1 have led many manufacturers to begin offering efficient transformer product lines.

In 2002, NEMA and efficiency supporters agreed to recommend that TP-1 levels for low voltage dry-type transformers should be adopted as uniform national standards. This recommendation was accepted by the relevant Congressional committees, and efficiency standards for low-voltage dry-type distribution transformers were incorporated into the pending federal energy bill. However, this omnibus energy legislation has been stalled by other controversial elements. Table 7 provides the TP-1 minimum efficiency levels for this class of equipment.

In August 2004, DOE published a Technical Support Document covering low-voltage distribution transformers that indicated that efficiency levels higher than TP-1 may be cost-effective for this equipment (DOE 2004b). However, manufacturers are concerned that DOE's analysis may either include some errors or ignore some critical factors (Gray 2004). It is clear that the TP-1 level would be a reasonable standard for low-voltage transformers. However, there is a good chance that a somewhat higher standard might be justified as well. Given this uncertainty, in subsequent sections we analyze low-voltage equipment savings at the TP-1 level, but these savings estimates will be conservative if it ultimately proves out that higher efficiency levels are technically feasible and economically justified.

Medium-Voltage Dry-Type Distribution Transformers

NEMA standard TP-1 also includes recommended efficiency levels for medium voltage transformers. However, probably more than half of the medium-voltage distribution transformers sold today already meet TP-1, including just under half of medium-voltage dry-type transformer sales and substantially more than half of medium-voltage liquid-immersed transformer sales.[16] Efficiency standards beyond TP-1 levels can result in significant savings of electricity. A 1996 study by Oak Ridge National Laboratory (Barnes et al. 1996) explored the savings potential of the entire transformer market under several energy-efficiency scenarios. These scenarios modeled the savings that would be possible if standards were to be established at levels above NEMA's TP-1. One such scenario was based upon the average of the most cost-effective energy-efficient products from three manufacturers. Under this "Average Losses" scenario, it was estimated that cumulative savings in 2000–2030 could result in as much as 71% greater savings than would be achieved by TP-1 alone. Medium- and high-voltage transformers would account for nearly 2/3 of this savings.

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[16] From discussions with industry experts.

Table 7. NEMA TP1-1996 Energy Efficiency Recommendations for Low-Voltage[b] Dry-Type Distribution Transformers (Single-Phase and Three-Phase)

Rated Capacity (kVA)	Minimum Efficiency[a] (%)
Single-Phase Transformers	
15	97.7
25	98.0
37.5	98.2
50	98.3
75	98.5
100	98.6
167	98.7
250	98.8
333	98.9
Three-Phase Transformers	
15	97.0
30	97.5
45	97.7
75	98.0
112.5	98.2
150	98.3
225	98.5
300	98.6
500	98.7
750	98.8
1000	98.9

Source: NEMA 2002

[a] The energy efficiency of distribution transformers is defined by NEMA's Standard Publication TP-1 as output kVA divided by the sum of output kVA plus losses, at a specified percent load and reference temperature.

[b] Low voltage transformers commonly step down 240-volt power to 120-volt service for selected circuits. Efficiency for these transformers is measured at 35% of nameplate load, at 75ºC.

More recently, Oak Ridge National Laboratory has done a more detailed analysis for DOE. The efficiency recommendations and cost estimates shown in Table 8 are based on data released by DOE for medium voltage dry-type three-phase transformers with capacities of 300, 1500, and 2000 kVA (DOE 2003b). The other values recommended in Table 8 are scaled to fit the curves presented in Figure 7. The recommended values correspond closely to ORNL's "Average Losses" case and equate to an increase of approximately 0.3% over the minimum efficiency levels in TP-1. This results in a 10–30% reduction in losses over a base efficiency transformer.

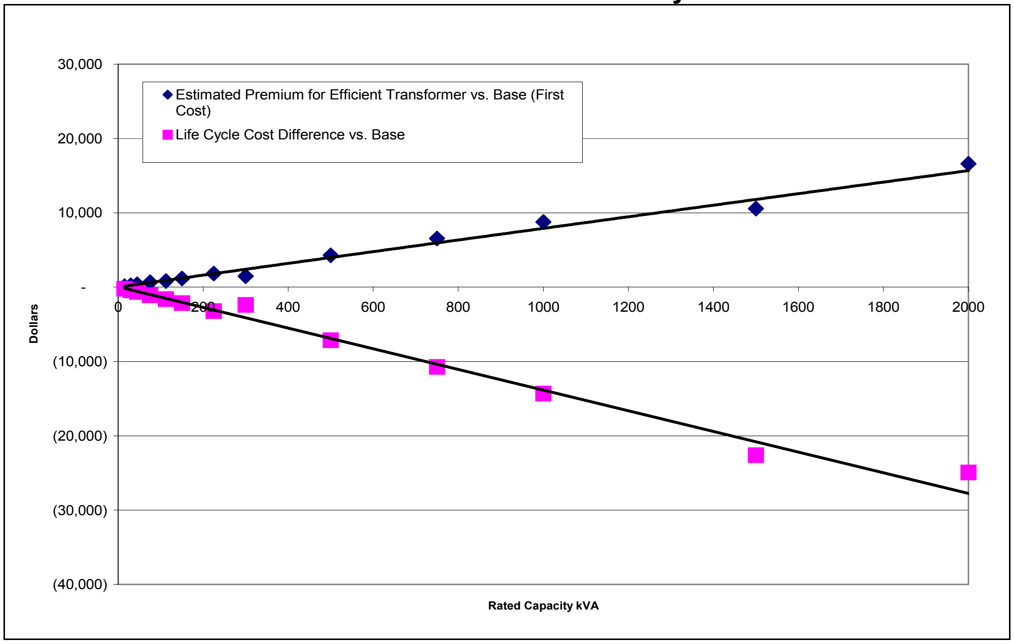
We recommend that the efficiency standard ultimately adopted be one that correlates to the point of lowest life-cycle cost. This is the point at which the efficiency and costs of a transformer are both optimized for maximum cost savings over the life of the equipment. This value of TP-1 + 0.3% is very close to the point of maximum life-cycle cost (LCC) savings for transformers of this type. There may however be a small amount of variation (either more or less than TP-1 + 0.3%) in efficiency levels among several of the capacity ratings in this class between this efficiency level and the minimum life-cycle cost efficiency level. The data available from DOE do not include the necessary information needed to estimate the exact LCC point for all capacity ratings (DOE 2003b, 2004b).

Table 8. Proposed Standards and Economic Justification for Medium Voltage Dry-Type Three-Phase Distribution Transformers (NEMA TP-1 + 0.3%)

Rated Capacity (kVA)	NEMA TP-1 Standard (Minimum % Efficiency)	Proposed New Standard (Minimum % Efficiency)	Cost Premium for Efficient Transformer ($)	Discounted Life-Cycle Cost Savings ($)
15	96.8	97.1	133	215
30	97.3	97.6	266	429
45	97.6	97.9	398	644
75	97.9	98.2	664	1,073
112.5	98.1	98.4	826	1,609
150	98.2	98.5	1,162	2,145
225	98.4	98.7	1,834	3,218
300	98.5	98.8	1,473	2,370
500	98.7	99.0	4,299	7,152
750	98.8	99.1	6,540	10,727
1000	98.9	99.2	8,781	14,303
1500	99.0	99.4	10,567	22,592
2000	99.0	99.4	16,621	24,931
2500	99.1	99.5	22,226	35,758

Note: The incremental costs displayed in this table are based on the difference between an efficient transformer and a typical transformer purchased in 2001. Optimal individual efficiencies may vary slightly from values in this table.

Figure 7. Estimated Cost Premium and Life-Cycle Cost Difference for Medium Voltage Dry-Type Three-Phase Transformers at NEMA TP1 + 0.3% Efficiency



Liquid-Immersed Distribution Transformers

For liquid-immersed transformers, the following efficiency recommendations and cost estimates are based on data released by DOE for liquid-immersed three-phase transformers with capacities of 150, 500, and 1500 kVA. The other values in Table 9 are scaled to fit the curves presented in Figure 8. The values displayed in Table 9 correspond closely to ORNL's "Average Losses" case as well as the minimum life-cycle cost point and equate to an increase of 0.2% over the minimum efficiency levels in TP-1. This results in a 10–30% average reduction in losses over a base efficiency.

Table 9. Proposed Standards and Economic Justification for Liquid-Immersed Three-Phase Distribution Transformers (NEMA TP-1 + 0.2%)

Rated Capacity (kVA)	NEMA TP-1 Standard (Minimum % Efficiency)	Proposed New Standard (Minimum % Efficiency)	Cost Premium for Efficient Transformer ($)	Discounted Life-Cycle Cost Savings ($)
150	98.9	99.1	502	723
225	99.0	99.2	1,697	2,020
300	99.0	99.2	2,892	3,318
500	99.1	99.3	6,078	6,777
750	99.2	99.4	10,061	11,101
1000	99.2	99.4	14,043	15,425
1500	99.3	99.5	22,009	24,074
2000	99.4	99.6	29,974	32,722
2500	99.4	99.6	37,940	41,371

Note: The incremental costs displayed in this table are based on the difference between an efficient transformer and a typical transformer purchased in 2001. As discussed in the text, the optimal individual unit efficiencies (lowest life-cycle cost) may vary slightly from values in this table.

For single-phase liquid-immersed transformers, we estimate that a TP-1 + 0.1% standard is on average the most cost-effective option based on recent analyses published by DOE (DOE 2003b, 2004b). However, the data for this class of transformers shows significant variation in optimal LCC point (varying anywhere from TP-1 to TP-1 + 0.4%). More data is needed in order to make specific standard recommendations for each transformer size.

Pros and Cons of Efficient Distribution Transformers

Equipment meeting the standards that we recommend will reduce transformer energy losses by 18 to 44%. This reduced waste translates into direct savings on energy bills. For example, a typical, 100,000 square foot office building with 600 kVa of dry type medium and low voltage transformers, will cut electricity use by about 14,000 kWh per year with equipment meeting the standard recommended above. At current national average commercial electricity prices, these savings would lower that buildings annual electricity bill by more than $1,100. Efficient transformers operate much the same as conventional equipment, so users do not experience any performance change.

This efficiency improvement is achieved at some additional cost to the purchaser. We estimate that the first cost for new transformers will increase by an average of approximately 35%. However, these increased costs are recouped well within the 30 year typical life of a transformer. On average, the increased cost will be covered by energy savings within 2 to 8 years (see Table 10).

Figure 8. Estimated Cost Premium and Life-Cycle Cost Difference for Liquid-Immersed Three-Phase Distribution Transformers at NEMA TP1 + 0.2% Efficiency

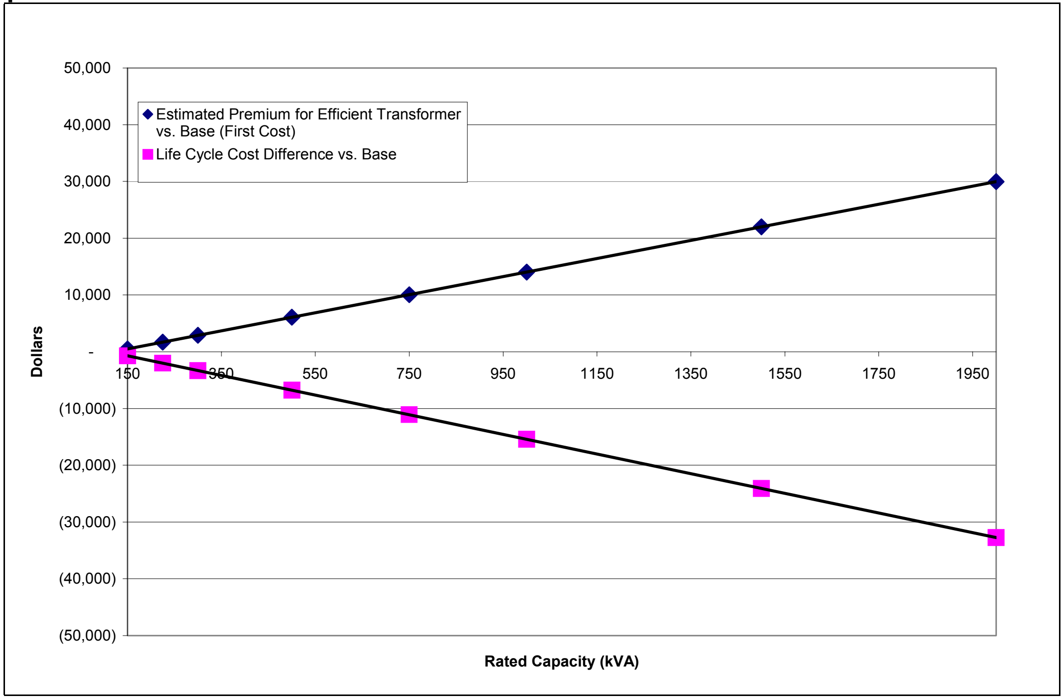


Table 10. Economics of More Efficient Distribution Transformers

Type	Proposed Standard Level	Annual Electricity Savings (kWh/kVA)	Incremental Product Cost ($/kVA)	Simple Payback (years)
Dry-type Low-Voltage	TP-1	22	3.00	1.7
Dry-type Medium-Voltage	"Average Losses"	26	5.90	4.8
Liquid-Immersed	"Average Losses"	6	2.30	7.7

Notes: Incremental costs and electricity savings derived from DOE 2003b and Barnes et al. 1997. Simple payback based on average U.S. electricity prices in 2003—$0.0813/kWh for commercial (used for dry-type, low-voltage) and $0.0495/kWh for industrial (used for the other two categories) (EIA 2004d). For liquid-immersed transformers, the efficiency values in the “average losses” case appear to be less than the minimum life-cycle cost point in DOE’s most recent analysis (DOE 2004b). DOE does not provide sufficient data to calculate costs and savings for the minimum life-cycle cost point, but when such data become available they will likely show somewhat higher costs and savings than shown for liquid-immersed transformers in this table.

For general duty commercial building applications where low-voltage dry-type transformers are generally used, TP-1 or ENERGY STAR distribution transformers offer very short payback periods today. These efficiency improvements will pay for themselves even more quickly as equipment prices decline with imposition of a standard. As usage of efficient products grows, increasing competition will reduce prices, and default warehousing by distributors will eliminate delays and extra fees. For these applications, there is no downside to the TP-1 level, and as noted in the text above, even higher efficiency levels may be justified.

Energy Efficiency and the Economy

Improved energy efficiency, whether through standards, other government policies, or as a result of market forces, helps the economy in at least two crucial ways. First, reducing demand for a commodity usually results in lower prices. This effect is especially true when supplies are especially tight, as they have been for key energy resources such as natural gas in recent years. Second, the money that consumers save on their energy bills (either as a result of lower prices or as a result of direct savings from more efficient appliances) is either saved or spent on other goods and services in the economy. Because energy production and distribution is relatively capital intensive compared to other goods and services, shifting spending to other goods and services results in job creation. For businesses, lower energy bills translate into improved profits.

Energy Efficiency and Energy Prices

Natural gas prices have tripled over the past three years and are projected to stay high. These high natural gas prices have started to translate into higher electricity prices, with the U.S. DOE projecting a nearly 5% rise in national average electricity prices over the next year (EIA 2004b). Many economic observers have warned about how rising energy prices can dampen economic growth, most notably Federal Reserve Chairman Alan Greenspan (Greenspan 2003).

Reducing demand through more efficient use of energy helps to rein in energy prices. In 2003, the National Petroleum Council reported that improved energy efficiency was a fundamental element of a strategy to control natural gas prices (NPC 2003). A 2003 study by ACEEE relying on the same modeling consultant as the NPC report found that policies that reduce natural gas use and electricity consumption by 4.1 and 3.2% respectively combined with a 2.3 to 6.3% increase in renewables-based electric generation would decrease wholesale gas prices by 22% (Elliott et al. 2003).

Energy Efficiency, Economic Growth, and Job Creation

Multiple economic studies have shown how improving energy efficiency helps fuel economic growth and create jobs. For example, a study by Rand for the state of Massachusetts found that the

There are, however, some applications for which specialized transformers are more appropriate. These may include transformers feeding circuits supporting sensitive electronic equipment, which may need "harmonics-canceling" transformers. TP-1 describes several exceptions recommended by transformer manufacturers, and all legislation enacted or proposed offers exemptions for some specialized equipment types. DOE will need to define exceptions to the standard with care to avoid creating loopholes that could greatly diminish the savings from this standard.

For medium-voltage dry-type and liquid-immersed transformers, a discussion of pros and cons boils down to economics. As shown in Table 10, these economics are generally quite favorable.

Energy, Economic, and Environmental Benefits of the Proposed Standard

Distribution transformer standards along these lines would result in substantial energy and peak demand savings, while providing substantial economic and emissions-reduction benefits as well. We conservatively estimate that these proposed transformer standards will result in annual energy savings of about 18.6 billion kWh by 2030.[17] This is

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[17] As noted above, our savings calculations for liquid-immersed transformers are based on the "average losses" case and savings from a standard at the minimum life-cycle cost point will likely be somewhat higher.

about the same as the total industrial sector statewide electricity use in Florida or Missouri in 2000 (EIA 2003d). Of these savings, 32% are attributable to low-voltage dry-type transformers, 23% to medium-voltage dry-type transformers, and 45% to liquid-immersed transformers. The need for summer peak electric generating capacity will be reduced by nearly 2,600 MW in 2030, equivalent to the output of about eight new power plants of 300 MW each. Net economic benefits to businesses (discounted benefits minus costs) total approximately $5.4 billion for equipment purchased by 2030. The benefit-cost ratio is 3.3:1—benefits are more than three times greater than costs. Emissions reductions are also significant, including 10,600 metric tons of nitrogen oxides, 45,800 metric tons of sulfur dioxide, and nearly 3.6 million metric tons of carbon per year by 2030. Achieving such carbon reductions today would be the equivalent of taking 2.5 million cars off the road.

See Appendix A for state-by-state savings achievable by this standard.

state's economy grew by 5% more than it would have absent energy efficiency improvements between 1977 and 1997 (Bernstein et al. 2002). A study by ACEEE for New York, New Jersey, and Pennsylvania found that improved efficiency could yield 164,000 new jobs in those states over a thirteen year period (Nadel et al. 1997). A similar macroeconomic study conducted by Tellus Institute and MRG Associates looked at the nation as a whole. That study found that a package of clean energy policies featuring energy efficiency could create 1.3 million jobs over twenty years while increasing gross domestic product by nearly $44 billion (Bailie et al. 2001). Finally, an analysis that examined the impact of a package of efficiency standards using a Florida State University econometric model found that the energy savings achieved by implementing those standards would increase wages and salaries in the state by about $8.1 billion and create more than 40,000 jobs over a twenty-five year period (FloridaPIRG 2003).

These studies show that shifting spending away from energy production and distribution toward other goods and services results in economic growth and net job creation. In other words, it takes relatively fewer workers to create and deliver a dollar's worth of energy than it does to create and deliver a dollar's worth of other goods and services.

Summary

Standards have been one of the most effective ways for improving energy efficiency in the U.S. economy over the medium and long term and, thus, are an important tool for job creation, spurring economic growth and helping to maintain a demand and supply balance that keeps energy prices in check.—*Andrew deLaski*

OTHER STANDARDS DUE FOR UPGRADES

In addition to the three product categories featured in this report, there are several other existing federal efficiency standards that can be cost-effectively upgraded. Some of these opportunities are discussed in the paragraphs below and summarized in Table 11.

Also, if higher efficiency levels for low-voltage dry-type transformers ultimately prove to be justified, savings will likewise increase.

Residential Refrigerators and Freezers

The average new residential refrigerator/freezer uses about 525 kWh per year (AHAM 2003). About 32% of sales earn the ENERGY STAR designation, meaning they use at least 15% less energy than units meeting the current federal standard (McNary 2004). Furthermore, units are now being sold that use 30% less energy than the current standard. Costs for these improvements are likely to be modest. DOE estimates that reducing the current standard by 30% will reduce energy use by 5.8 quadrillion Btu (quads) over the 2010–2035 period, on a par with recent major standards such as those on residential clothes washers, water heaters and central air conditioners and heat pumps. Net benefits of such a standard to consumers are likely to be in the range of $3-10 billion. DOE has upgraded the refrigerator standard twice, with the first upgrade taking effect in 1993, the second in 2001. A coalition of energy efficiency supporters has recently petitioned DOE to begin a rulemaking to set a new standard. If DOE proceeds with such a rulemaking at a reasonable pace, the new standard can take effect in 2011 at the earliest, ten years after the effective date of the last upgrade. We recommend that DOE proceed on this schedule (Nadel et al. 2004).

Residential Dishwashers

Residential dishwashers meeting the current federal standard use about 467 kWh per year (including energy to heat the hot water used by the dishwasher). ENERGY STAR dishwashers use about 20% less energy and now account for nearly three-quarters of dishwasher sales (McNary 2004). The incremental cost of the improvement is now about $25 (ACEEE 2003), but can be expected to decline further if this level of efficiency becomes the new standard. DOE estimates that setting a new standard at this level will save about 0.5 quads of energy on a cumulative basis (DOE 2004c), which while not as large as some recent standards, is still significant. ACEEE estimates such a standard will also result in substantial water savings, and that considering energy and water savings, consumers will receive discounted net savings of more than $1 billion from such a standard for products purchased through 2030. DOE last revised the dishwasher standard in 1991, with the standard taking effect in 1994. It is time to upgrade the standard again to at least the current ENERGY STAR level.

Commercial Packaged Terminal Air Conditioners and Heat Pumps

Packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs) are through-the-wall units used in commercial applications, particularly in hotels and motels. Efficiency standards for this equipment are contained in ASHRAE standard 90.1. For an 8,500 Btu/hour PTAC, the standard is 8.38 EER. The current standard was adopted by Congress in 1992 and is based on ASHRAE's 1989 standard. Under the federal law, whenever ASHRAE revised its standard, DOE reviews this standard and is instructed to adopt the ASHRAE standard unless there is "clear and convincing evidence" that a stronger standard is justified. ASHRAE revised its standard in 1999 (requiring 9.09 EER for 8,500 Btu/hour equipment), and DOE completed its review in 2001, concluding that it is at least reasonably likely that a stronger standard (e.g., 10.6 EER for 8,500 Btu/hour equipment) is justified. DOE was then supposed to begin a rulemaking to consider such a stronger standard, but little progress has been made for the past three years. DOE estimates that the 1999 ASHRAE standard will save about 0.107 quads over the 2004–2030 period and the minimum life-cycle cost standard will save 0.562 quads, a five-fold increase in savings (DOE 2000a). Furthermore, a voluntary specification developed by the New Buildings Institute (NBI) recommends even higher efficiency levels based on the most efficient equipment now on the market from multiple manufacturers (e.g., they recommend 11.3 EER for an 8,500 Btu/hour unit). DOE should restart this rulemaking and consider the NBI specification as a possible standard level.

Commercial Boilers

Commercial boilers are used to heat many commercial buildings. The boilers heat hot water which is used for both heating and sanitary purposes. As with PTACs, Congress set an initial standard for this equipment (calling for a combustion efficiency of 80% for gas boilers and 83% for oil boilers), based on the 1989 ASHRAE standard. The ASHRAE 1999 standard sets a new standard of 75% *thermal* efficiency for gas boilers and 78% for oil boilers less than 2.5 million Btu/hour of heating capacity. This standard is approximately equivalent to a combustion efficiency of 80 and 83% respectively (thermal and combustion efficiency differ in that the former includes non-combustion losses such as heat losses from the boiler itself). For larger equipment, ASHRAE kept the 80 and 83% combustion efficiency standards for gas and oil respectively. In 2001 DOE reviewed this standard and concluded the new ASHRAE standard will save no energy with hot water systems and a little energy with steam systems, but that a standard of about 78% thermal efficiency (or even higher for some sizes) is the minimum life-cycle cost point and merits consideration as a standard. (DOE did not evaluate oil boilers). DOE estimates that a standard at the minimum cost point will save about 0.28 quads of energy relative to the ASHRAE standard (DOE 2001). However, as with PTACs, DOE has done no further work on this rulemaking. The commercial boiler rulemaking should again be started; we recommend that this be combined with the PTAC rulemaking in order to efficiently use DOE's resources.

Commercial Central Air Conditioners & Heat Pumps, three-phase under 65,000 Btu/hr

This equipment uses three-phase motors but otherwise is the same as residential central air conditioners and heat pumps. The efficiency standard for this equipment is typically the same as that for residential single-phase equipment since the two types of equipment are nearly identical in design. Now that DOE has finalized the residential standard at SEER 13, it should adopt the same standard for the same-size commercial equipment.

Incandescent Reflector Lamps

Incandescent reflector lamps are designed to direct light in one direction. They are commonly used in recessed ceiling fixtures and for flood and spot lighting such as in retail stores, museums, and outdoor illumination around residences and small commercial buildings. In 1993 Congress set standards on these lamps which were generally designed to require use of halogen lamps which produce about 18% more lumens of light per Watt input than a typical incandescent reflector lamp (DOE 2004c). However, the standard exempted a very minor niche product called “BR” lamps (BR stands for Bulged Reflector, due to a slight bulge in the bottom of the reflector). Since these standards took effect, BR lamps have grown from less than 1% of incandescent reflector lamp sales to more than half of incandescent reflector lamp sales (DOE 2004c). To address this problem, California has recently started a rulemaking to set standards on BR lamps and other exempted products (e.g., ER, R20, and PAR 20 lamps). Other states are observing what California does. DOE should start a rulemaking to set a standard for BR lamps to close this loophole, most likely using the same standard for BR and other exempted lamps as apply to other incandescent reflector lamps.[18] DOE estimates that such a standard will save 0.74 quads of energy over the 2010-2035 period (DOE 2004c). In addition, in the longer term, DOE should consider setting an even stronger standard for incandescent reflector lamps based on halogen IR (infrared reflecting) technology which improves lumens/Watt by about 30% relative to standard halogen lamps (DOE 2004c).

Residential Central Air Conditioners and Heat Pumps

In 2001 DOE set a new standard for residential central air conditioners and heat pumps that calls for a Seasonal Energy Efficiency Ratio (SEER) of at least 13. This standard takes effect in 2006. During the 2001-2003 period, DOE (under a new administration) and manufacturers attempted to reduce this standard to SEER 12, but this effort was ultimately rejected by the courts. In winter 2004, those manufacturers that had sought to overturn the SEER 13 standard announced they would no longer oppose it and the DOE announced it would implement the standard as required in 2006. Federal law calls for an additional, required review of this standard. While some further increase in SEER may be possible, even larger energy savings can probably be achieved by designing air conditioners to perform better under field conditions, rather than the laboratory conditions used for the SEER test procedure. Two ways to increase efficiency under field conditions would be 1) to set requirements that equipment performance degrade only marginally with improper refrigerant charge; and 2) to rate equipment at the static pressures (friction in duct systems) typically found in the field. Therefore, a review of and revision to the central air conditioner test procedure is an important first step in the process of further improving central air conditioner efficiency. We recommend that DOE start this test procedure revision process in 2005, so that a new test procedure can be finalized before a new standard-setting process needs to begin. An improved test procedure will also be very useful for voluntary efficiency programs, and could provide lower cost options for meeting the 2006 standard.

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[18] We recommend such a rulemaking only under the condition that DOE proceeds without preempting state standards until DOE issues a final rule. Only once a final rule is issued is a federal standard a certainly. It makes no sense for DOE to preempt state standards in California and other states before there is certainty that there will be a federal standard. Also, early preemption will increase energy use because state standards would be preempted years before DOE is able to issue a final rule.

Table 11. Opportunities to Upgrade Other Efficiency Standards

Product Category	Type of Action	Basis for Proposed Standard
Residential Refrigerators and Freezers	standard	reduce current standard by 30%
Residential Dishwashers	standard	Current ENERGY STAR level
Commercial Packaged Terminal Air Conditioners & Heat Pumps	standard	Most efficient equipment now available from multiple manufacturers
Commercial Boilers	standard	Minimum life-cycle cost point
Commercial Central Air Conditioners & Heat Pumps, 3-Phase less than 65,000 Btu/hour	standard	SEER 13 (same as new residential central AC-HP)
Incandescent Reflector Lamps—Exempt Types	standard	Same standard as other reflector lamps
Residential Central AC & Heat Pumps	test procedure	NA

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APPENDIX A: STATE-BY-STATE ENERGY, ECONOMIC, AND ENVIRONMENTAL BENEFITS

The following tables provide a break-out of the benefits estimated to accrue to each state as a result of the new or revised efficiency standards described in this report. The first three tables present the benefits of each of the three standards individually, while the fourth table presents the combined benefits of all three standards.

Table A-1. State Benefits from Revised Efficiency Standards for Residential Furnaces and Boilers

		Energy				Economic			Environmental			
State	Cold/ Warm State*	Annual End Use Natural Gas Savings – Mil. cu. ft. (2030)	Annual End Use Electricity Savings – GWh (2030)	Annual Energy Savings (All Fuels) Bil. Btu (2030)	Summer Peak Electric System Capacity Reduction MW (2030)	Nominal Value of Energy Savings (2030) $ million	Net Present Value $ million	Benefit -Cost ratio	Carbon – 1000 MT (2030)	N0x – MT (2030)	SO_2 – MT (2030)	PM10 – MT (2030)
AL	W	199	258	2,787	173	21.2	64	2.3	49	157	936	6
AK	C	468	77	1,253	-	11.8	27	2.9	13	91	70	37
AZ	W	431	389	4,336	299	37.5	102	2.3	64	16	474	2
AR	W	480	445	4,952	107	37.9	158	4.8	87	79	967	10
CA	W	1,732	1,158	13,380	594	154.2	180	1.5	322	240	811	56
CO	C	12,292	614	18,770	17	132.7	356	2.0	238	59	750	193
CT	C	835	184	4,190	11	51.5	177	4.2	79	327	223	213
DE	W	67	79	883	8	7.8	29	5.1	18	78	189	3
DC	W	18	65	684	7	5.8	22	5.3	14	61	154	3
FL	W	58	761	7,678	558	66.4	166	2.2	126	163	1,701	17
GA	W	1,734	606	7,977	159	69.7	256	3.5	134	429	2,200	18
HI	W	0	37	368	55	6.1	4	1.4	10	55	55	55
ID	C	1,539	162	3,208	9	22.2	76	2.4	55	79	132	69
IL	C	30,016	2,328	54,407	390	464.3	1,553	2.8	984	3,008	8,053	2,197
IN	C	12,303	1,092	23,698	210	196.6	706	2.8	392	2,300	4,440	1,313
IA	C	2,898	556	8,667	106	76.0	264	3.4	186	279	1,451	186
KS	C	4,012	439	8,597	224	71.3	205	2.2	136	121	955	126
KY	W	244	257	2,829	86	17.3	71	2.7	53	316	1,045	9
LA	W	327	531	5,657	232	45.7	157	3.3	100	91	1,154	11
ME	C	215	92	1,917	1	24.8	86	6.0	37	152	112	91
MD	W	1,101	563	6,905	57	57.7	237	5.1	135	595	1,341	27
MA	C	1,935	360	8,561	17	103.7	364	4.3	161	663	437	449
MI	C	19,815	1,974	40,358	181	316.8	1,055	2.9	673	3,953	8,025	2,126
MN	C	8,099	1,059	19,161	85	154.1	594	3.7	401	599	2,762	488
MS	W	326	150	1,834	116	14.6	35	1.9	31	100	543	4
MO	C	2,518	941	12,173	375	91.7	342	3.0	207	186	2,044	96
MT	C	1,112	151	2,651	3	19.5	69	3.0	46	67	122	51
NE	C	4,461	318	7,829	84	57.8	185	2.3	157	233	830	251
NV	W	321	174	2,074	71	18.6	55	2.9	39	57	141	8
NH	C	832	81	2,327	2	27.1	100	4.4	43	176	98	136
NJ	C	7,197	714	16,137	119	152.0	443	2.6	287	1,236	1,704	794
NM	W	199	185	2,056	22	17.7	56	3.2	30	8	226	1
NY	C	13,057	1,709	35,363	108	451.9	1,316	3.5	425	2,855	4,651	1,577
NC	W	790	667	7,641	122	66.1	240	4.0	132	425	2,418	17
ND	C	725	157	2,356	12	22.8	72	4.2	51	76	410	48
OH	C	17,947	2,062	39,320	312	339.6	1,150	3.0	662	3,896	8,379	1,936
OK	W	750	636	7,141	164	54.2	226	5.0	125	113	1,382	15
OR	C	3,990	205	6,150	9	54.8	99	1.5	101	143	166	171
PA	C	10,336	1,164	25,037	156	257.0	882	3.2	448	1,932	2,779	1,186
RI	C	452	58	1,484	3	17.5	59	3.6	28	114	70	82
SC	W	223	292	3,212	78	26.5	95	3.6	56	180	1,059	7
SD	C	1,255	153	2,853	24	22.7	84	3.3	59	89	399	75
TN	W	352	342	3,785	153	25.9	92	2.5	66	212	1,240	8
TX	W	3,048	2,624	29,409	1,247	269.9	843	3.5	540	934	4,188	63
UT	C	5,255	236	7,766	17	55.6	149	1.9	126	179	192	224
VT	C	770	49	1,644	1	17.8	65	4.0	30	122	59	103
VA	W	615	699	7,812	78	64.2	257	4.9	136	437	2,537	17
WA	C	3,076	375	6,910	9	50.1	117	1.7	120	172	304	140
WV	C	834	215	3,070	15	21.4	95	3.8	54	322	874	98
WI	C	5,373	1,114	16,814	81	148.3	557	4.3	324	1,003	3,848	426
WY	C	346	82	1,177	2	8.3	33	3.5	17	4	100	6
US total		**186,980**	**29,640**	**507,250**	**6,968**	**4,526.7**	**14,626**	**2.9**	**8,795**	**29,126**	**79,145**	**15,193**

*Cold/warm state: We recommend a 90 AFUE natural gas furnace standard for “cold” states and a 81 AFUE furnace standard for “warm” states. States with more than 5000 average heating degree days are defined as “cold.”

Table A-2. State Benefits from Revised Efficiency Standards for Commercial Central Air Conditioners and Heat Pumps (65,000 to 240,000 Btu/hour)

	Energy		Economic			Environmental			
State	Annual Energy Savings – GWh (2030)	Summer Peak Electric System Capacity Reduction – MW (2030)	Nominal Value of Energy Savings – $Million (2030)	Net Present Value – $Million (2030)	Benefit-Cost Ratio	Carbon – 1000 MT (2030)	N0x – MT (2030)	SO_2 – MT (2030)	PM10 – MT (2030)
AL	360	433	25	87	3.1	64	208	1,304	8
AK	19	-	3	(0)	1.0	2	15	17	1
AZ	396	530	29	104	3.7	60	16	483	2
AR	116	132	7	25	2.5	21	19	251	2
CA	1,247	936	157	238	2.1	311	232	873	51
CO	98	75	6	2	1.1	15	4	120	1
CT	79	58	8	5	1.2	17	73	96	3
DE	30	31	2	5	2.0	6	27	71	1
DC	68	77	5	12	2.0	14	62	162	3
FL	1,340	1,600	95	378	4.6	221	286	2,996	30
GA	390	487	26	89	2.7	70	225	1,416	9
HI	109	52	17	31	4.8	29	31	94	3
ID	46	38	3	3	1.2	9	13	37	2
IL	400	487	32	57	1.7	84	264	1,382	15
IN	195	249	12	28	1.7	37	223	790	6
IA	77	83	5	9	1.5	18	28	200	4
KS	159	221	10	29	2.0	29	26	346	3
KY	193	213	11	39	2.3	37	222	785	6
LA	321	323	24	80	3.2	58	52	697	6
ME	18	11	2	(1)	0.9	4	17	22	1
MD	208	237	16	37	2.0	43	190	496	8
MA	125	92	13	4	1.1	27	116	151	5
MI	272	297	20	25	1.3	52	312	1,106	8
MN	79	73	5	4	1.2	19	28	206	4
MS	239	300	17	60	3.3	43	138	867	5
MO	296	365	17	49	1.9	53	48	643	6
MT	18	13	1	0	1.0	4	5	15	1
NE	72	85	4	10	1.6	17	26	188	4
NV	90	117	8	21	2.7	18	26	73	3
NH	20	14	2	(0)	1.0	4	18	24	1
NJ	330	245	30	41	1.5	68	301	788	13
NM	54	47	4	8	1.7	8	2	66	0
NY	482	321	63	48	1.4	66	456	1,309	18
NC	351	419	23	73	2.4	62	202	1,272	8
ND	18	18	2	1	1.1	4	6	46	1
OH	327	398	25	40	1.5	62	375	1,329	10
OK	170	208	11	37	2.6	31	28	368	3
OR	151	82	10	12	1.3	30	43	123	6
PA	263	195	22	28	1.4	54	239	626	10
RI	17	11	2	1	1.1	4	16	20	1
SC	209	249	14	48	2.8	37	120	756	5
SD	21	24	1	2	1.4	5	8	55	1
TN	381	459	25	82	2.5	68	220	1,383	8
TX	1,402	1,718	111	353	3.3	265	460	2,238	29
UT	58	52	3	7	1.5	11	17	47	2
VT	10	6	1	(0)	0.9	2	9	12	0
VA	240	274	14	43	2.0	43	139	871	5
WA	225	81	14	15	1.2	44	64	182	9
WV	49	53	3	7	1.7	9	56	199	1
WI	123	134	9	10	1.3	26	81	426	5
WY	16	11	1	0	1.1	2	1	19	0
U.S. Total	**11,976**	**12,634**	**968**	**2,289**	**2.1**	**2,285**	**5,795**	**28,047**	**339**

Table A-3. State Benefits from New Efficiency Standards for Distribution Transformers

	Energy		Economic			Environmental			
State	**Annual Energy Savings – GWh (2030)**	**Summer Peak Electric System Capacity Reduction – MW (2030)**	**Nominal Value of Energy Savings – $Million (2030)**	**Net Present Value – $Million (2030)**	**Benefit-Cost Ratio**	**Carbon – 1000 MT (2030)**	**N0x – MT (2030)**	**SO$_2$ – MT (2030)**	**PM10 – MT (2030)**
AL	338	47	17	100	3.5	60	195	1,225	7
AK	44	6	4	13	3.5	5	36	40	2
AZ	357	49	21	107	3.5	54	14	436	2
AR	182	25	9	53	3.3	33	30	395	4
CA	1,457	201	122	365	2.7	363	272	1,020	60
CO	314	43	17	93	3.5	48	12	383	2
CT	242	33	20	71	3.4	53	225	293	10
DE	59	8	3	18	3.5	12	54	141	2
DC	88	12	6	29	4.4	18	80	209	3
FL	1,217	168	73	365	3.5	201	260	2,720	27
GA	592	82	31	178	3.5	106	342	2,148	13
HI	71	10	9	20	3.2	18	20	61	2
ID	101	14	4	31	3.7	20	29	82	4
IL	857	118	49	251	3.4	180	566	2,960	32
IN	427	59	20	124	3.3	81	490	1,735	13
IA	201	28	10	57	3.2	47	72	523	11
KS	210	29	11	63	3.5	38	34	457	4
KY	284	39	11	83	3.3	54	326	1,153	9
LA	327	45	22	97	3.5	59	54	710	7
ME	87	12	7	25	3.2	19	81	105	3
MD	418	58	24	127	3.6	86	381	997	16
MA	306	42	29	77	2.7	67	284	371	12
MI	709	98	42	208	3.4	135	813	2,878	21
MN	239	33	11	61	2.7	56	86	623	13
MS	205	28	11	61	3.5	37	118	744	4
MO	435	60	21	130	3.5	78	71	944	9
MT	65	9	4	19	3.3	13	19	53	2
NE	128	18	6	38	3.4	30	46	335	7
NV	123	17	8	36	3.4	24	35	99	5
NH	81	11	8	23	3.3	18	75	99	3
NJ	602	83	52	179	3.5	124	548	1,435	23
NM	121	17	8	36	3.4	18	5	148	1
NY	922	127	51	236	2.7	127	873	2,506	35
NC	609	84	33	183	3.5	108	351	2,207	13
ND	48	7	3	14	3.4	11	17	126	3
OH	828	114	47	242	3.3	158	949	3,362	25
OK	251	35	13	74	3.4	45	41	544	5
OR	266	37	13	80	3.5	52	76	216	10
PA	767	106	49	213	3.1	158	698	1,829	29
RI	68	9	7	19	3.2	15	63	82	3
SC	295	41	15	88	3.5	53	170	1,069	6
SD	51	7	3	15	3.3	12	18	134	3
TN	442	61	23	133	3.5	79	255	1,602	10
TX	1,450	200	91	433	3.5	274	476	2,315	30
UT	134	18	6	40	3.5	26	38	108	5
VT	43	6	4	12	3.3	9	40	52	2
VA	514	71	25	152	3.4	92	297	1,866	11
WA	438	60	23	130	3.4	86	126	355	17
WV	138	19	6	40	3.3	26	158	559	4
WI	375	52	19	109	3.3	79	248	1,296	14
WY	42	6	2	13	3.6	6	2	51	0
U.S. Total	**18,568**	**2,562**	**1,125**	**5,363**	**3.3**	**3,570**	**10,567**	**45,798**	**561**

Note: As noted in the body of this report, savings estimates for transformers are very conservative and ultimate savings from a standard at the levels we recommend are likely to be somewhat higher than the values shown here.

Table A-4. State Benefits from Three Priority New or Revised Efficiency Standards

	Energy				Economics		Environmental			
State	**Annual End Use Natural Gas Savings – Mil. cu. ft. (2030)**	**Annual End Use Electricity Savings – GWh (2030)**	**Annual Energy Savings (All Fuels) Bil. Btu (2030)**	**Summer Peak Electric System Capacity Reduction MW (2030)**	**Nominal Value of Energy Savings (2030) $ million**	**Net Present Value $ million**	**Carbon – 1000 MT (2030)**	**N0x – MT (2030)**	**SO_2 – MT (2030)**	**PM10 – MT (2030)**
AL	199	955	9	652	63	252	173	560	3,465	21
AK	468	140	1	6	19	40	21	142	127	39
AZ	431	1,142	11	878	88	312	178	46	1,393	7
AR	480	743	7	264	53	236	N/A	N/A	N/A	N/A
CA	1,732	3,862	40	1,731	434	783	760	583	2,860	122
CO	12,292	1,026	22	135	156	452	384	256	1,314	58
CT	835	505	7	103	79	253	150	625	612	226
DE	67	168	1	47	13	52	36	159	402	7
DC	18	220	2	96	16	63	46	203	525	9
FL	58	3,317	33	2,325	235	908	548	709	7,416	75
GA	1,734	1,589	17	728	126	522	309	996	5,764	40
HI	0	217	2	117	31	55	57	107	211	61
ID	1,539	310	4	61	29	110	84	121	251	75
IL	30,016	3,586	67	995	546	1,861	1,248	3,839	12,395	2,244
IN	12,303	1,714	29	519	228	859	510	3,013	6,965	1,332
IA	2,898	834	11	217	91	330	251	378	2,173	202
KS	4,012	809	12	474	93	297	203	182	1,757	133
KY	244	735	7	339	39	193	143	863	2,983	23
LA	327	1,179	12	599	92	334	217	197	2,561	25
ME	215	198	2	24	34	110	60	249	239	95
MD	1,101	1,189	13	352	98	401	264	1,165	2,835	51
MA	1,935	791	12	151	145	446	256	1,063	958	466
MI	19,815	2,956	50	575	379	1,288	859	5,078	12,009	2,155
MN	8,099	1,377	22	191	170	659	476	713	3,591	506
MS	326	594	6	444	43	157	110	357	2,154	14
MO	2,518	1,671	19	800	130	521	338	306	3,631	110
MT	1,112	234	3	25	25	88	63	91	190	54
NE	4,461	519	9	187	68	233	204	305	1,353	262
NV	321	387	4	205	35	111	80	118	313	16
NH	832	182	3	27	37	123	65	270	221	140
NJ	7,197	1,646	25	447	234	663	478	2,084	3,926	830
NM	199	360	3	86	29	100	57	15	440	2
NY	13,057	3,113	49	557	566	1,600	618	4,183	8,466	1,631
NC	790	1,626	17	624	122	495	303	978	5,897	38
ND	725	223	3	37	28	87	66	100	582	52
OH	17,947	3,217	50	824	412	1,432	881	5,221	13,069	1,971
OK	750	1,056	11	406	79	337	201	182	2,294	23
OR	3,990	623	10	128	77	191	182	263	505	187
PA	10,336	2,194	35	457	329	1,123	659	2,869	5,234	1,225
RI	452	142	2	23	26	79	46	192	172	85
SC	223	795	8	368	55	231	146	471	2,884	18
SD	1,255	225	3	55	27	101	76	115	587	79
TN	352	1,165	12	673	74	306	212	687	4,224	26
TX	3,048	5,476	57	3,165	472	1,628	1,079	1,870	8,741	122
UT	5,255	428	9	88	65	195	164	234	348	231
VT	770	101	2	13	23	77	41	171	123	106
VA	615	1,454	15	423	103	452	270	873	5,275	34
WA	3,076	1,037	13	150	87	262	250	362	841	165
WV	834	402	4	87	30	142	90	536	1,632	104
WI	5,373	1,612	21	267	176	676	429	1,332	5,570	445
WY	346	139	1	19	11	46	25	6	170	6
U.S. Total	**186,980**	**60,184**	**813**	**22,165**	**6,619**	**22,278**	**14,367**	**45,435**	**151,649**	**15,949**

APPENDIX B: ASSUMPTIONS, DETAILED METHODOLOGY, AND SOURCES

Overview

We obtained preliminary national energy savings from proposed new standards by multiplying annual sales figures for each product by per-unit energy savings. We calculated electricity and natural gas savings separately, and then summed to obtain total primary energy savings.[19] To calculate peak generation savings, we multiplied electric generation savings by a peak factor (kilowatt per kilowatt-hour). The peak factor for each product 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. We calculated financial costs by multiplying the per-unit incremental cost for each product by the number of units affected by the standard. As noted below, for each product, we exclude from our cost and savings calculations the portion of the market that would meet or exceed the standard absent implementation of the standard. For cumulative costs and savings, we discounted to 2003 using a 5% real discount rate. Cumulative costs and savings cover the period from the effective date of the standard to 2030. The present value of savings also includes savings after 2030 for equipment sold prior to 2030. We derived emission reductions by multiplying regional electric sector emission factors (in metric tons/MWh) to the electricity savings and EPA emission factors for direct combustion of natural gas.

Savings for individual states were calculated by allocating national savings to the states based on a variety of allocation factors (see below for more detail), adjustments to savings levels based on climate where necessary, and estimates of current market penetration of products meeting the proposed standard levels. State level energy bill savings were calculated using state specific energy prices; we assume no increase in current price levels over the analysis period. We summed the energy, economic and environmental benefits from the individual states to arrive at the national savings figures reported.

Detailed Methodology

Calculation of National Energy and Peak Demand Savings

We obtained national energy savings from proposed new standards by multiplying annual national sales figures for each appliance by per-unit energy savings. The analysis is static and assumes that equipment sales remain at 2001 levels for most products. We also assumed 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 assumed that these factors counterbalance each other.

We used one of the following equations to calculate end-use electricity savings:

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

(a) End-use electricity savings = annual sales volume x (years from effective date - 0.5) x per-unit electricity savings
(b) End-use electricity savings = annual sales volume x average product life x per-unit elec. savings

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

(a) NG savings = annual sales volume x (years from effective date - 0.5) x per-unit NG savings
(b) NG savings = annual sales volume x average product life x per-unit NG savings

In each case, we used equation (a) when the average product lifetime is longer than the number of years from the effective date. Otherwise, we used equation (b) in order to avoid double counting the savings from replacements after 100% saturation. We subtracted 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.

For heat rates to calculate primary energy savings (primary energy input required to generate a unit of electricity, in Btu/kWh), we use 10,752 Btu/kWh for 2010 and 10,337 Btu/kWh for 2020 (EIA 2003a). We use a 0.91 transmission and distribution (T&D) loss factor, reflecting 9% T&D losses (EIA 2003b).

To calculate peak generation savings, we multiplied electric generation savings by a peak factor (kilowatt per kilowatt-hour) that quantifies the fraction of a product's annual hours of usage that occur during times of peak system demand. Table B-1 provides the sources of the peak factors used for this analysis.

We calculated peak capacity savings as:

Peak capacity savings = end-use electricity savings ÷ T&D loss factor x peak factor x reserve factor

The analysis assumed a conservative 10% reserve margin. Thus the reserve factor in the formula is 1.1. Historically, a reserve margin of 20% was typical, but utilities have cut down their margins during restructuring of the electric utility industry.

State Allocation Factors

For residential gas furnaces, national sales are allocated to the states based on state-level furnace shipments data (Kendall 2002). For boilers and oil furnaces, sales are allocated based on the ratio of households in a state to total national households (Census 2001). We further adjusted the allocation factors for each appliance according to the saturation and usage of each appliance by Census Region (e.g., Northeast) and Division (e.g., New

England). We found the data that supports saturation and usage rates in the Residential Energy Consumption Survey 1997 (EIA 1999b). Since each Census Division includes several states, we adjusted for usage differences within each Division on the basis of average heating degree days for each state relative to average heating degree days for the Census Division (from NOAA 2002a).

For commercial air conditioners, we calculated the allocation factor in several steps: the factor started as the ratio of commercial building square footage to total building square footage in each Census Division, then we adjusted it using the ratio of state commercial sector energy use to commercial sector energy use in that Census division (EIA 1999a). We further adjusted the allocation factors for each appliance according to the saturation and usage of each appliance by Census region and division using data in the Commercial Building Energy Consumption Survey (CBECS) (EIA 1999c). Since each Census Division includes several states, we adjusted for usage differences by Division on the basis of a "cooling index" for each state relative to the cooling index for the Census Division. The cooling index was developed by ACEEE to account for the fact that a portion of commercial cooling loads are due to heat gain from the outside and a portion due to internal heat gains. The cooling index is defined to be 2.32 + 0.00299 x Cooling Degree Days where this formula was derived by regression analysis that compared CBECS Census Division data on average cooling energy use per square foot of commercial building floor area to average cooling degree days by Census Division (NOAA 2002b).

For low-voltage dry-type distribution transformers we allocated sales among the states on the basis of commercial electricity sales for each state. For medium-voltage dry-type and liquid-immersed transformers, we allocated sales based on state electricity consumption for all sectors.

Thus we used the following formulas to derive state allocation factors:

For residential furnaces and boilers:

Allocation factor = (state sales ÷ national sales or state households ÷ national households)
x (saturation % in region/division ÷ national avg. saturation %)
x (usage in region/division ÷ national avg. usage)
x (heating degree days in state ÷ heating degree days in division)
x (fraction of sales in state that do not already meet standard)

For commercial air conditioners:

Allocation factor = (building sq. footage in Census division ÷ national building square footage)
x (state commercial electricity use ÷ commercial electricity use in Census division)
x (saturation % in Census division ÷ national avg. saturation %)
x (usage in Census division ÷ national avg. usage)

x (commercial cooling index in state ÷ commercial cooling index in division)
x (fraction of sales in state that do not already meet standard)

For transformer products:

Allocation factor = (commercial or all-sector electricity sales in state
÷ national commercial or all-sector electricity sales)
x fraction of sales in state that do not already meet standard

The fraction of sales that do not already meet a standard level were estimated using available data at the national, regional, and local levels and professional judgment. Product-specific assumptions and sources are listed in Table B-1.

Calculation of Economic Costs and Savings

We calculated consumer bill savings using the following formula:

Consumer bill savings = (end-use electricity savings x state avg. electricity price) + (natural gas savings x state avg. natural gas price)

For electricity and natural gas prices, we used 2003 state-by-state prices reported by the U.S. Energy Information Administration and assumed that prices over the analysis period would remain constant at current levels.

We calculated expected investment using the following formula:

Expected investment = Annual sales volume x per-unit incremental cost

We discounted present value (PV) calculations to 2003 assuming a 5% real discount rate. The present value (PV) of expected investment aggregates the annual investments from the effective date of each standard through 2030. The PV of savings aggregates the business and consumer bill savings from the effective date of the standard through the year in which products installed through 2030 die out. These two measures give the cumulative costs and benefits of standard-compliant products installed through 2030. Subtracting the PV of the investments from the PV of the savings yields the net present value of the standards policy.

Calculation of Emission Reductions

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

*Emission reductions = end-use electricity savings ÷ T&D loss factor x marginal emission factor*s

We used 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 base load plants. They are the dirtiest, but also the cheapest to operate under current regulatory conditions, so are likely to remain in operation absent regulatory changes, even with improvements in end-use energy efficiency. Carbon emissions savings for natural gas are based on DOE projections (EIA 1998). 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 emission 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 improved energy efficiency (Geller, Bernow & Dougherty 1999). For additional details, see Thorne, Kubo & Nadel (2000a).

Table B-1: Assumptions and their Sources

Products	2001 Sales	Current Standard or Baseline	New Standard or Average Use	Average Product Life	Annual Baseline and Savings/Unit Calculation	Per Unit Incremental Cost	Coincidental Peak Factor
Residential Furnaces and Boilers	DOE 2002	Kendall 2002; NAECA 1987	DEG/ ACEEE 2004 for fans; Kendall 2002 for AFUE	DOE 2001	EIA 1999c; Sachs & Smith 2003	DOE 2002; Jakob et al. 1994; Sachs & Smith 2003	Thorne, Kubo & Nadel 2000a
Commercial Air Conditioners and Heat Pumps	Thorne et al. 2000b	ASHRAE 2001; manuf. Web sites	DOE 2003c	ASHRAE 1996; DOE 2003c	ASHRAE 1993 for op hrs	Cool Choice 1998; DOE 2003c	Thorne, Kubo & Nadel 2000b
Distribution Transformers	Barnes et al. 1997	Barnes et al. 1997	Barnes et al. 1996; DOE 2003b, 2004b; NEMA 2002	DOE 2000b	Barnes et al. 1996; DOE 2003b	Barnes et al. 1997; DOE 2003b	Thorne, Kubo & Nadel 2000a