INCORPORATING NEW EFFICIENCY STANDARDS AND CODES IN UTILITY FORECASTS

Steven Nadel

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American Council for an Energy-Efficient Economy
1001 Connecticut Avenue, NW
Suite #801
Washington, DC 20036

INTRODUCTION

During the 1980s and 1990s, in an effort to reduce energy use, state governments and the Federal government adopted energy codes and equipment efficiency standards to reduce energy use.

Energy codes, which are typically part of building codes, require that many energy-saving measures be designed into new buildings. Among the building components that are regulated are insulation, windows, and heating, cooling, and lighting systems. These codes have been adopted by 36 state governments, as well as many municipalities. An excellent summary of the different state energy codes was prepared by NCSBCS (1991).

Equipment efficiency standards require that equipment, such as refrigerators, air conditioners, lamps, and electric motors, exceed a certain efficiency level in order to be sold. Such standards have been adopted by states such as California, Massachusetts, and New York as well as the Federal government. Federal standards fall under two different laws -- the National Appliance Conservation Act of 1987 (and 1988 amendments) and the Energy Policy Act of 1992. Efficiency standards set under these two laws are summarized in Tables 1 and 2. Further information on the efficiency standards in these two laws can be found in Turiel et al. 1990 and Geller and Nadel 1992.

Energy codes and equipment efficiency standards are periodically updated. Many state energy codes are updated on three- or five-year cycles or are updated on an "as needed" basis. Efficiency standards are typically updated every five years. However, at both the state and Federal levels, rulemaking procedures can become delayed, with the result that many codes and standards are updated one to two years behind schedule.

Electric and gas utilities, and some state governments, periodically prepare forecasts of future demand for electricity and natural gas. These forecasts are used to plan for adequate supplies of electricity and gas, and for other energy policy initiatives. Most commonly, forecasters incorporate the effects of new codes and standards midway between the date a new code or standard is formally adopted, and the date it actually takes effect (the period between adoption and effective date typically is one to three years). In some cases, new codes and standards are not factored into forecasts until after they take effect. However, very few forecasts factor in the effects of code and standard updates that have yet to be adopted, even though update schedules stretching well into the next century are written into Federal law. By not allowing for code and standard updates, these forecasts are implicitly assuming that codes and standards will not change in the future. Recent history indicates that this is a very poor assumption. As a result, most forecasts may be significantly overestimating future electricity and natural gas demand.

Table 1. Efficiency Standards Established Under the National Appliance Energy Conservation Act of 1987 (and 1988 amendments).

Product	Effective Date of Initial Standard	Effective Dates of Updates
Refrigerator/freezers	1990	1993, 1998, 2003
Freezers	1990	1993, 1998, 2003
Clothes washers	1988	1994, 1999, 2004
Clothes dryers	1988	1994, 1999, 2004
Dishwashers	1988	1994, 1999
Ranges and ovens	1990	1998, 2003
Water heaters	1990	1998, 2005
Room air conditioners	1990	1998, 2003
Central air conditioners	1992-93	1999, 2006
Heat pumps	1992-93	2002, 2006
Furnaces and boilers	1992	2002, 2012
Direct heating equipment	1990	1998, 2003
Pool heaters	1990	1998, 2003
Ballasts for fluorescent lamps	1990	1998, 2003

Notes: Dates are rounded to the nearest New Year's Day. Where a range of dates is shown, standards for different classes of products take effect on different dates. Dates in 1998 assume DOE completes these rulemakings in 1995. Dates in 1999 and beyond assume DOE meets the statutory schedule.

Table 2. Efficiency Standards Established Under the Energy Policy Act of 1992.

Product	Effective Date of Initial Standard	Effective Date of First Update
Fluorescent lamps	1994-96	1999
Reflector incandescent lamps	1996	1999
Electric motors (1-200 horsepower)	1998-2000	2003-05
Packaged commercial air conditioners and heat pumps (up to 240,000 Btu/hr)	1995-96	1999-2000
Commercial water heaters	1995	1999
Commercial furnaces and boilers	1995	1999
Showerheads	1994	1999?
Faucet aerators	1994	1999?
Toilets and urinals	1994-97	1999?

Notes: Dates are rounded to the nearest New Year's Day. Where a range of dates is shown, standards for different classes of products take effect on different dates. Dates of updates assume DOE completes rulemakings in accordance with the schedule established in the legislation. Dates for commercial HVAC standards assume new ASHRAE 90.1 standard published in late 1996 and that DOE accepts these standards. Dates for updated plumbing standards are uncertain as the schedule for updates is determined by ANSI, or in the absence of ANSI action, determined by actions of individual states.

In order to help address this problem, this paper provides estimates of possible future codes and standards for particular products. These estimates are provided in formats that make them easy to incorporate in many of the most commonly used residential and commercial load forecasting models. This paper also includes a simple forecast that projects the impacts of these possible code and standard updates on future demand for electricity and natural gas in the U.S.

STANDARD AND CODE UPDATE PREDICTIONS

Approach

Standards and codes are set through a process in which the technical and economic merit of different efficiency measures are assessed and standard and code levels are set based on these analyses plus the decision-makers' subjective judgement about what standard and code levels are practical and politically acceptable. For Federal equipment standards, under the legislation, standards must generally be set by the U.S. Department of Energy (DOE) at the maximum levels of energy efficiency that are "technically feasible and economically justified." The criteria that are used to assess technical and economic merit are spelled out in the legislation. The emphasis in this process is on technical and economic analysis, but subjective judgements are required to interpret the data and to weigh the different criteria. For example, at what point are impacts on manufacturers adverse enough to reduce the stringency of a standard?

For codes, decisions are often made by committees of experts convened by such organizations as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the Council of American Building Officials (CABO). In many cases, the standard or code level selected corresponds to the minimum life-cycle cost point in the economic analysis. In other cases, decision-makers select standards and code levels less stringent than the minimum life-cycle cost point because of concerns that the minimum life-cycle cost point is not technically feasible or may have adverse impacts on equipment manufacturers. In the case of building codes, strong opposition from building and design professionals can stymie potential code requirements.

Given these complex decision-making processes, predicting the final decisions that will be made is a speculative undertaking. However, by carefully observing decisions that have been made in the past, by examining data that decision-makers are likely to use in their decisions, and by actively participating in these standard- and code-setting processes (by participating in committees and public hearings), reasonable estimates about future standards and codes can be made. This paper attempts to make these estimates based on the author's more than ten years of experience working on standards and codes, including helping to negotiate initial standard levels set in state and federal implementing legislation, participating on several code-setting committees, and actively participating in many rulemakings.

Given the many uncertainties involved, three sets values regarding possible future standard levels are provided. First, an estimate of the most likely result of each standard- and code-setting process is provided, which we label the "midpoint estimate." Second, a conservative estimate of future standard and code levels is provided, levels which are very likely to be equalled if not exceeded. We label these predictions the "high likelihood scenario." Third, a set of estimates of the maximum standard or code level which stands a significant chance of being selected is provided. We label these predictions the "maximum savings scenario." As is implied in the titles, the first scenario is useful for a baseline energy use forecast. The second scenario is useful for high load growth forecasts and the third scenario is useful for estimates of the minimum energy requirements a utility might have to supply. Taken together, the three scenarios provide a broad range of potential standard and code impacts, bounding what is likely to be adopted in our view.

In this paper, future standard and codes are considered for the 1995-2007 period. Of course, the farther from the present one goes, the greater the uncertainty regarding stringency and timing.

In addition to revisions of existing standards and codes, state and Federal governments may adopt efficiency standards on products not presently covered. Under EPAct, DOE is authorized to set efficiency standards on several new products. Two of these products -- incandescent and high intensity discharge lamps -- are included in this analysis. Except for these two cases, this paper does not attempt to make predictions about these potential new standards. For a discussion about many of the equipment types that may ultimately be subject to standards, please see a paper on this topic by Nadel (1994).

For many of the products discussed in this paper, the American Council for an Energy-Efficient Economy (ACEEE) is an advocate for strong standards and codes. The estimates made here are not necessarily the standard and code levels ACEEE supports, nor necessarily the levels we believe are justified. Instead, these estimates represent our reading of the range of possible future codes and standards that are likely to emerge from the different decision-making processes.

In the sections below, most of the major standard and code decisions that will be made over the next decade are discussed. Included in these discussions are summary tables that present the data in a form that can be readily adapted to the most common forecasting models.

Residential Standards

The most commonly used residential forecasting models are end-use models in which energy used for each end-use is predicted based on the number of units in the building stock and the average energy consumption of these units. In calculating the average energy consumption for each type of equipment, new equipment is generally modeled separately from existing equipment because, due to the impacts of past standards and codes, as well technological developments and increased consumer interest in saving energy, new equipment is generally more efficient than old equipment. In the sections below, the efficiency of new equipment is assessed. These assessments are either expressed in kWh/unit -- for equipment whose energy use does not vary appreciably from region to region -- or as a percentage savings relative to current new equipment -- for equipment such as space heating and cooling and water heating in which energy use patterns vary significantly from region to region. In these latter cases, the percentage reductions should be applied to local data on the energy use of new equipment purchased today. Based on these estimates for new equipment, and available data on existing equipment, forecasters can construct estimates on the efficiency of existing equipment throughout the forecast period. Specific predictions, for each of the three scenarios, are summarized in Table 3.

Refrigerators

DOE published an Advanced Notice of Proposed Rulemaking (ANOPR) regarding the next refrigerator efficiency standard in September, 1993 (DOE 1993a). Under NAECA the next standard is scheduled to take effect January 1, 1998. However, in order to meet this schedule, the entire rulemaking must be completed by January 1, 1995. Currently refrigerator manufacturers are negotiating with a group of energy-efficiency advocates, state energy offices, and electric utilities over what the new standard level might be. If these parties reach agreement, they plan to jointly petition DOE to adopt their agreement. If DOE acts quickly on considering such an agreement, a final rule on the new refrigerator standard could be issued close to the January 1, 1995 date. If the negotiations are not successful, or if DOE takes a long time to consider the agreement, then it is highly unlikely the standard will be finalized in early 1995 since two more steps are needed in the rulemaking, and each step can take a year.

For the last refrigerator rulemaking, DOE selected a standard that reduced refrigerator energy use by an average of 25% relative to the previous standard (DOE 1989). For this next rulemaking we estimate savings of 20%, 30%, and 40% (for the three scenarios) relative to the current standard. Each of the major manufacturers already produces some refrigerator models with energy use 20% better than the current standard (AHAM 1994a). As a result of the Super-Efficient Refrigerator Program (SERP), one manufacturer is now producing a single model that uses 30% less energy than the current standard. Furthermore, under the SERP program, this manufacturer is scheduled to introduce a model in 1995 that uses 40% less energy than the current standard (Langreth 1994).

DOE is likely to develop another refrigerator standard which will take effect five years after the previous (circa 1999) standard. Estimating this next standard level is very speculative. Based on the 1989 rulemaking (25% savings), and based on our estimate of the 1998 standard (30% savings), our midpoint estimate is for an additional 25% savings in the midpoint case and a 20% savings in the conservative case. In the maximum savings case we estimate a new standard of 250 kWh per refrigerator, based on a U.S. Environmental Protection Agency (EPA) analysis showing that these levels will probably be achievable at reasonable cost with additional research and development (EPA 1993).

In forecasting the energy use of refrigerators into the next century, another set of factors that comes into play are changes in the size and features of refrigerators over time. Treating these issues here is beyond the scope of this paper; however, forecasters need to be aware of these issues and make appropriate adjustments for these changes. A set of historic data on size and feature trends is published by the Association of Home Appliance Manufacturers (AHAM 1994).

Freezers

Freezers are included in the same rulemaking proceeding as refrigerators and will follow the same time schedule. Also, a negotiation process is underway on the next freezer standard, involving the same parties as the refrigerator negotiations. In DOE's previous rulemaking they

Table 3. Predictions for Future Residential Equipment Efficiency Standards.

Product	Effective Year of Standard	Current Std.	Units	Highly Likely New Std. Std.	Highly Likely New Std. Basis	Midpoint Est. for New Std. Std.	Midpoint Est. for New Std. Basis	Maximum Possible New Std. Std.	Maximum Possible New Std. Basis
Refrigerators	1998	704	kWh	560	20% savings	490	30% savings	420	40% savings
Refrigerators	2003			450	~20% savings	370	~25% savings	250	EPA Mult. pathways
Freezers	1998	474	kWh	400	~15% savings	350	DOE Level 5	315	DOE Level 5 - 10%
Freezers	2003			360	10% savings	315	DOE Level 5 - 10%	250	DOE Level 5 - 20%
Clothes washers	1999 *	608	kWh	485	~20% savings	255	'89 TSD H-Axis	220	~CEE Tier 2
Electric clothes dryers	1999	805	kWh	500	Hi spin spd	475	Hi spin spd - 5%	325	Hi spin spd + HP dryer
Gas clothes dryers	1999	33	therms	20	Hi spin spd	19	Hi spin spd - 5%	18	Hi spin spd - 10%
Dishwashers	1999	498	kWh	425	~15% savings	375	~25% savings	~345	Best European model
Electric water heaters	1998 *	0.86	EF	5% svgs	EF >= .93	40% svgs	EF>=1.89 for 40+ gals	64% svgs	EF>= 2.4 (HPWH)
Electric water heaters	2005			2% svgs	EF >= .95	21% svgs	EF>= 2.4 for 40+ gals	20% svgs	EF>= 3.0
Gas water heaters	1998	0.54	EF	7% svgs	EF >= .58	14% svgs	EF >= .63	21% svgs	EF >= .68
Gas water heaters	2005			8% svgs	EF >= .63	0% svgs	Next step unclear	21% svgs	EF >= .86
Room air conditioners	1998	8.7	EER	13% svgs	EER >= 10	19% svgs	EER >= 10.8	23% svgs	EER >= 11.3
Electric ranges	1998	none		0% svgs	No change	350	8% svgs -- 1/2 of NOPR	320	DOE NOPR -- 16% svgs
Gas ranges	1998	33	therms	25% svgs	AHAM stds proposal	40% svgs	Avg. of max & min	55% svgs	DOE NOPR
Microwave ovens	1998	none		270 kWh	0% svgs - AHAM prop	252 kWh	DOE NOPR	233 kWh	DOE NOPR
Central air conditioners	1999	10	SEER	17% svgs	SEER >= 12	29% svgs	SEER >= 14	37% svgs	SEER >= 16
Central air conditioners	2006			14% svgs	SEER >= 14	12% svgs	SEER >= 16	20% svgs	SEER >= 20
Central heat pumps	2002	6.8	HSPF	10% svgs	HSPF >= 7.5	20% svgs	HSPF >= 8.5	32% svgs	HSPF >= 10
Furnaces	2002	78%	AFUE	2.5% svgs	AFUE 80%	16% svgs	AFUE 93% (condensing)	38% svgs	AFUE 125% (heat pump)
Boilers	2002	78%	AFUE	2.5% svgs	AFUE 80%	10% svgs	AFUE 87% (condensing)	13% svgs	AFUE 90% (condensing)
Televisions	1998	none		145 kWh	Prelim. Sony data	145 kWh	Prelim. Sony data	139 kWh	DOE NOPR
Incandescent lamps	2001	none		10% svgs	Energy Saver lamps	27% svgs	Halogen IR	27% svgs	Halogen IR
Incandescent lamps	2006			19% svgs	Halogen IR	45% svgs	Coated filament	45% svgs	Coated filament
Showerheads	2000	2.5	gpm	0% svgs	No change	20% svgs	2.0 gpm	40% svgs	1.5 gpm
Showerheads	2005			0% svgs	No change	25% svgs	1.5 gpm	0% svgs	1.5 gpm
Faucets	2000	2.5	gpm	20% svgs	2.0 gpm	30% svgs	1.75 gpm	40% svgs	1.5 gpm

Notes:

- % savings figures are relative to prior standard.
- An asterisk after effective date indicates that standard effective date may be delayed two years if a horizontal-axis clothes washer standard or heat pump water heater standard were adopted in order to give manufacturers extra time for a total product redesign.

examined a freezer efficiency level -- a sales-weighted average of 350 kWh per freezer, that was the minimum lifecycle cost point but was assessed to not be technically feasible for implementation in 1993 (DOE 1989a). This level is our midpoint estimate for the 1999 freezer standard. Our conservative estimate is 15% savings, which is somewhat less than our conservative estimate for refrigerators because achieving savings is somewhat more difficult in freezers than refrigerators. Our maximum savings estimate is 10% beyond the 350 level examined in 1989, based on the likelihood that technology has advanced somewhat since 1989.

For the next standard (circa 2004), predictions are more speculative. We predict 10% savings from the 1999 standard for the conservative and midpoint cases (somewhat less than the 1993 and 1999 standards). Our maximum savings estimate is a standard of 218 kWh per unit, based on a published estimate that this level of efficiency may be technically feasible and cost effective (Alliance to Save Energy et al. 1992).

Clothes Washers

The next Federal clothes washer standard is scheduled to take effect in May, 1999; five years after the current standard. An ANOPR for this product is due out shortly. However, in 1990, DOE announced that it was very interested in developing a new clothes washer standard based on horizontal-axis technology (DOE 1990). Unlike conventional vertical-axis washers, which must be filled with water to wash clothes, horizontal-axis machines are only partially filled with water. As the washtub rotates, the clothes are dumped into the wash water with every rotation. Energy is saved because most of the energy used in the washcycle is used to heat water. The less water that is used, the less energy the water heater uses. Traditionally horizontal-axis washers are front-loading machines, however top-loading machines are also available (for more information see Lebot et al. 1990; also DSTR 1993).

Based on DOE's interest in horizontal-axis technology, and based on the fact that the 1990 clothes washer rulemaking found that horizontal-axis machines had the lowest life-cycle costs (DOE 1990b), our midpoint estimate is that the 1999 standard will be based on horizontal-axis technology, although DOE may choose to delay the effective date by a year or two to give manufacturers more time to retool for what will be a total product redesign. According to DOE's 1990 analysis, a horizontal-axis washer will use 255 kWh per year for homes with electric water heat (DOE 1990b), which translates into approximately 33 therms for homes with gas water heat (Nadel et al. 1993). Such a standard does not represent the maximum efficiency which can be obtained with horizontal-axis technology -- our maximum savings estimate is approximately 220 kWh, which is based on the "Tier 2" eligibility levels for a clothes washer incentive program developed by the Consortium for Energy Efficiency (CEE 1993). While horizontal-axis washers appear to make technical and economic sense, some manufacturers are likely to oppose a standard based on horizontal-axis technology, arguing that U.S. consumers will not like horizontal-axis washers (they are presently the dominant technology in Europe) and that it will be too costly for manufacturers to retool for horizontal-axis production. If these arguments win out, DOE would still likely issue a standard that reduces energy use at least 20% from the current standard. Such savings can be achieved through the use of automatic clothes washer controls (Nadel et al. 1993).

Clothes Dryers

Clothes dryers will be included in the same rulemaking as clothes washers. The easiest way (from a technical and economic perspective) to reduce clothes dryer energy use is to modify the clothes washer to have a faster spin speed. The faster spinning during the washer spin cycle extracts more water from the clothes, leaving less water to be evaporated in the clothes dryer. DOE could not develop a standard based on high spin speeds for the 1994 standard because clothes washer test procedures did not give credit for high spin speeds. DOE has done work to make the test procedure changes, and thus a 1999 clothes washer standard that all but requires high spin speeds is likely. We project 38% energy savings from this feature based on a 1981 study by the National Institute of Standards and Testing (Lovett 1981). For the conservative case we assume no additional dryer improvements. For the midpoint estimate we assume a 5% improvement in dryer efficiency. For the maximum savings scenario, we assume both high spin speed and use of a heat pump clothes dryer which uses 65% less energy than current clothes dryers (Nadel et al. 1993).

Dishwashers

Dishwashers will be included in the same DOE rulemaking as clothes washers and clothes dryers. The highest efficiency dishwasher on the market uses approximately 31% less energy than the current DOE standard (Nadel et al. 1993). This unit, which is imported from Europe and differs in some fundamental ways from U.S. machines, is the basis for our maximum savings prediction. A major U.S. manufacturer is reportedly working on a clothes washer that saves 25% relative to the current U.S. standard (Nadel et al. 1993). This is the basis for our midpoint prediction. Our conservative estimate -- 15% savings -- is similar to the percentage savings from the 1994 dishwasher standard (DOE 1990b).

Electric Water Heaters

In March, 1994 DOE issued a Notice of Proposed Rulemaking (NOPR) proposing a new standard for electric water heaters of 1.89 Energy Factor (EF). This standard would take effect three years after the final rule is published (approximately early 1995). This proposed standard is based on heat pump water heater technology (DOE 1994). Heat pump water heaters use approximately half the energy of a conventional electric resistance water heater, because instead of generating heat with an electric resistance element, they transfer heat from the surrounding air to the water in the tank. With a heat pump water heater, energy is used to power the compressor that moves heat into the water tank; electric resistance heat is used very sparingly as a backup when the heat pump alone does not provide enough heat.

The DOE proposed rule has generated a large amount of opposition, primarily from electric utilities who fear that even though heat pump water heaters are much more efficient than conventional water heaters, the high initial cost of the heat pump water heater will cause many customers to switch to gas water heaters. Opponents also allege that heat pump water heaters are uneconomic for small households and that because heat pump water heaters are larger than conventional water heaters, they will be difficult to fit into many homes. On the other hand proponents argue that heat pump water heaters are highly cost-effective in most applications, will save a very large amount of energy, and that the difficulties raised by opponents can generally be overcome.

Due to this opposition, we assume full use of heat pump water heaters only for our maximum savings scenario (although in this scenario we estimate an EF of 2.4 based on a new heat pump water heater that recently entered the market (EPRI 1993a). A more likely compromise is for a standard of 1.89 EF on water heaters with more than 30 gallons of storage capacity and a more modest standard (e.g. 0.93 EF) for smaller tanks. This compromise has been suggested in several sets of written comments on the DOE proposal (see for example ACEEE 1994). By exempting tanks of 30 gallons and less from a heat pump water heater standard, most small households will not be covered. Also, smaller tanks are more likely to be used in applications where space is tight and it may be difficult to accommodate a heat pump. Based on a rough estimate that one-third of tanks are 30 gallons or less, the resulting weighted average EF is 1.57, an energy savings of approximately 40% from the current standard. If DOE does set a standard based on heat pump water heaters, the effective date of the standard could be delayed by one to two years to give manufacturers more time to design heat pump water heaters and retool to produce heat pump water heaters. Our conservative estimate for this standard is 0.93 EF on all tank sizes -- such a standard can be met by hundreds of units already on the market (GAMA 1994a).

After the 1998 standards (i.e. those expected to be finalized in 1995), the next water heater standard is scheduled to take effect in 2005. DOE's decision in the current rulemaking may largely determine the results of the next rulemaking as well. If DOE determines that heat pump water heaters should not be required through standards, then the 2005 standard is likely to result in only modest levels of energy savings -- e.g. 0.95 EF -- based on the most efficient electric resistance water heaters now on the market. If determines that heat pump water heaters can be the basis for a standard in some or all tank sizes, then the 2005 standard is likely to call for improved heat pump coefficient of performance (COP). Currently available heat pump water heaters designed for small commercial applications have a COP of 3 (Lloyd 1991), which translates into an EF of approximately 3 as well.

Gas Water Heaters

Gas water heaters are part of the same rulemaking as electric water heaters. In the March, 1994 NOPR, DOE proposed a standard of 0.58 EF (DOE 1994). This proposal forms the basis of our conservative prediction as even manufacturers and the gas industry are supporting this standard (see for example GAMA 1994b). In fact, more than half of all gas water heaters now on the market exceed this efficiency level (GAMA 1994a). A more reasonable estimate, and the basis for our midpoint estimate is 0.63 EF. Approximately 10% of gas water heaters now on the market can meet this standard (GAMA 1994a). Our maximum savings estimate -- 0.68 EF -- is based on the maximum efficiency non-condensing water heater now on the market (GAMA 1994a).

For the 2005 standards, 0.63 EF is likely, for the reasons outlined above, and is the basis for our conservative estimate. It is unclear whether manufacturers can safely get above EF's in the 0.63 range without getting some condensation in the flue pipe, and hence our midpoint estimate does not include any increase in the standard. Our maximum savings scenario assumes a condensing water heater with 0.86 EF.

Room Air Conditioners

Room air conditioners are included in the same rulemaking as water heaters. DOE proposed a standard with a weighted average EER of 10.8 in the March, 1994 NOPR (DOE 1994). This forms the basis of our midpoint estimate. In the NOPR, DOE also examined a slightly higher standard (weighted average EER of 11.3) with slightly lower life-cycle costs than the proposed standard. This slightly higher level is used for our maximum savings scenario. The conservative estimate -- EER 10.0 -- is based on the standard proposed by one of the largest U.S. room air conditioner manufacturers for several of the major room air conditioner classes (Giordano 1994).

Ranges

Electric and gas ranges are also part of the same rulemaking as water heaters and room air conditioners. In the March, 1994 NOPR, DOE proposed a standard for ranges that reduces oven and burner top energy use by approximately 16% for electric ranges and 55% for gas ranges (the large gas savings are due to eliminating the pilot light and substituting an electronic ignition) (DOE 1994). These proposals have encountered substantial opposition from manufacturers who have found several errors in DOE's analysis. For this reason we use the DOE proposal for our maximum savings case. Our conservative estimate for the new standard is based on a proposal by the Association of Home Appliance Manufacturers (AHAM) for DOE to issue no standard for electric ranges and to issue a gas range standard that bans pilot lights but includes no further savings (AHAM 1994b). Our midpoint estimate for electric ranges -- 8% savings -- is based on half of the savings in the DOE proposal. It is also based on an analysis of the technical and viability of measures that would be needed to reach 8% savings. For gas ranges, our midpoint estimate -- 40% savings -- lies midway between the DOE and AHAM proposals.

Microwave Ovens

Microwave ovens are part of the same rulemaking as ranges. In the March, 1994 NOPR DOE proposed a standard of 233 kWh (DOE 1994). Manufacturers are opposed to any standard (Weizeorick 1994). Based on these views, our maximum savings analysis is based on the DOE proposal, our conservative estimate includes no standard, and the midpoint estimate lies midway between the other two cases.

Central Air Conditioners

Central air conditioners are included in the same rulemaking as refrigerators and freezers. Based on comments DOE received on the ANOPR, DOE is now analyzing potential standard levels. A NOPR on these products is scheduled for late 1994 or early 1995. The new standard is scheduled to take effect in 1999. This is the first DOE rulemaking on central air conditioners and substantial efficiency improvements are likely. Our conservative estimate assumes a standard of Seasonal Energy Efficiency Ratio (SEER) equal to 12.0. This level is the basis for most utility rebate programs and hundreds of models already on the market meet this level (CEE 1994b). Our midpoint estimate -- 14.0 SEER -- is based on discussions with several industry experts as well as a recent draft analysis by PG&E that found that such a level can be met at a reasonable cost (Proctor Engineering Group 1994). Several dozen models on the market already meet this level (CEE 1994b). Our maximum savings estimate -- 16.0 SEER -- is based on the most efficient units presently on the market (Wilson and Morrill 1993).

The central air conditioner standard is scheduled to be updated again in 2006. For our conservative and midpoint scenarios, we estimate SEERs of 14.0 and 16.0, based on the rationale discussed above. Our maximum savings estimate -- SEER 20 -- is based on discussions with industry experts of what might be achievable (e.g. Hoffman 1993).

Heat Pumps

Heat pumps operating in the cooling mode are subject to the central air conditioner standards discussed above. In the heating mode, a separate standard applies, which is not scheduled to go into effect until 2002. The heating standard is expressed in terms of Heating Season Performance Factor (HSPF). Our conservative estimate -- 7.5 HSPF -- is based on the median HSPF for heat pumps with 12 SEER (CEC 1994). Our midpoint estimate -- 8.5 HSPF -- is based on heat pumps with 14 SEER (CEC 1994). Our maximum savings estimate -- 10.0 HSPF -- is based on the most efficient heat pump now on the market.

Furnaces and Boilers

Central furnaces and boilers are included in the same rulemaking as central air conditioners and heat pumps. These new standards are scheduled to go into effect in 2002. The efficiency of central furnaces and boilers is measured in terms of Annual Fuel Utilization Efficiency (AFUE) -- a measure of seasonal efficiency. In this rulemaking the key issue will be whether to base the new standard on condensing technology or whether to stop short of any condensation risk. Condensing furnaces currently enjoy a 22% market share in the U.S. (ASE 1994). Due to this large existing market share, we believe that condensing furnaces and boilers will be found to be technically feasible and economically justified and hence we base our midpoint estimate on condensing technology. Specifically, we estimate an AFUE of 92% for furnaces and 87% for boilers. These estimates are based on levels obtained by multiple manufacturers with high efficiency equipment (Wilson and Morrill 1993). Our maximum savings estimate is based on the highest efficiency equipment on the market -- 90% AFUE for boilers (Wilson and Morrill 1993) and AFUE 125% for furnaces. This latter efficiency is based on the gas engine-driven heat pump which is scheduled to enter the market in mid-1994 (Randazzo 1994). Our conservative estimate -- 80% AFUE -- is based on non-condensing furnaces and boilers produced by many manufactures (GAMA 1994a).

Televisions

Televisions are included in the same rulemaking as water heaters and room air conditioners. In the March, 1994 NOPR DOE proposed a sales weighted average standard of 139 kWh per year (DOE 1994). Manufacturers have responded that the DOE analysis is based on dated information and suggest that the standard be slightly higher in order to allow for new features such as stereo sound and captioning. One manufacturer noted that several models of televisions he produces consume 140-150 kWh/year according to the DOE test procedure (Travers 1994). Our conservative and midpoint estimates -- 145 kWh/year -- are both based on these data. Our maximum savings estimate is based on the DOE proposal.

Incandescent Lamps

Under EPAct, DOE is supposed to begin considering standards on general service incandescent lamps (the standard pear-shaped light bulb) by mid-1997, and if standards are justified, to issue the standard in late 1998, to become effective three years later. Our conservative estimate for this new standard is 10% energy savings, which is based on so-called "Energy-Saver" lamps produced by all major manufacturers. In 1989 these lamps had a market share in the residential sector of approximately 30% (Nadel et al. 1989). Our midpoint and maximum savings estimates are based on halogen infrared reflecting lamps. This technology is presently available in incandescent reflector lamps and uses approximately 27% less energy than conventional incandescent lamps. General service infrared reflecting lamps are expected to enter the market shortly (Nadel et al. 1993).

An initial incandescent lamp standard will be updated five years later. Under the conservative scenario we assume halogen infrared technology. Under the midpoint and maximum savings scenarios we assume coated filament technology. Coated filament lamps are projected to use 60% less energy per lumen of light output than conventional incandescent lamps. Coated filament technology is now in the laboratory, but shows great promise of being on the market around the turn-of-the-century (Nadel et al. 1993).

Showerheads

Showerhead standards were first established under EPAct. This standard, which sets a maximum flow rate of 2.5 gallon per minute (gpm) at 80 psi of pressure, took effect January 1, 1994. Under the showerhead provision in EPAct, DOE does not set new showerhead standards. Instead, new standards are set by a committee of the American Society of Mechanical Engineers (ASME) with DOE review. Under ASME rules, the ASME committee is supposed to revise its showerhead standard at least every five years. Once ASME sets a new standard, DOE reviews this standard against certain basic criteria and then sets a new Federal standard based on the ASME standard. However, if ASME does not develop a tighter showerhead standard within five years, or if DOE determines that additional energy can be cost-effectively saved with a tighter standard, then DOE can authorize individual states to set tighter standards than the ASME standard. Given this convoluted process, it is unclear when a new standard will be developed. For purposes of this analysis we estimate that ASME will act in 1998 (five years after its last standard) and that this will become a Federal standard two years later. For our midpoint estimate we estimate a showerhead flow rate of 2.0 gpm. This flow rate is now used by the Bonneville Power Administration for their energy-saving showerhead program (Byers 1994). Our maximum savings estimate -- 1.5 gpm -- is based on the most efficient showerheads that are widely available. Our conservative scenario assumes no change in the standard, because some people question whether showerheads of 2.0 gpm can provide a good quality shower.

The showerhead standard could be revised again five years later. For this revision our midpoint estimate is 1.5 gpm. For the other scenarios, no change in standard is estimated.

Faucets

Faucets standards, which apply to kitchen and bathroom faucets, are subject to the same standard, and the same revision process as showerheads. Our conservative estimate is that at the turn-of-the-century this standard will be revised to 2.0 gpm -- a standard that is now included in the plumbing codes of Georgia, New York, and Rhode Island. Our midpoint estimate is 1.75 gpm and our maximum savings estimate is 1.5 gpm.

Building Codes

In addition to equipment efficiency standards, building codes can also reduce energy use in the residential sector. Residential building codes are generally set at the state level and are based on the CABO Model Energy Code. In the CABO code, requirements vary as a function of local climate. Due to this climate variability, energy savings from code updates will vary substantially from region to region. For this reason we do not predict a single national code level and do not include residential building codes in our analysis. Instead, forecasters should develop local estimates based on current local codes. Savings from revised residential energy codes are likely to be substantial. For example, a 1991 study by the Alliance to Save Energy estimated that adoption of the 1989 CABO code could reduce energy used by new homes by 5-53%, depending on the state. Overall, national savings would average 11% (Howard and Prindle 1991). Even larger savings are likely to be possible in the future. For example, low-emissivity windows are rarely required under the CABO code. An analysis for Illinois found that this measure alone could reduce energy use in the typical new home by 4-14% depending on location (Smith et al. 1994).

Commercial Standards and Codes

In the commercial sector, the most commonly used forecasting models are also end-use models. In these models data are compiled on floor area by building type, energy use per square foot for each end use, and equipment saturations for each building type and end-use (e.g. the percentage of office space with electric heat). By multiplying floor areas times the equipment saturation, times the energy use intensity (e.g. kWh/sq. ft.) for a particular for a particular building type and end-use, energy use is forecast. Like the residential models, most commercial models examine existing buildings and new buildings separately. Building codes have a large impact on the energy use intensities for new buildings. Equipment efficiency standards impact the energy use intensity of existing buildings as equipment in existing buildings are replaced. Equipment efficiency standards also influence the energy use intensity of new buildings, to the extent that more efficient equipment is not already incorporated into building codes.

In the sections below we discuss the impact of new standards and codes on energy use for each end-use. For each new standard or code component we project the reduction in energy use, on a percentage basis, below levels prevailing today. Existing and new buildings are examined separately. Our analysis treats the commercial sector as a whole, and is not disaggregated by building type. Standard and code predictions are summarized in Table 4. In tables A-F in the appendix we translate these predictions into impact on the energy use intensity of existing and new commercial buildings over the 1994-2015 time frame. The results of these analyses are a set of energy use intensity multipliers which are summarized in Tables 5, 6 and 7 (one for each of the three scenarios). These multipliers can be applied to the energy use intensity variables in a specific forecasting model in order to adjust the energy use intensities for the impact of revised codes and standards.

Table 4. Predictions for Future Commercial Equipment and Building Standards.

Product	Effective Year of Standard	Current Std.	Units	Highly Likely New Std. Std.	Highly Likely New Std. Basis	Midpoint Est. for New Std. Std.	Midpoint Est. for New Std. Basis	Maximum Possible New Std. Std.	Maximum Possible New Std. Basis
Equipment Standards:									
Fluorescent ballasts	1998	1.06	BEF	16% svgs	Magnetek testimony	16% svgs	Magnetek testimony	19% svgs	DOE proposal
Fluorescent ballasts	2007			3% svgs	Electronic improve.	30% svgs	Surface wave lamp	30% svgs	Surface wave lamp
Fluorescent lamps	2001	75	LPW	0% svgs	No change	5% svgs	T8 lamps	5% svgs	T8 lamps
Fluorescent lamps	2007			Included under ballasts		Included under ballasts		Included under ballasts	
HID lamps	1999	none		8% svgs	Ban mercury vapor	8% svgs	Ban mercury vapor	13% svgs	No merc. vapor + 5%
HID lamps	2004			0% svgs	No change	26% svgs	Electrodeless lamp	22% svgs	Electrodeless lamp
Incandescent lamps	2001	none		10% svgs	Energy-Saver lamps	27% svgs	Halogen IR lamps	27% svgs	Halogen IR lamps
Incandescent lamps	2006			19% svgs	Halogen IR lamps	45% svgs	Coated filament lamps	45% svgs	Coated filament lamps
Unitary A/C & HP	1999	8.9	EER	11% svgs	EER 10	11% svgs	EER 10	11% svgs	EER 10
Unitary A/C & HP	2002			0% svgs	No change	9% svgs	EER 11	17% svgs	EER 12
Unitary A/C & HP	2005			9% svgs	EER 11	8% svgs	EER 12	14% svgs	Variable speed
Motors	2002	varies by hp		0% svgs	No change	2% svgs	Best on market - 1993	4% svgs	New products
PC's	1996	none		50% svgs	Power Management	50% svgs	Power Management	50% svgs	Power Management
Imaging equipment	1997	none		50% svgs	Power Management	50% svgs	Power Management	85% svgs	Power Management
Building Codes:									
Lighting	1999			15% svgs	Electronic ballasts	20% svgs	Work on 90.1	25% svgs	Aggressive 90.1
Lighting	2005			10% svgs	Mandate ltg controls	20% svgs	Mandate ltg controls	25% svgs	Mandate ltg controls
Air conditioning	1999			10% svgs	Equip&system improve	15% svgs	Equip&system improve	20% svgs	More systems svgs
Air conditioning	2005			15% svgs	Equip&system improve	15% svgs	Equip&system improve	10% svgs	Mostly systems svgs
Elec. space heating	1999			5% svgs	Equip&system improve	5% svgs	Equip&system improve	10% svgs	More systems svgs
Elec. space heating	2005			5% svgs	Equip&system improve	10% svgs	Equip&system improve	10% svgs	Equip&system improve
Gas space heating	1999			5% svgs	Equip&system improve	10% svgs	Equip&system improve	15% svgs	Equip&system improve
Gas space heating	2005			5% svgs	Equip&system improve	10% svgs	Equip&system improve	15% svgs	Equip&system improve
Ventilation	1999			10% svgs	Move towards ASDs	15% svgs	Primarily ASDs	20% svgs	Primarily ASDs
Ventilation	2005			10% svgs	ASDs	0% svgs	No change	0% svgs	No change

Notes:

* Savings are presented relative to previous standard or code.

Table 5. Energy Use Intensity (EUI) Multipliers for Estimating Savings from Revised Codes and Standards.
Midpoint Estimate

Existing Buildings:

Saturation Weighted EUI Index

Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.97	1.00
1997	1.00	1.00	1.00	1.00	0.92	1.00
1998	0.99	0.99	1.00	1.00	0.87	1.00
1999	0.99	0.99	1.00	1.00	0.82	1.00
2000	0.98	0.98	0.99	1.00	0.78	1.00
2001	0.94	0.98	0.99	1.00	0.76	1.00
2002	0.93	0.97	0.99	1.00	0.76	1.00
2003	0.92	0.96	0.98	1.00	0.76	1.00
2004	0.91	0.96	0.98	1.00	0.76	1.00
2005	0.90	0.95	0.97	1.00	0.76	1.00
2006	0.86	0.94	0.97	1.00	0.76	1.00
2007	0.84	0.93	0.96	1.00	0.76	1.00
2008	0.83	0.92	0.96	1.00	0.76	1.00
2009	0.81	0.91	0.95	0.99	0.76	1.00
2010	0.79	0.90	0.94	0.99	0.76	1.00
2011	0.78	0.89	0.94	0.99	0.76	1.00
2012	0.76	0.88	0.93	0.99	0.76	1.00
2013	0.75	0.87	0.93	0.99	0.76	1.00
2014	0.74	0.86	0.92	0.99	0.76	1.00
2015	0.73	0.85	0.92	0.99	0.76	1.00

New Buildings:

Saturation Weighted EUI Index

Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.87	1.00
1997	1.00	1.00	1.00	1.00	0.74	1.00
1998	1.00	1.00	1.00	1.00	0.74	1.00
1999	0.80	0.85	0.95	0.93	0.74	0.90
2000	0.80	0.85	0.95	0.93	0.74	0.90
2001	0.79	0.85	0.95	0.93	0.74	0.90
2002	0.79	0.80	0.92	0.93	0.74	0.90
2003	0.79	0.68	0.83	0.93	0.74	0.90
2004	0.78	0.68	0.83	0.93	0.74	0.90
2005	0.62	0.58	0.75	0.93	0.74	0.81
2006	0.61	0.58	0.75	0.93	0.74	0.81
2007	0.50	0.58	0.75	0.93	0.74	0.81
2008	0.50	0.58	0.75	0.93	0.74	0.81
2009	0.50	0.58	0.75	0.93	0.74	0.81
2010	0.50	0.58	0.75	0.93	0.74	0.81
2011	0.50	0.58	0.75	0.93	0.74	0.81
2012	0.50	0.58	0.75	0.93	0.74	0.81
2013	0.50	0.58	0.75	0.93	0.74	0.81
2014	0.50	0.58	0.75	0.93	0.74	0.81
2015	0.50	0.58	0.75	0.93	0.74	0.81

Notes:
* Assumptions underlying these figures are summarized in Tables A and B.

Table 6. Energy Use Intensity Multipliers for Estimating Savings from Revised Codes and Standards.
High Liklihood Scenario

Existing Buildings:

	Saturation Weighted EUI Index					
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.97	1.00
1997	1.00	1.00	1.00	1.00	0.92	1.00
1998	0.99	0.99	1.00	1.00	0.87	1.00
1999	0.98	0.99	1.00	1.00	0.82	1.00
2000	0.98	0.98	0.99	1.00	0.78	1.00
2001	0.96	0.98	0.99	1.00	0.76	1.00
2002	0.95	0.98	0.99	1.00	0.76	1.00
2003	0.95	0.97	0.99	1.00	0.76	1.00
2004	0.94	0.97	0.98	1.00	0.76	1.00
2005	0.93	0.96	0.98	1.00	0.76	1.00
2006	0.92	0.95	0.98	1.00	0.76	1.00
2007	0.90	0.95	0.97	1.00	0.76	1.00
2008	0.89	0.94	0.97	1.00	0.76	1.00
2009	0.87	0.93	0.96	0.99	0.76	1.00
2010	0.86	0.93	0.96	0.99	0.76	1.00
2011	0.84	0.92	0.96	0.99	0.76	1.00
2012	0.83	0.91	0.95	0.99	0.76	1.00
2013	0.82	0.91	0.95	0.99	0.76	1.00
2014	0.81	0.90	0.95	0.99	0.76	1.00
2015	0.80	0.90	0.94	0.99	0.76	1.00

New Buildings:

	Saturation Weighted EUI Index					
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.87	1.00
1997	1.00	1.00	1.00	1.00	0.74	1.00
1998	1.00	1.00	1.00	1.00	0.74	1.00
1999	0.85	0.90	0.95	0.95	0.74	0.95
2000	0.85	0.90	0.95	0.95	0.74	0.95
2001	0.85	0.90	0.95	0.95	0.74	0.95
2002	0.85	0.90	0.95	0.95	0.74	0.95
2003	0.85	0.77	0.90	0.95	0.74	0.95
2004	0.85	0.77	0.90	0.95	0.74	0.95
2005	0.72	0.65	0.86	0.95	0.74	0.90
2006	0.71	0.65	0.86	0.95	0.74	0.90
2007	0.69	0.65	0.86	0.95	0.74	0.90
2008	0.69	0.65	0.86	0.95	0.74	0.90
2009	0.69	0.65	0.86	0.95	0.74	0.90
2010	0.69	0.65	0.86	0.95	0.74	0.90
2011	0.69	0.65	0.86	0.95	0.74	0.90
2012	0.69	0.65	0.86	0.95	0.74	0.90
2013	0.69	0.65	0.86	0.95	0.74	0.90
2014	0.69	0.65	0.86	0.95	0.74	0.90
2015	0.69	0.65	0.86	0.95	0.74	0.90

Notes:

* Assumptions underlying these figures are summarized in Tables C and D.

Table 7. Energy Use Intensity Multipliers for Estimating Savings from Revised Codes and Standards.
High Liklihood Scenario

Existing Buildings:

Saturation Weighted EUI Index

Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.96	1.00
1997	1.00	1.00	1.00	1.00	0.89	1.00
1998	0.99	0.99	1.00	1.00	0.82	1.00
1999	0.98	0.99	1.00	1.00	0.76	1.00
2000	0.97	0.98	0.99	1.00	0.71	1.00
2001	0.93	0.98	0.99	1.00	0.69	1.00
2002	0.92	0.97	0.98	1.00	0.69	1.00
2003	0.91	0.96	0.98	1.00	0.69	1.00
2004	0.89	0.95	0.97	1.00	0.69	1.00
2005	0.88	0.93	0.96	1.00	0.69	1.00
2006	0.84	0.92	0.95	1.00	0.69	1.00
2007	0.83	0.90	0.95	0.99	0.69	1.00
2008	0.81	0.89	0.94	0.99	0.69	1.00
2009	0.79	0.87	0.93	0.99	0.69	1.00
2010	0.77	0.86	0.92	0.99	0.69	1.00
2011	0.76	0.84	0.91	0.99	0.69	1.00
2012	0.74	0.83	0.90	0.99	0.69	1.00
2013	0.73	0.82	0.89	0.99	0.69	1.00
2014	0.72	0.81	0.89	0.99	0.69	1.00
2015	0.71	0.80	0.88	0.99	0.69	1.00

New Buildings:

Saturation Weighted EUI Index

Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Gas Sp.Heat
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	1.00	1.00	1.00	1.00	1.00	1.00
1996	1.00	1.00	1.00	1.00	0.87	1.00
1997	1.00	1.00	1.00	1.00	0.74	1.00
1998	1.00	1.00	1.00	1.00	0.74	1.00
1999	0.80	0.85	0.95	0.93	0.74	0.85
2000	0.80	0.85	0.95	0.93	0.74	0.85
2001	0.79	0.85	0.95	0.93	0.74	0.85
2002	0.79	0.80	0.92	0.93	0.74	0.85
2003	0.79	0.68	0.83	0.93	0.74	0.85
2004	0.78	0.68	0.83	0.93	0.74	0.85
2005	0.62	0.58	0.75	0.93	0.74	0.72
2006	0.61	0.58	0.75	0.93	0.74	0.72
2007	0.50	0.58	0.75	0.93	0.74	0.72
2008	0.50	0.58	0.75	0.93	0.74	0.72
2009	0.50	0.58	0.75	0.93	0.74	0.72
2010	0.50	0.58	0.75	0.93	0.74	0.72
2011	0.50	0.58	0.75	0.93	0.74	0.72
2012	0.50	0.58	0.75	0.93	0.74	0.72
2013	0.50	0.58	0.75	0.93	0.74	0.72
2014	0.50	0.58	0.75	0.93	0.74	0.72
2015	0.50	0.58	0.75	0.93	0.74	0.72

Notes:

* Assumptions underlying these figures are summarized in Tables E and F.

Fluorescent Ballasts

Fluorescent ballasts are covered by the same DOE rulemaking that includes residential water heaters, ranges, and room air conditioners. The ballast standard will take effect three years after a final rule is published, probably some time in 1995. In the NOPR, DOE proposed a standard that reduces ballast energy use by 19%, based on the efficiency of the most efficient electronic ballasts (DOE 1994). However, DOE appears to have made a mistake in calculating the Ballast Efficiency Factors (BEF) for the proposed standard. According to oral testimony by Magnetek, correcting this mistake would result in 15-17% savings relative to the current standard (Burke 1994). Based on this estimate, our conservative and midpoint predictions assume 16% savings. The maximum savings prediction is based on the current DOE proposal (19% savings).

Fluorescent Lamps

Efficiency standards on fluorescent lamps were established in EPAct and first take effect in May, 1994 for eight foot lamps and October, 1995 for four foot lamps. The first revision to this standard is scheduled to take effect in 2001. Our midpoint and maximum savings estimate assume that the new standard is based on high efficacy thin-tube lamps such as T8 (one inch diameter) and T10 (1.25 inch diameter) lamps with triphosphor coatings. These lamps are approximately 5% more efficient than the T12 (1.5 inch diameter) "Energy Saver" and triphosphor lamps that just meet the current lamp efficiency standard. For the high likelihood case we assume no change in the standard, since a standard that virtually requires use of T8 lamps may be controversial, because T8 lamps usually will not operate on ballasts designed for T12 lamps (although high-cost T10 lamps can operate on T12 ballasts).

High Intensity Discharge Lamps

High intensity discharge lamps are primarily used for outdoor lighting and for lighting large indoor spaces such as factories and sports facilities, although in recent years new smaller products can be found in retail and other settings. Under EPAct DOE is instructed to evaluate efficiency standards for high intensity discharge (HID) lamps, and to set standards if justified. HID lamps come in several types including mercury vapor, metal halide, high pressure sodium and low pressure sodium. Mercury vapor lamps are generally the least efficient type of HID lamp. Most mercury vapor lamps have been replaced with more efficient HID lamps, but approximately 20% of the HID market remains mercury vapor (Atkinson 1994). Our conservative and midpoint estimates are that new standards will eliminate mercury vapor lamps, resulting in approximately 40% energy savings in the 20% of the HID market now held by mercury vapor. For our maximum savings scenario, we add an additional 5% savings to the entire HID market, which could happen if the new standards also eliminate the least efficient of the other HID lamp types.

Five years after the first HID lamp standard is set, the standard will be revised. Our conservative scenario assumes no change in the standard. The midpoint and maximum savings scenarios, with 26% energy savings, are based on electrodeless HID lamps that are just starting to enter the market (Nadel et al. 1993).

Incandescent Lamps

Predictions and rationales are the same as those discussed in the residential section.

Packaged Air Conditioners and Heat Pumps

Under EPAct, efficiency standards were set on packaged air conditioners and heat pumps up to 240,000 Btu/hour cooling capacity. These standards take effect in 1994 and 1995, depending on equipment size. Revisions to these standards are complex in that DOE cannot act until ASHRAE develops a new standard 90.1 which deals with energy-efficient design of new commercial buildings. Specifically, as part of 90.1, ASHRAE sets recommended efficiency levels for commercial packaged equipment. Once the new ASHRAE standard is published, DOE reviews the efficiency values based on its standard criteria of technical feasibility and economic justification. If the ASHRAE standard passes these criteria, then DOE adopts these values for the new standard. If DOE concludes that higher efficiency levels are technically feasible and economically justified, then DOE can set higher standard levels, but these new levels do not take effect until four years after DOE's decision. Based on this process, for this analysis, we estimate that new standards will take effect in 1999 (two years after a new ASHRAE standard is published around 1997), 2002 (four years after DOE completes its rulemaking in 1998), and 2005 (two years after the next ASHRAE standard).

Under the present standard, the most common types of commercial packaged air conditioners must have an Energy Efficiency Ratio (EER) of 8.9. For the midpoint estimate, we predict that the new standard will be EER 10 in 1999 (based on equipment now being sold by many of the major manufacturers), EER 11 in 2003 (since the cost data used to develop the ASHRAE standard was developed by manufacturers and appears to be excessively high), and EER 12 in 2005 (a prototype unit with this efficiency is now being built by the California Institute for Energy Efficiency; preliminary cost projections look promising -- Blumstein 1994). Our conservative scenario assumes EER 10 in 1999, no change in 2003, and EER 11 in 2005. For the maximum savings scenario we estimate EER 10 in 1999, EER 12 in 2003, and variable speed equipment (with a seasonal efficiency equivalent to EER 14) in 2005.

Electric Motors

Electric motor standards were set in EPAct and first take effect in 1997. A new standard is scheduled to go into effect five years later. For the conservative scenario we assume no change in the standard, as improving motor efficiency may be difficult for some specialized motors. The midpoint estimate assumes a sales weighted average saving of 2%, based on the most efficient motors on the market in 1993 (WASEO 1993). The maximum savings estimate -- 4% average savings -- is based on new products just entering the market. However, these motors will probably not be appropriate for all applications (Easton Consultants 1994).

Office Equipment

There are presently no efficiency standards for office equipment and formal standards are unlikely to be set in the near future. However, in lieu of standards the U.S. Environmental Protection Agency (EPA) has developed the Energy Star program to promote efficient personal computers and printers. Work is now underway to develop similar programs for copiers and fax machines (Latham 1994). The Energy Star program promotes equipment with built-in power management features -- e.g. controls which dramatically reduce the energy use of the machine during periods when the machine is turned on but is not in active use. Energy savings from power management average 50% (Ledbetter and Smith 1993). Due in large part to the EPA program, power management is expected to become standard for PCs and imaging equipment over the next few years. For the conservative and midpoint scenarios we estimate 50% energy savings from power management. For the maximum savings case for PCs, we estimate 85% savings, based on the most efficient PCs now on the market (Nadel 1993). For imaging equipment, the maximum savings case is kept at 50% savings.

Building Codes

Most commercial building codes in the U.S. are based on ASHRAE Standard 90.1. As discussed above, this standard is now undergoing revision. The first public review draft of this standard is scheduled for Fall, 1994. The public review and revision process typically takes two to three years with the result that the new standard will be finalized in late 1996 or sometime in 1997. Under EPAct, states are required to adopt the new 90.1 or its equivalent within two years of final approval by ASHRAE. Thus state building codes based on the new ASHRAE standard will likely go into effect in 1999. However, some states are likely to adopt the standard (or significant portions of it) sooner, thereby accelerating energy savings somewhat. ASHRAE procedures call for 90.1 to be updated every five years; our analysis assumes the process will take six years, resulting in a second 90.1 update taking effect in 2005. The first revision (circa 1997-1999) will contain two tiers -- a basic tier that will generally be incorporated into building codes, and an advanced tier that can be used for voluntary programs that encourage efficiency improvements beyond code. Measures in this second tier provide some insight into what may be contained in the circa 2005 code.

The new 90.1 standard will contain many changes that will reduce building energy use. The review draft of the new standard is now being assembled and is still subject to substantial change. Furthermore, a comprehensive analysis of the savings from the proposed standard has yet to be conducted, and hence savings estimates made now are only educated guesses. With these caveats, the following paragraphs discuss the possible impact of this revised standard on new commercial buildings.

Perhaps the largest area of savings in the new standard is in lighting. In the new standard, maximum lighting power allowances (expressed in watts per square foot) will be based on electronic ballasts and T8 lamps, which should result in approximately 20% savings in spaces with fluorescent lamps (approximately two-thirds of commercial floor area -- Nadel et al. 1989). For applications traditionally using incandescent lamps, if compact fluorescent lamps (CFLs) can be used, they will be assumed in calculating the lighting power allowances. Furthermore, the new standard is likely to require automatic shutoff controls in large buildings, to turn lights off automatically at the end of the day. Taken together, our midpoint estimate is 20% lighting energy savings. For the conservative estimate we subtract five percentage points (making for 15% savings), and for the maximum savings estimate we add five percentage points (25% savings). In the 2005 code, the most likely area of change is to require use of occupancy sensors and automatic daylight dimming systems in appropriate applications. A recent analysis by Lawrence Berkeley Laboratory estimates approximately 20% savings from occupancy sensors (beyond savings attributable to timers) and daylight dimming systems (Atkinson et al. 1992); we use this estimate for the midpoint estimates. For the conservative case we subtract five percentage points and for the maximum savings case we add five percentage points.

For air conditioning, the next 90.1 standard will include many changes. Cooling system minimum efficiencies will be increased by approximately 10% (e.g. changing from EER 8.9 to approximately EER 10 for packaged systems) and a number of changes will be made to the controls and systems design sections, resulting in some additional savings. For the midpoint case we estimate 15% savings. For the conservative case we subtract five percentage points; for the maximum savings cases we add five percentage points. For the circa 2005 code, we estimate 15% additional savings for the conservative and midpoint cases and 10% savings in the maximum savings cases. The midpoint and maximum savings estimates are in addition to savings from DOE's 2002 packaged air conditioning equipment standard (the conservative case assumes no 2002 standard). These savings are based on continued equipment improvements as discussed in the packaged air conditioner standard section, plus some control and systems design savings.

For electric space heat, we estimate 5% savings for the conservative and midpoint estimates, and 10% savings for the maximum savings case as a result of the forthcoming 90.1 standard. The 5% figure is based on 10% savings in packaged equipment (as discussed above under air conditioning) times 33% (a rough estimate of the proportion of electric heating in new buildings that is done with heat pumps) plus an additional two percentage points of savings from improved heating system design. For the maximum savings case we estimate 10% savings, based on 5% savings due to building shell improvements in addition to the heating equipment and systems savings. For the 2005 code we estimate 5% additional savings for the conservative case and 10% savings for the other two cases. These savings are primarily based on shell and heating system design improvements.

For gas space heating equipment, our midpoint estimate for the new 90.1 standard is 10% savings, which is primarily due to 25% savings from use of power venting and electronic ignition in the up to 44% of the gas space heating market provided by unit heaters and duct furnaces (Krauss et al. 1992). For the conservative case we reduce these savings by five percentage points, for the maximum savings case we add five percentage points. For the 2005 code, we estimate 5% savings for the conservative cases (based primarily on unit heater savings), 10% savings for the midpoint case (based on packaged system savings plus building shell improvements), and 15% savings for the maximum savings case (based primarily on condensing boilers and furnaces).

For ventilation, the new ASHRAE 90.1 standard is likely to require adjustable speed drives (ASDs) on ventilation fans (or a speed reduction equivalent) of mid- to large size. Fan motor efficiency will also improve. Based on these measures, we estimate 20% savings in the maximum savings case (based on typical ASD savings -- Nadel et al. 1992), 15% savings in the midpoint case (small buildings will not have ASDs), and 10% savings in the conservative case (if the majority of applications are exempted from the ASD requirement). For 2005 no further savings are assumed.

Industrial Standards

Standards and codes will also affect the industrial sector. Most industrial energy use forecasts are based on econometric forecasts which cannot be easily modified to incorporate the effects of codes and standards. Also, standard and code impacts are likely to be more modest in the industrial sector than in the residential and commercial sectors. Still, industrial impacts are worth noting. The primary savings in the industrial sector will probably be from motor efficiency standards. Motors account for approximately 78% of industrial electricity use (Nadel et al. 1992) and thus even 1-2% savings from improved motors can have an impact on industrial electricity use. Lamp and ballast standards, including HID lamp standards, might reduce industrial lighting energy use by 20%, although savings will be limited by the fact that lighting accounts for only approximately 7% of industrial electricity use (Elliott 1994). Heating and cooling equipment standards and building codes will also save energy in the industrial sector, although the lack of good data on space conditioning energy use in the industrial sector make estimating the savings difficult.

ESTIMATING THE IMPACTS OF STANDARD AND CODE UPDATES ON U.S. ENERGY USE

In the previous sections of this paper, data on unit energy consumption and energy use intensity were provided to allow forecasters to modify local forecasts to incorporate the impacts of revised standards and codes. In this section, we apply these estimates to a simple forecasting model of U.S. energy use in order to indicate the approximate magnitude of potential savings. Following this analysis, we briefly examine the results of other studies that have attempted to forecast the impacts of revised standards and codes.

Forecast of Standard and Code Updates on U.S. Energy Use

For this analysis, two simple end-use energy-saving models were developed -- one for the residential sector and one for the commercial sector.

In the residential model, energy savings are estimated for 2000, 2005, 2010, and 2015 for each type of equipment. Savings are calculated as the product of annual equipment sales, savings per unit from new standards, and number of years since the standard took effect. Specific assumptions and calculations are detailed in Tables G, H, and I in the appendix.

In the commercial model, savings are estimated for existing buildings and new construction for each year from 1994 through 2015. Savings estimates are based on the product of energy use intensity (kWh or therms per square foot) for each end-use, total floor area, and energy-use intensity multipliers for each end-use (from Tables 5, 6, and 7). Specific assumptions and calculations are detailed in Tables J, K, and L in the appendix.

Results of these two analyses are summarized in Table 8 and Figure 1. As can be seen in these summaries, under the midpoint estimates, total U.S. energy use from all fuels declines by more

Table 8. Summary of Savings from Revised Standards and Codes.

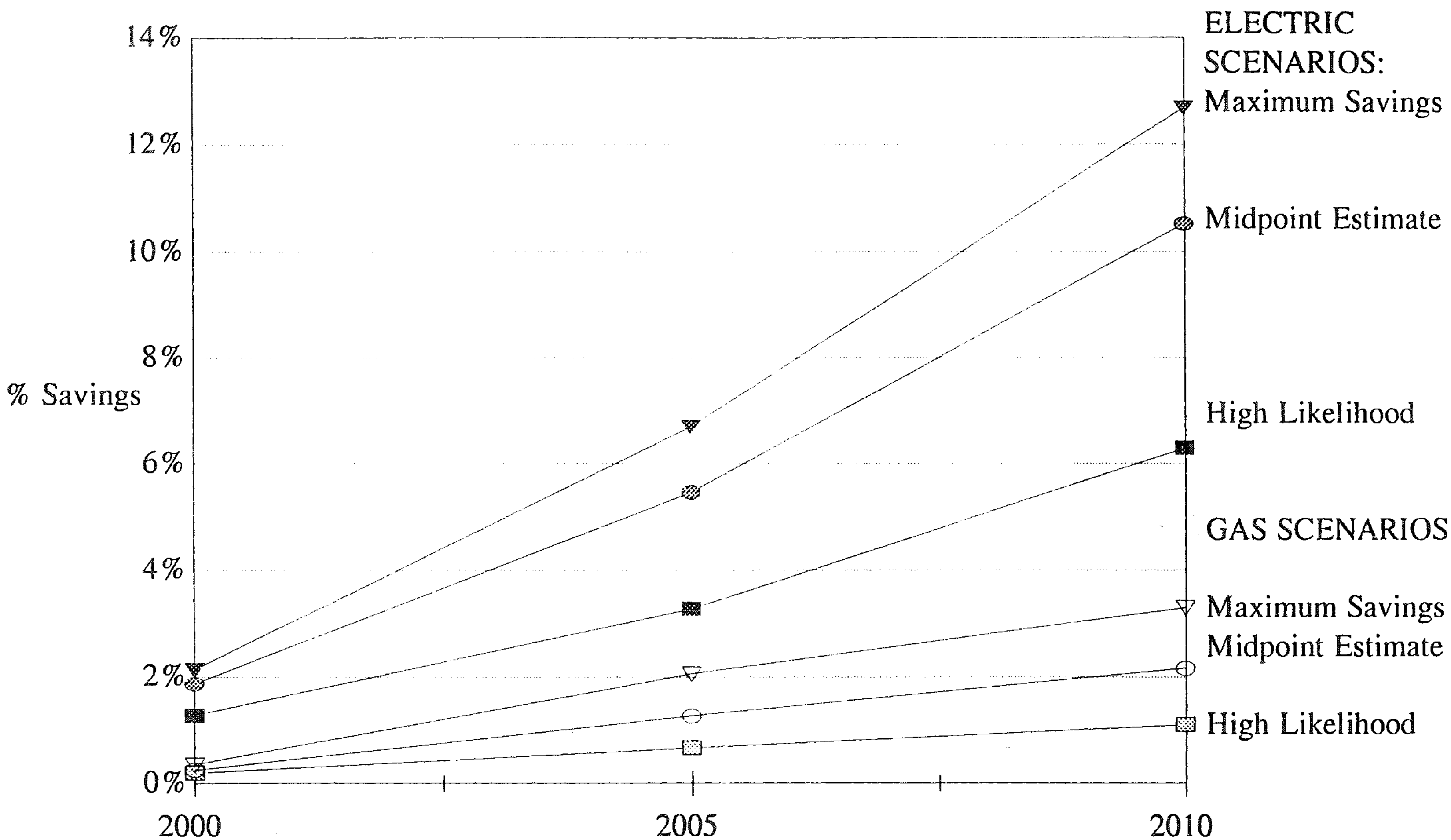
	High Likelihood Scenario			Midpoint Estimate			Maximum Savings Scenario		
	(GWh)	(million therms)	(Quads)	(GWh)	(million therms)	(Quads)	(GWh)	(million therms)	(Quads)
Residential									
2000	19,502	363	0.25	37,091	465	0.45	41,370	690	0.52
2005	55,425	1,520	0.76	106,779	2,936	1.47	137,381	4,836	1.99
2010	111,441	2,634	1.49	216,440	5,224	2.90	274,252	8,031	3.82
2015	139,741	3,492	1.89	262,368	8,427	3.73	331,442	14,110	5.06
Commercial									
2000	20,356	95	0.23	21,154	109	0.24	25,000	123	0.29
2005	52,775	116	0.59	73,800	145	0.83	83,805	171	0.94
2010	107,003	124	1.19	148,793	154	1.65	166,070	183	1.85
2015	153,170	124	1.70	210,810	154	2.33	233,531	183	2.59
Total									
2000	39,858	458	0.48	58,245	574	0.70	66,370	813	0.81
2005	108,200	1,636	1.35	180,579	3,081	2.29	221,186	5,007	2.93
2010	218,444	2,758	2.68	365,233	5,378	4.56	440,322	8,214	5.66
2015	292,911	3,616	3.58	473,178	8,581	6.06	564,973	14,293	7.64
Savings as % of EIA forecast									
Residential									
2000	2.0%	0.7%	1.4%	3.7%	0.9%	2.5%	4.2%	1.4%	2.9%
2005	5.4%	3.0%	4.2%	10.4%	5.9%	8.1%	13.4%	9.7%	11.0%
2010	10.5%	5.3%	8.0%	20.3%	10.4%	15.6%	25.8%	16.1%	20.5%
Commercial									
2000	2.1%	0.3%	1.3%	2.2%	0.4%	1.4%	2.6%	0.4%	1.6%
2005	5.2%	0.4%	3.2%	7.3%	0.5%	4.5%	8.3%	0.6%	5.1%
2010	10.4%	0.4%	6.3%	14.4%	0.5%	8.8%	16.1%	0.6%	9.8%
Total									
2000	1.3%	0.2%	0.5%	1.9%	0.3%	0.7%	2.1%	0.4%	0.8%
2005	3.3%	0.7%	1.3%	5.5%	1.3%	2.3%	6.7%	2.1%	2.9%
2010	6.3%	1.1%	2.5%	10.5%	2.2%	4.3%	12.7%	3.3%	5.4%

Notes:

* Detailed analysis can be found in the appendix.

* EIA forecast from 1994 Annual Energy Outlook, Reference Case Projections.

Figure 1. Savings from Revised Standards and Codes in the U.S. as a Percent of EIA Forecast.



Note: Percent Savings are savings of electricity or natural gas from all sectors as a % of projected electricity or natural gas use for all sectors in EIA 1994 Reference Forecast.

than 4% from forecast levels in 2010 as a result of revised standards and codes.[1] Included in these savings are a 20% reduction in residential electricity use, a 14% reduction in commercial electricity use, and an 11% reduction in electricity used by all sectors. Natural gas savings total approximately 10% in the residential sector and 1% in the commercial sector. Even under the conservative "high likelihood scenario," savings in 2010 total more than 2% of total U.S. energy use including approximately 10% reductions in residential and commercial electricity use. For the maximum savings scenario, savings in 2010 total more than 5% of total U.S. energy use, including more than a 25% reduction in residential electricity use and more than 16% savings in residential gas use and commercial electricity use.

Savings of these magnitudes can have a particularly dramatic impact on the need for new electric generating plants. Assuming a 50% average capacity factor (the average projected by DOE for the U.S. in 2010 -- EIA 1994), under the midpoint scenario, the need for generating capacity will be reduced by over 83 GW. This represents nearly half of the new utility and non-utility generating capacity DOE projects will be added over the 1992-2010 period (EIA 1994).

Comparison to Other Forecasts

The author has worked with two states and two utilities to incorporate the estimated impacts of revised standards and codes into their load forecasts. While each state and utility used somewhat different assumptions (due to forecast-specific issues as well as the fact that standard and code forecasts change over time), the results are generally similar to the results presented above.

Northeast Utilities began incorporating standard and code predictions into its forecast beginning in 1994. Using estimates similar to those in the midpoint case discussed in this paper, forecasted energy sales in 2010 were reduced by 8.6% relative to a forecast which assumed no code and standard updates (Northeast Utilities 1994).

The New York State Energy Office incorporated code and standard updates into their 1994 State Energy Plan. Two scenarios were examined, an "Enhanced" case (even more conservative than the conservative case in this paper) and an "Aggressive" scenario (midway between the conservative and midpoint cases in this paper). Results of these two scenarios were a 5.4% and 8.3% reduction in forecasted statewide energy requirements in 2010 (NYSEO et al. 1994).

The State of Illinois modified its Energy 2020 forecasting model to incorporate the impacts of revised standards and codes. This forecast, which included assumptions similar to the midpoint case in this paper, projected a 5% reduction in forecasted electricity requirements and a 2% reduction in forecasted natural gas requirements for 2010. Included in these forecasts are a 10% reduction in residential electricity use and a 14% reduction in commercial electricity use (Smith et al. 1994).

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[1] These savings percentages are relative to the Energy Information Administration's (EIA) 1994 Reference Forecast. These percentages may be slightly exaggerated because the EIA forecast includes modest amounts of efficiency improvements that may somewhat overlap with the efficiency improvements attributable to updated codes and standards.

New England Electric incorporated impacts of code and standard updates into its 1994 forecast. For the basecase forecast, assumptions were similar to the conservative case in this paper. For the "high certainty" forecast (highest certainty that the utility would have load to serve, which means lowest possible energy and demand levels), assumptions were similar to the maximum savings scenario in this paper. For the basecase forecast, the impacts of revised codes and standards were analyzed along with many other input assumptions and cannot be isolated from the main forecast. For the high certainty case, impacts of revised codes and standards were isolated; in 2008, these impacts reduced the forecast by 4.7% below basecase levels (in other words, the difference between the basecase and high certainty code and standard assumptions reduced the basecase forecast by 4.7%) (NEES 1994).

CONCLUSIONS

Equipment efficiency standards and building codes have a significant impact on energy use in the residential and commercial sectors. These standards and codes are updated on a regular basis. While there is substantial uncertainty about the exact efficiency levels that will be ultimately incorporated into these updates, it is likely that these updates will result in substantial energy savings. Ignoring the impacts of revised standards and codes in the forecast process will likely lead to overpredicting future energy use by a substantial degree. We urge all forecasters to systematically incorporate the impacts of code and standard updates, whether those contained in this paper or those developed from other sources. Doing so should substantially increase the accuracy of energy demand forecasts.

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REFERENCES

ACEEE. 1994. *Initial Comments of the American Council for an Energy-Efficient Economy on the Department of Energy's Eight Product Rulemaking,* Docket EE-RM-90-201, presented April 5-7, 1994. American Council for an Energy-Efficient Economy, Washington, DC.

AHAM. 1993. "Refrigerators, Energy Efficiency and Consumption Trends," Association of Home Appliance Manufacturers, Chicago, IL.

AHAM. 1994a. *Directory of Certified Refrigerators and Freezers.* Association of Home Appliance Manufacturers, Chicago, IL.

AHAM. 1994b. *DOE Range Rulemaking.* Docket No. EE-RM-90-201, presented April 7, 1994. Association of Home Appliance Manufacturers, Chicago, IL.

Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, and Union of Concerned Scientists. 1992. *America's Energy Choices.* Union of Concerned Scientists, Cambridge, MA.

Alliance to Save Energy. 1993. *Industry Profile: The High-Efficiency Gas Furnace Industry.* Alliance to Save Energy, Washington, DC.

Appliance Magazine, 51 (4), April 1994. "Statistical Review." pp. 39-42.

Atkinson, Barbara. 1994. Personal communication. Lawrence Berkeley Laboratory, Berkeley, CA.

Atkinson, Barbara A., James E. McMahon, Evan Mills, Peter Chan, Terry W. Chan, Joseph H. Eto, Judith D. Jennings, Jonathan G. Koomey, Kenny W. Lo, Matthew Lecar, Lynn Price, Francis Rubinstein, Osman Sezgen, Tom Wenzel. 1992. *Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings.* Lawrence Berkeley Laboratory, Berkeley, CA.

Blumstein, Carl. 1994. Personal communication. California Institute for Energy Efficiency, Berkeley, CA.

Burke, Robert. 1994. Oral testimony at DOE hearing, April 5, 1994. Magnetek, Paramus, NJ.

Byers, Debra. 1994. Personal communication. Bonneville Power Administration, Portland, OR.

CEC. 1994. "CEC Appliance Database," (central air conditioner and heat pump files), March. California Energy Commission, Sacramento, CA.

CEE. 1993. "Program Outline for Multi-Utility Clothes Washer Incentive Eligibility Standards." Consortium for Energy Efficiency, Boston, MA.

CEE. 1994a. "High Efficiency Commercial Air Conditioning (HECAC) Initiative, Program, Program Description." Consortium for Energy Efficiency, Boston, MA.

CEE. 1994b. "Residential Central Air Conditioner and Heat Pump Program, Program Description." Consortium for Energy Efficiency, Boston, MA.

Competitek. 1992. *The State of the Art: Space Cooling and Air Handling.* Competitek, Boulder, CO.

DOE. 1989a. "Energy Conservation Program for Consumer Products: Final Rule for Refrigerators, Refrigerator-Freezers, Freezers, and Small Gas Furnaces," Federal Register, 54 (221), November 17, pp. 47916 - 47921. U.S. Department of Energy, Washington, DC.

DOE. 1989b. *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces.* U.S. Department of Energy, Washington, DC.

DOE. 1990b. *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers.* U.S. Department of Energy, Washington, DC.

DOE. 1990a. "Energy Conservation Program for Consumer Products: Advance Notice of Proposed Rulemaking Regarding Energy Conservation Standards for Nine Types of Consumer Products," Federal Register 55, September 28, pp. 39624 - 39632. U.S. Department of Energy, Washington, DC.

DOE. 1993a. "Energy Conservation Program for Consumer Products: Advance Notice of Proposed Rulemaking Regarding Energy Conservation Standards for Three Types of Consumer Products," Federal Register 58 (215), November 9, pp. 47326 - 47338. U.S. Department of Energy, Washington, DC.

DOE. 1993b. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Room Air Conditioners, Water Heaters, Direct Heating Equipment, Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts and Television Sets.* U.S. Department of Energy, Washington, DC

DOE. 1994. "Energy Conservation Program for Consumer Products: Notice of Proposed Rulemaking and Public Hearing," Federal Register 59 (43), March 4, pp. 10464 - 10532. U.S. Department of Energy, Washington, DC.

DSTR. 1993. "Top-Loading, Horizontal Axis Washing Machine Debuts," Demand-Side Technology Report, November 1993, pp. 8-9.

Easton Consultants. 1994. Presentation to Consortium for Energy Efficiency Motor Systems Subcommittee, June 24.

EIA. 1992: Energy Information Administration, Residential Energy Consumption Survey. *Housing Characteristics 1990,* DOE/EIA-0314(90). U.S. Department of Energy, Washington, DC.

EIA. 1994: Energy Information Administration. *Annual Energy Outlook 1994 With Projections to 2010.* U.S. Department of Energy, Washington, DC.

Elliot, R. Neal. 1994. *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector.* American Council for an Energy-Efficient Economy, Washington, DC.

EPA. 1993. *Multiple Pathways to Super-Efficient Refrigerators,* EPA-430-R-93-008. Environmental Protection Agency, Washington, DC.

EPRI. 1993. COMMEND 4.0 (default data set). Electric Power Research Institute, Palo Alto, CA.

EPRI. 1993a. "EPRI/E-Tech Heat Pump Water Heater Sets New Standards for Efficiency, Cost, and Performance," *Electric Water Heating News*, Fall. Electric Power Research Institute, Palo Alto, CA.

GAMA. 1994a. *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment.* Gas Appliance Manufacturers Association, Arlington, VA.

GAMA. 1994b. *Statement of the Gas Appliance Manufacturers Association (GAMA) on Proposed Efficiency Standards for Water Heaters.* Docket No. EE-RM-90-201, presented April 5, 1994. Gas Appliance Manufacturers Association, Arlington, VA.

Geller, Howard and Steven Nadel. 1992. *Consensus National Efficiency Standards for Lamps, Motors, Showerheads and Faucets, and Commercial HVAC Equipment,* in *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings*, pp. 6.71 - 6.82. American Council for an Energy-Efficient Economy, Berkeley, CA.

Giordano, Sal Jr. 1994. *Energy Conservation Program for Consumer Products, Eight Products Rulemaking*. Docket No. EE-RM-90-201. Fedders Corporation, Peacack, NJ.

GRI. 1986. *Commercial Appliance Energy Use Update.* Report No. TE4342-15-86. Gas Research Institute, Chicago, IL.

Hoffman, John. 1993. Personal communication. Environmental Protection Agency, Washington, DC.

Howard, Bion D. and William R. Prindle. 1991. *Better Building Codes for Energy Efficiency.* Alliance to Save Energy, Washington, DC.

Krauss, W.E., M.J. Hewett, and M.S. Lobenstein. 1992. *Commercial Gas Space Heating Equipment: Opportunities to Increase Energy Efficiency.* CEUE/TR91-3-CM. Center for Energy and the Urban Environment, Minneapolis, MN.

Latham, Linda. 1994. Personal communication. Environmental Protection Agency, Washington, DC.

Langreth, R. 1994. "$30 Million Refrigerator." *Popular Science*, January 1994, pp. 65-67, 87.

Lebot, Benoit, Isaac Turiel, and Gregory Rosenquist. 1990. "Horizontal Axis Domestic Clothes Washers: An Alternative Technology that Can Reduce Residential Energy and Water Use," in *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings,* pp. 1.147-1.156. American Council for an Energy-Efficient Economy, Berkeley, CA.

Ledbetter, Marc, and Loretta A. Smith. 1993. *Guide to Energy-Efficient Office Equipment.* American Council for an Energy-Efficient Economy, Washington, DC.

Lovett, C. Denver. 1981. "An Evaluation of Assigning Credit/Debit to the Energy Factor of Clothes Washers Based on Water Extraction Performance," NBSIR 81-2309. National Bureau of Standards, Washington, DC.

Nadel, Brian. 1993. "The Green Machine," *PC Magazine*, 12 (10), May 25, p.120.

Nadel, Steven, Howard Geller, Fred Davis, and David Goldstein. 1989. *Lamp Efficiency Standards for Massachusetts: Analysis and Recommendations.* Prepared for Massachusetts Executive Office of Energy Resources. American Council for an Energy-Efficient Economy, Washington, DC.

Nadel, S., M. Shepard, S. Greenberg, G. Katz and A.T. de Almeida. 1991. *Energy-Efficient Motor Systems.* American Council for an Energy-Efficient Economy, Washington, DC.

Nadel, S., D. Bourne, M. Shepard, L. Rainer, and L. Smith. 1993. *Emerging Technologies to Improve Energy Efficiency in the Residential and Commercial Sectors.* American Council for an Energy-Efficient Economy, Washington, DC.

Nadel, Steven. 1994. *Minimum Efficiency Standards -- Options for Federal and State Action* American Council for an Energy-Efficient Economy, Washington, DC.

NCSBCS. 1991. *Energy Directory.* National Conference of States on Building Codes and Standards, Herndon, VA.

NEES. 1994. *Integrated Least Cost Resource Plan for the Fifteen Year Period 1994-2008.* New England Electric System, Westborough, MA.

NYSEO et al. 1994. *Draft New York State Energy Plan.* New York State Energy Office, New York State Department of Environmental Conservation, and New York State Department of Public Service, Albany, NY.

Northeast Utilities. 1994. *The Northeast Utilities System, 1994 Forecast of Loads and Resources for 1994-2013.* Northeast Utilities, Hartford, CT.

Randazzo, M. 1994. Gas Heat Pump Set to Debut in U.S. Market in 2nd Quarter of '94. *Energy User News*, 19(1), p. 34,41.

Smith, Loretta A. and Steven Nadel. 1994. *Energy Efficiency Codes and Standards for Illinois.* American Council for an Energy-Efficient Economy, Washington, DC.

Travers, David. 1994. Testimony at DOE public hearing, April 5. Sony Corp.

Turiel, I., D. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M. Levine, J. McMahon, G. Rosenquist, and S. Stoft. 1990. "U.S. Residential Appliance Energy Efficiency: Present Status and Future Directions," in *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings,* pp. 1.213-1.234. American Council for an Energy-Efficient Economy, Berkeley, CA.

WASEO. 1993. "MotorMaster Electronic Motor Selection Software, Version 2.1." Washington State Energy Office, Olympia, WA.

Weizeorick, Jack. 1994. Oral testimony at DOE hearing, April 7, 1994. Association of Home Appliance Manufacturers, Chicago, IL.

Wilson, Alex and John Morrill. 1993. *Consumer Guide to Home Energy Savings,* Third Edition. American Council for an Energy-Efficient Economy, Washington, DC.

Table A. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards.
Midpoint Estimate

Existing Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Phase-In Period (Measure Life)	Savings/ Year	Notes
Lighting						
1998 fluor. ballast	Electronic ballasts	15%	63%	15	0.63%	Savings based on Magnetek comments on DOE 1993.
1999 HID lamp	Ban mercury vapor	8%	6%	6	0.08%	40% savings in 20% of HID that's now mercury.
2001 flour. lamps	T8 lamps	5%	63%	6	0.53%	Savings based on CEC et al. 1992.
2001 incand. lamps	Halogen IR	27%	9%	1	2.55%	Savings based on Nadel et al. 1993. Assume 1/2 lamps already CFL or equivalent.
2004 HID lamp	Electrodeless lamp	26%	6%	15	0.11%	Savings based on Nadel et al. 1993.
2006 incand. lamps	Coated filament	45%	6%	1	2.81%	Savings based on Nadel et al. 1993 and only include savings beyond the 2001 lamp stds. Assume 2/3 lamps already CFL or equivalent.
2007 fluor. lamp & ballast	Surface wave lamp	30%	63%	15	1.26%	Savings based on Nadel et al. 1993.
Air conditioning						
1999 Unitary AC & HP	EER 10	11%	59%	15	0.43%	Savings assume base EER of 9.0.
2002 Unitary AC & HP	EER 11	9%	59%	15	0.35%	
2005 Unitary AC & HP	EER 12	8%	59%	15	0.31%	
Elec. space heating						
1999 Unitary AC & HP	EER 10	10%	33%	15	0.22%	Savings assume base EER of 9.0.
2002 Unitary AC & HP	EER 11	9%	33%	15	0.20%	
2005 Unitary AC & HP	EER 12	8%	33%	15	0.18%	
Ventilation						
2002 motor	Best motors on mkt	2%	50%	15	0.07%	Based on WASEO 1993.
Office equipment						
PC's (1996)	Power Managed PC	50%	26%	5	2.60%	Savings based on Nadel et al. 1993.
Imaging equip (1997)	50% savings	50%	29%	5	2.90%	Savings based on Nadel et al. 1993.

Notes:

* Savings/yr = product of first two columns divided by third column.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment). For incandescent lamps these standards are only applied to 50% of current lamps, assuming that the remainder switch to CFLs as a result of utility programs.
* Office equipment is not covered by standards but is instead affected by EPA's Energy Star program and COPEE labeling program.

Table B. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards.
Midpoint Estimate

New Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Percent Reduction in EUI	Notes:
Lighting					
1997 90.1/1999 State Energy Codes	20% savings	20%	100%	20%	Based on preliminary work by 90.1 committee. Includes electronic ballasts, T8 lamps, CFLs.
2001 incand. lamps	Halogen IR	27%	3%	1%	Savings based on Nadel et al. 1993. Assume 3/4 lamps already CFL or equivalent.
2004 HID lamp	Electrodeless lamp	26%	6%	2%	Savings based on Nadel et al. 1993.
2003 90.1/2005 State Energy Codes	20% add'l savings	20%	100%	20%	Savings for lighting controls -- based on preliminary analysis by 90.1 committee.
2006 incand. lamps	Coated filament	45%	5%	2%	Savings based on Nadel et al. 1993 and only include savings beyond the 2001 lamp stds. Assume 3/4 lamps already CFL or equivalent.
2007 fluor. lamp & ballast	Surface wave lamp	30%	63%	19%	Savings based on Nadel et al. 1993.
Air conditioning					
1997 90.1/1999 State Energy Codes	15% savings	15%	100%	15%	Based on .58 kW/ton chillers, EER 10 unitary equip., plus a small allowance for system improvements.
2002 Unitary AC & HP	EER 11 Unitary equi	9%	65%	6%	
2003 90.1/2005 State Energy Codes	15% add'l savings	15%	100%	15%	Primarily system improvements.
Elec. space heating					
1997 90.1/1999 State Energy Codes	5% savings	5%	100%	5%	Includes 10% improvements to heat pumps (applies to 1/3 elec. htd bldgs) and 5% system improvements.
2002 Unitary AC & HP	EER 11 Unitary equi	9%	33%	3%	
2003 90.1/2005 State Energy Codes	10% add'l savings	10%	100%	10%	Primarily system improvements.
Gas space heating					
1997 90.1/1999 State Energy Codes	10% savings	10%	100%	10%	Based primarily on 25% savings in unit heaters and duct furnaces attributable to power venting and elec. ignition.
2003 90.1/2005 State Energy Codes	10% add'l savings	10%	100%	10%	Includes system and building shell improvements.
Ventilation					
1997 90.1/1999 State Energy Codes	15% savings	15%	50%	8%	Savings primarily from use of ASDs.
Office equipment					
PC's (1996)	Power Managed PC	50%	26%	13%	Savings based on Nadel et al. 1993.
Imaging equip (1997)	50% savings	50%	29%	15%	Savings based on Nadel et al. 1993.

Notes:

* Percent reduction in EUI (kWh/sq.ft.) = product of first two columns.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment).

Table C. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards.
High Liklihood Scenario

Existing Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Phase-In Period (Measure Life)	Savings/ Year
Lighting					
1998 fluor. ballast	Electronic ballasts	16%	63%	15	0.67%
1999 HID lamp	Ban mercury vapor	8%	6%	6	0.08%
2001 flour. lamps	No change	0%	63%	6	0.00%
2001 incand. lamps	Energy Saver lamps	10%	9%	1	0.95%
2004 HID lamp	No change	0%	6%	15	0.00%
2006 incand. lamps	Halogen IR	17%	6%	1	1.06%
2007 fluor. lamp & ballast	3% improvement	3%	63%	15	0.13%
Air conditioning					
1999 Unitary AC & HP	EER 10	10%	59%	15	0.39%
2002 Unitary AC & HP	No change	0%	59%	15	0.00%
2005 Unitary AC & HP	EER 11	9%	59%	15	0.35%
Elec. space heating					
1999 Unitary AC & HP	EER 10	10%	33%	15	0.22%
2002 Unitary AC & HP	No change	0%	33%	15	0.00%
2005 Unitary AC & HP	EER 11	9%	33%	15	0.20%
Ventilation					
2002 motor	Best motors on mkt	2%	50%	15	0.07%
Office equipment					
PC's (1996)	Power Managed PC	50%	26%	5	2.60%
Imaging equip (1997)	50% savings	50%	29%	5	2.90%

Notes:

* Savings/yr = product of first two columns divided by third column.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment). For incandescent lamps these standards are only applied to 50% of current lamps, assuming that the remainder switch to CFLs as a result of utility programs.
* Office equipment is not covered by standards but is instead affected by EPA's Energy Star program and COPEE labeling program.

Table D. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards
High Likelihood Scenario

New Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Percent Reduction in EUI
Lighting				
1997 90.1/1999 State Energy Codes	15% savings	15%	100%	15%
2001 incand. lamps	Energy Saver lamps	10%	3%	0%
2004 HID lamp	No change	0%	6%	0%
2003 90.1/2005 State Energy Codes	15% add'l savings	15%	100%	15%
2006 incand. lamps	Halogen IR	19%	5%	1%
2007 fluor. lamp & ballast	5% improvement	5%	63%	3%
Air conditioning				
1997 90.1/1999 State Energy Codes	10% savings	10%	100%	10%
2002 Unitary AC & HP	No change	0%	65%	0%
2003 90.1/2005 State Energy Codes	15% add'l savings	15%	100%	15%
Elec. space heating				
1997 90.1/1999 State Energy Codes	5% savings	5%	100%	5%
2002 Unitary AC & HP	No change	0%	33%	0%
2003 90.1/2005 State Energy Codes	5% add'l savings	5%	100%	5%
Gas space heating				
1997 90.1/1999 State Energy Codes	5% savings	5%	100%	5%
2003 90.1/2005 State Energy Codes	5% add'l savings	5%	100%	5%
Ventilation				
1997 90.1/1999 State Energy Codes	10% savings	10%	50%	5%
Office equipment				
PC's (1996)	Power Managed PC	50%	26%	13%
Imaging equip (1997)	50% savings	50%	29%	15%

Notes:

* Percent reduction in EUI (kWh/sq.ft.) = product of first two columns.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment).

Table E. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards.
Maximum Savings Scenario

Existing Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Phase-In Period (Measure Life)	Savings/ Year
Lighting					
1998 fluor. ballast	Electronic ballasts	19%	63%	15	0.80%
1999 HID lamp	No merc. vapor +5	13%	6%	6	0.14%
2001 flour. lamps	T8 lamps	5%	63%	6	0.53%
2001 incand. lamps	Halogen IR lamp	27%	9%	1	2.55%
2004 HID lamp	Electrodeless lamp	26%	6%	15	0.11%
2006 incand. lamps	Coated filament	45%	6%	1	2.81%
2007 fluor. lamp & ballast	Surface wave lamp	30%	63%	15	1.26%
Air conditioning					
1999 Unitary AC & HP	EER 12	11%	59%	15	0.43%
2002 Unitary AC & HP	No change	17%	59%	15	0.66%
2005 Unitary AC & HP	Var. spd -- IPLV 14	14%	59%	15	0.55%
Elec. space heating					
1999 Unitary AC & HP	EER 12	11%	33%	15	0.24%
2002 Unitary AC & HP	No change	17%	33%	15	0.37%
2005 Unitary AC & HP	Var. spd -- IPLV 14	14%	33%	15	0.31%
Ventilation					
2002 motor	Hi-E motor	3%	50%	15	0.10%
Office equipment					
PC's (1996)	Green PC	85%	26%	5	4.42%
Imaging equip (1997)	50% savings	50%	29%	5	2.90%

Notes:

* Savings/yr = product of first two columns divided by third column.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment). For incandescent lamps these standards are only applied to 50% of current lamps, assuming that the remainder switch to CFLs as a result of utility programs.
* Office equipment is not covered by standards but is instead affected by EPA's Energy Star program and COPEE labeling program.

Table F. Calculation Worksheet for Developing EUI Multiplier Factors for Revised Commercial Codes & Standards.
Maximum Savings Scenario

New Buildings:

End Use/Standard	Assumed Standard	Percent Savings	Percent End-Use Applies To	Percent Reduction in EUI
Lighting				
1997 90.1/1999 State Energy Codes	30% savings	30%	100%	30%
2001 incand. lamps	Halogen IR lamp	27%	3%	1%
2004 HID lamp	Electrodeless lamp	26%	6%	2%
2003 90.1/2005 State Energy Codes	25% add'l savings	25%	100%	25%
2006 incand. lamps	Coated filament	45%	5%	2%
2007 fluor. lamp & ballast	Surface wave lamp	30%	56%	17%
Air conditioning				
1997 90.1/1999 State Energy Codes	30% savings	30%	100%	30%
2000 90.1 2nd tier	No change	0%	65%	0%
2003 90.1/2005 State Energy Codes	20% add'l savings	7%	100%	7%
Elec. space heating				
1997 90.1/1999 State Energy Codes	20% savings	20%	100%	20%
2000 90.1 2nd tier	No change	0%	33%	0%
2003 90.1/2005 State Energy Codes	10% add'l savings	8%	100%	8%
Gas space heating				
1997 90.1/1999 State Energy Codes	15% savings	15%	100%	15%
2003 90.1/2005 State Energy Codes	15% add'l savings	15%	100%	15%
Ventilation				
1997 90.1/1999 State Energy Codes	20% savings	20%	50%	10%
Office equipment				
PC's (1996)	Green PC	85%	26%	22%
Imaging equip (1997)	50% savings	50%	29%	15%

Notes:

* Percent savings column includes adjustments to eliminate overlap w/ previous measures.
* Percent reduction in EUI (kWh/sq.ft.) = product of first two columns.
* Percent of saturation wtd EUI each measure applies to was estimated by ACEEE based on data from Nadel et al. 1989 (lighting), Competiek 1992 and GRI 1986 (HVAC), and Nadel et al. 1993 (office equipment).

Table G. Estimated National Savings from Future Residential Equipment Efficiency Standards (Midpoint Estimate).

Product	1990 Stock (10^6)	1993 Sales	Avg. Energy Used by New Units	Average Life (years)	Svgs/Unit (kWh) 1st Std	Svgs/Unit (kWh) 2nd Std	Savings in Year Listed (GWh) 2000	2005	2010	2015	Savings (Quads) 2015
Refrigerators	112.6	8.1	669	19	201	117	4,063	14,559	27,425	40,291	0.44
Freezers	32.4	2	450	21	118	33	589	1,933	3,444	4,954	0.05
Clothes washers (elec dhw)	30.0	3.0	578	14	335	--	0	4,519	9,540	14,059	0.15
Electric clothes dryers	49.5	3.9	765	17	314	--	0	5,502	11,615	17,728	0.20
Dishwashers (elec dhw)	17.8	1.7	473	13	118	--	304	1,317	2,329	2,633	0.03
Electric water heaters	36.1	3.6	2617	10	1047	330	0	17,554	42,335	49,562	0.55
Room air conditioners	55.0	3.1	873	15	166	--	1,286	3,857	6,428	7,713	0.08
Electric ranges	54.3	3.4	338	19	28	--	241	723	1,206	1,688	0.02
Microwave ovens	74.1	7.3	270	10	31	--	558	1,675	2,234	2,234	0.02
Central air conditioners	48.2	4.1	2769	12	803	246	4,939	21,404	42,403	49,088	0.54
Central heat pumps	6.4	0.9	2513	12	503	--	0	1,583	3,846	5,429	0.06
Televisions	192.8	23.3	179	11	41	--	2,409	7,226	10,598	10,598	0.12
Incandescent lamps	94.0	94.0	844	1	239	263	22,492	22,492	47,251	47,251	0.52
Showerheads (elec dhw)	39.3	2.0	638	20	128	128	125	1,502	4,006	6,511	0.07
Faucets (elec dhw)	39.3	2.0	288	20	86	--	85	933	1,781	2,629	0.03
Subtotal							37,091	106,779	216,440	262,368	2.89
					(therms)		(Million therms)				
Furnaces	34.9	2.6	559	23	89	--	0	814	1,154	3,140	0.31
Boilers	8.3	0.2	559	22	56	--	0	39	179	151	0.02
Clothes washers (gas dhw)	41.7	4.2	31	14	20	--	0	377	795	1,172	0.12
Gas clothes dryers	14.5	1.2	31	17	12	--	0	67	141	216	0.02
Dishwashers (gas dhw)	24.9	2.4	19	13	5	--	17	74	130	147	0.01
Gas water heaters	50.3	4.5	218	14	31	unclear	343	1,030	1,717	1,923	0.19
Gas ranges	33.0	2.4	33	19	13	--	79	238	396	554	0.06
Showerheads (gas dhw)	54.7	2.7	58	20	12	12	16	189	504	819	0.08
Faucets (gas dhw)	54.7	2.7	24	20	7	--	10	108	207	305	0.03
Subtotal							465	2,936	5,224	8,427	0.84
TOTAL											3.73

Notes:

* Number of units from EIA 1993 except for RAC which comes from DOE 1993.
* Sales in 1993 from April, 1994 Appliance magazine except for lamps, showerheads, and faucets. Sales for these products were estimated by dividing the stock by the average measure life.
* Life from DOE Technical Support Documents (TSDs) from current & previous efficiency standard dockets, except for showerheads & faucets which were estimated by ACEEE.
* Avg. energy used by new units from DOE TSDs and EIA 1993 adjusted for efficiency differences between stock and new units.
* Analysis assumes new equipment exceeds standards by an average of 5%.
* Savings = Annual sales * Savings/unit * # of years standard has been in effect. For heat pump water heaters and horizontal-axis clothes washers, a two-year delay in the effective date is assumed.
* Calculation of savings in Quads assumes 11,000 Btu/kWh.

Table H. Estimated National Savings from Future Residential Equipment Efficiency Standards (High Likelihood Scenario).

Product	1990 Stock (10^6)	1993 Sales	Avg. Energy Used by New Units	Average Life (years)	Svgs/Unit (kWh) 1st Std	Svgs/Unit (kWh) 2nd Std	Savings in Year Listed (GWh) 2000	2005	2010	2015	Savings (Quads) 2015
Refrigerators	112.6	8.1	669	19	134	107	2,709	10,293	20,044	29,795	0.33
Freezers	32.4	2	450	21	68	38	338	1,205	2,263	3,321	0.04
Clothes washers (elec dhw)	30.0	3.0	578	14	117	--	525	2,274	4,024	4,899	0.05
Electric clothes dryers	49.5	3.9	765	17	290	--	0	5,085	10,735	16,385	0.18
Dishwashers (elec dhw)	17.8	1.7	473	13	71	--	182	790	1,398	1,580	0.02
Electric water heaters	36.1	3.6	2617	10	131	50	1,178	3,623	5,517	6,502	0.07
Room air conditioners	55.0	3.1	873	15	113	--	880	2,639	4,398	5,278	0.06
Electric ranges	54.3	3.4	338	19	0	--	0	0	0	0	0.00
Microwave ovens	74.1	7.3	270	10	0	--	0	0	0	0	0.00
Central air conditioners	48.2	4.1	2769	12	471	322	2,895	12,547	28,136	35,698	0.39
Central heat pumps	6.4	0.9	2513	12	251	--	0	792	1,923	2,715	0.03
Televisions	192.8	23.3	179	11	41	--	2,409	7,226	10,598	10,598	0.12
Incandescent lamps	94.0	94.0	844	1	89	137	8,330	8,330	21,218	21,218	0.23
Showerheads (elec dhw)	39.3	2.0	638	20	0	0	0	0	0	0	0.00
Faucets (elec dhw)	39.3	2.0	288	20	58	--	57	622	1,187	1,753	0.02
Subtotal							19,502	55,425	111,441	139,741	1.54
					(therms)		(Million therms)				
Furnaces	34.9	2.6	559	23	14	--	0	127	180	491	0.05
Boilers	8.3	0.2	559	22	14	--	0	10	45	38	0.00
Clothes washers (gas dhw)	41.7	4.2	31	14	20	--	125	541	957	1,165	0.12
Gas clothes dryers	14.5	1.2	31	17	11	--	0	62	130	198	0.02
Dishwashers (gas dhw)	24.9	2.4	19	13	3	--	10	44	78	88	0.01
Gas water heaters	50.3	4.5	218	14	15	unclear	172	515	858	961	0.10
Gas ranges	33.0	2.4	33	19	8	--	50	149	248	347	0.03
Showerheads (gas dhw)	54.7	2.7	58	20	0	0	0	0	0	0	0.00
Faucets (gas dhw)	54.7	2.7	24	20	5	--	7	72	138	203	0.02
Subtotal							363	1,520	2,634	3,492	0.35
TOTAL											1.89

Notes:

* See notes on Table G.

Table I. Estimated National Savings from Future Residential Equipment Efficiency Standards (Maximum Savings Scenario).

Product	1990 Stock (10^6)	1993 Sales	Avg. Energy Used by New Units	Average Life (years)	Svgs/Unit (kWh) 1st Std	Svgs/Unit (kWh) 2nd Std	Savings in Year Listed (GWh) 2000	2005	2010	2015	Savings (Quads) 2015
Refrigerators	112.6	8.1	669	19	268	151	5,417	19,315	36,277	53,238	0.59
Freezers	32.4	2	450	21	151	30	755	2,415	4,225	6,035	0.07
Clothes washers (elec dhw)	30.0	3.0	578	14	369	--	0	4,967	10,486	15,453	0.17
Electric clothes dryers	49.5	3.9	765	17	456	--	0	8,003	16,895	25,787	0.28
Dishwashers (elec dhw)	17.8	1.7	473	13	145	--	373	1,618	2,863	3,236	0.04
Electric water heaters	36.1	3.6	2617	10	1675	330	0	27,730	63,819	72,176	0.79
Room air conditioners	55.0	3.1	873	15	201	--	1,556	4,669	7,781	9,337	0.10
Electric ranges	54.3	3.4	338	19	57	--	482	1,447	2,411	3,375	0.04
Microwave ovens	74.1	7.3	270	10	49	--	888	2,664	3,551	3,551	0.04
Central air conditioners	48.2	4.1	2769	12	1025	246	6,302	27,308	52,849	59,988	0.66
Central heat pumps	6.4	0.9	2513	12	804	--	0	2,534	6,153	8,686	0.10
Televisions	192.8	23.3	179	11	47	--	2,741	8,222	12,059	12,059	0.13
Incandescent lamps	94.0	94.0	844	1	239	263	22,492	22,492	47,251	47,251	0.52
Showerheads (elec dhw)	39.3	2.0	638	20	255	0	250	2,754	5,259	7,763	0.09
Faucets (elec dhw)	39.3	2.0	288	20	115	--	113	1,244	2,375	3,505	0.04
Subtotal							41,370	137,381	274,252	331,442	3.65
					(therms)		(Million therms)				
Furnaces	34.9	2.6	559	23	212	--	0	1,933	2,740	7,458	0.75
Boilers	8.3	0.2	559	22	73	--	0	51	233	196	0.02
Clothes washers (gas dhw)	41.7	4.2	31	14	17	--	0	325	686	1,011	0.10
Gas clothes dryers	14.5	1.2	31	17	13	--	0	72	153	233	0.02
Dishwashers (gas dhw)	24.9	2.4	19	13	6	--	21	91	162	183	0.02
Gas water heaters	50.3	4.5	218	14	46	unclear	515	1,545	2,575	2,884	0.29
Gas ranges	33.0	2.4	33	19	18	--	109	327	545	762	0.08
Showerheads (gas dhw)	54.7	2.7	58	20	23	0	31	346	661	976	0.10
Faucets (gas dhw)	54.7	2.7	24	20	10	--	13	144	276	407	0.04
Subtotal							690	4,836	8,031	14,110	1.41
TOTAL											5.06

Notes:

* See notes on Table G.

Table J. Estimated National Savings from Future Commercial Codes and Standards
Midpoint Estimate.

Existing Buildings:

	Saturation Weighted kWh/sq.ft.						Sat. Wtd. Gas Space	Total Floor	Savings from Codes and Stds	
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	Heat (MBtu/sf)	Area (10^6 sf)	(GWh)	(million therms)
1994	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1995	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1996	4.72	2.99	1.26	1.33	0.43	10.73	26.22	64,175	734	0
1997	4.72	2.98	1.26	1.33	0.41	10.69	26.22	64,175	3,049	0
1998	4.69	2.96	1.26	1.33	0.38	10.63	26.22	64,175	7,366	0
1999	4.66	2.95	1.25	1.33	0.36	10.56	26.22	64,175	11,842	0
2000	4.62	2.94	1.25	1.33	0.34	10.49	26.22	64,175	16,226	0
2001	4.45	2.93	1.25	1.33	0.33	10.29	26.22	64,175	28,991	0
2002	4.40	2.90	1.24	1.33	0.33	10.20	26.22	64,175	34,370	0
2003	4.34	2.88	1.24	1.33	0.33	10.12	26.22	64,175	39,694	0
2004	4.28	2.86	1.23	1.33	0.33	10.03	26.22	64,175	45,262	0
2005	4.23	2.83	1.23	1.33	0.33	9.94	26.22	64,175	51,246	0
2006	4.06	2.80	1.22	1.33	0.33	9.73	26.22	64,175	64,682	0
2007	3.98	2.77	1.21	1.32	0.33	9.61	26.22	64,175	72,336	0
2008	3.90	2.74	1.20	1.32	0.33	9.50	26.22	64,175	79,862	0
2009	3.82	2.71	1.20	1.32	0.33	9.38	26.22	64,175	87,264	0
2010	3.74	2.68	1.19	1.32	0.33	9.27	26.22	64,175	94,543	0
2011	3.67	2.65	1.18	1.32	0.33	9.16	26.22	64,175	101,702	0
2012	3.60	2.62	1.18	1.32	0.33	9.05	26.22	64,175	108,743	0
2013	3.55	2.59	1.17	1.32	0.33	8.96	26.22	64,175	114,233	0
2014	3.50	2.57	1.16	1.32	0.33	8.89	26.22	64,175	118,785	0
2015	3.45	2.56	1.16	1.32	0.33	8.82	26.22	64,175	123,286	0

New Buildings:

	Saturation Weighted kWh/sq.ft.						Sat. Wtd. Gas Space	Total Floor	Savings from Codes and Stds	
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	Heat (MBtu/sf)	Area (10^6 sf)	(GWh)	(million therms)
1994	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1995	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1996	4.31	3.08	1.89	1.32	0.37	10.97	20.47	1,400	76	81
1997	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	227	81
1998	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	378	81
1999	3.45	2.62	1.80	1.22	0.31	9.39	18.42	1,400	2,653	109
2000	3.45	2.62	1.80	1.22	0.31	9.39	18.42	1,400	4,928	109
2001	3.42	2.62	1.80	1.22	0.31	9.37	18.42	1,400	7,244	109
2002	3.42	2.46	1.74	1.22	0.31	9.16	18.42	1,400	9,849	109
2003	3.42	2.10	1.57	1.22	0.31	8.62	18.42	1,500	13,457	117
2004	3.36	2.10	1.57	1.22	0.31	8.56	18.42	1,500	17,148	117
2005	2.69	1.78	1.41	1.22	0.31	7.42	16.58	1,500	22,554	145
2006	2.63	1.78	1.41	1.22	0.31	7.36	16.58	1,500	28,047	145
2007	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,500	34,286	145
2008	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	40,941	154
2009	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	47,595	154
2010	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	54,250	154
2011	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	60,905	154
2012	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	67,560	154
2013	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	74,215	154
2014	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	80,869	154
2015	2.14	1.78	1.41	1.22	0.31	6.86	16.58	1,600	87,524	154

Notes:

* kWh/sf from Commend 4.0 Default Data Set. These data are for 1991 – we assume 1994 values are identical.
* Floor area projections from EIA 1994.
* Savings assume that in the absence of codes & standards, energy use intensities would remain at 1994 levels.

Table K. Estimated National Savings from Future Commercial Codes and Standards
High Likelihood Scenario

Existing Buildings:

Year	Saturation Weighted kWh/sq.ft. Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	Sat. Wtd. Gas Space Heat (MBtu/sf)	Total Floor Area (10^6 sf)	Savings from Codes and Stds (GWh)	(million therms)
1994	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1995	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1996	4.72	2.99	1.26	1.33	0.43	10.73	26.22	64,175	734	0
1997	4.72	2.98	1.26	1.33	0.41	10.69	26.22	64,175	2,974	0
1998	4.68	2.97	1.26	1.33	0.38	10.62	26.22	64,175	7,597	0
1999	4.65	2.96	1.25	1.33	0.36	10.55	26.22	64,175	12,122	0
2000	4.61	2.94	1.25	1.33	0.34	10.48	26.22	64,175	16,555	0
2001	4.54	2.93	1.25	1.33	0.33	10.38	26.22	64,175	23,120	0
2002	4.50	2.92	1.25	1.33	0.33	10.33	26.22	64,175	26,286	0
2003	4.47	2.91	1.24	1.33	0.33	10.28	26.22	64,175	29,432	0
2004	4.43	2.90	1.24	1.33	0.33	10.23	26.22	64,175	32,559	0
2005	4.40	2.88	1.24	1.33	0.33	10.18	26.22	64,175	36,236	0
2006	4.33	2.86	1.23	1.33	0.33	10.07	26.22	64,175	42,865	0
2007	4.25	2.83	1.23	1.32	0.33	9.97	26.22	64,175	49,398	0
2008	4.18	2.81	1.22	1.32	0.33	9.87	26.22	64,175	55,837	0
2009	4.11	2.79	1.22	1.32	0.33	9.77	26.22	64,175	62,184	0
2010	4.04	2.77	1.21	1.32	0.33	9.67	26.22	64,175	68,439	0
2011	3.97	2.75	1.20	1.32	0.33	9.58	26.22	64,175	74,605	0
2012	3.90	2.73	1.20	1.32	0.33	9.48	26.22	64,175	80,682	0
2013	3.86	2.71	1.19	1.32	0.33	9.42	26.22	64,175	85,009	0
2014	3.82	2.70	1.19	1.32	0.33	9.36	26.22	64,175	88,453	0
2015	3.78	2.69	1.19	1.32	0.33	9.31	26.22	64,175	91,866	0

New Buildings:

Year	Saturation Weighted kWh/sq.ft. Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	Sat. Wtd. Gas Space Heat (MBtu/sf)	Total Floor Area (10^6 sf)	Savings from Codes and Stds (GWh)	(million therms)
1994	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1995	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1996	4.31	3.08	1.89	1.32	0.37	10.97	20.47	1,400	76	81
1997	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	227	81
1998	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	378	81
1999	3.66	2.77	1.80	1.25	0.31	9.80	19.45	1,400	2,089	95
2000	3.66	2.77	1.80	1.25	0.31	9.80	19.45	1,400	3,801	95
2001	3.65	2.77	1.80	1.25	0.31	9.79	19.45	1,400	5,529	95
2002	3.65	2.77	1.80	1.25	0.31	9.79	19.45	1,400	7,256	95
2003	3.65	2.36	1.71	1.25	0.31	9.28	19.45	1,500	9,859	102
2004	3.65	2.36	1.71	1.25	0.31	9.28	19.45	1,500	12,462	102
2005	3.10	2.00	1.63	1.25	0.31	8.30	18.47	1,500	16,539	116
2006	3.08	2.00	1.63	1.25	0.31	8.27	18.47	1,500	20,657	116
2007	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,500	24,921	116
2008	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	29,468	124
2009	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	34,016	124
2010	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	38,564	124
2011	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	43,112	124
2012	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	47,660	124
2013	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	52,208	124
2014	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	56,756	124
2015	2.98	2.00	1.63	1.25	0.31	8.18	18.47	1,600	61,304	124

Notes:
* See notes on Table J.

Table L. Estimated National Savings from Future Commercial Codes and Standards
Maximum Savings Scenario

Existing Buildings:

	Saturation Weighted kWh/sq.ft.						Sat. Wtd. Gas Space Heat	Total Floor Area	Savings from Codes and Stds	
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	(MBtu/sf)	(10^6 sf)	(GWh)	(million therms)
1994	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1995	4.72	2.99	1.26	1.33	0.44	10.74	26.22	64,175	0	0
1996	4.72	2.99	1.26	1.33	0.42	10.72	26.22	64,175	1,248	0
1997	4.72	2.98	1.26	1.33	0.39	10.68	26.22	64,175	4,012	0
1998	4.68	2.96	1.26	1.33	0.36	10.60	26.22	64,175	9,246	0
1999	4.64	2.95	1.25	1.33	0.34	10.51	26.22	64,175	14,734	0
2000	4.60	2.94	1.25	1.33	0.31	10.43	26.22	64,175	20,072	0
2001	4.41	2.93	1.25	1.33	0.30	10.22	26.22	64,175	33,357	0
2002	4.35	2.89	1.24	1.33	0.30	10.12	26.22	64,175	40,097	0
2003	4.29	2.86	1.23	1.33	0.30	10.01	26.22	64,175	46,752	0
2004	4.22	2.83	1.22	1.33	0.30	9.90	26.22	64,175	53,618	0
2005	4.16	2.79	1.21	1.32	0.30	9.79	26.22	64,175	61,251	0
2006	3.98	2.74	1.20	1.32	0.30	9.55	26.22	64,175	76,156	0
2007	3.90	2.70	1.19	1.32	0.30	9.41	26.22	64,175	85,327	0
2008	3.81	2.65	1.18	1.32	0.30	9.27	26.22	64,175	94,326	0
2009	3.73	2.61	1.17	1.32	0.30	9.13	26.22	64,175	103,156	0
2010	3.65	2.57	1.16	1.32	0.30	9.00	26.22	64,175	111,820	0
2011	3.57	2.52	1.15	1.32	0.30	8.87	26.22	64,175	120,323	0
2012	3.50	2.48	1.14	1.32	0.30	8.74	26.22	64,175	128,666	0
2013	3.45	2.44	1.13	1.31	0.30	8.64	26.22	64,175	135,088	0
2014	3.40	2.41	1.12	1.31	0.30	8.55	26.22	64,175	140,581	0
2015	3.35	2.38	1.11	1.31	0.30	8.46	26.22	64,175	146,007	0

New Buildings:

	Saturation Weighted kWh/sq.ft.						Sat. Wtd. Gas Space Heat	Total Floor Area	Savings from Codes and Stds	
Year	Light	A/C	Elec. Sp.Heat	Vent.	Off.Eq.	Elec. Total	(MBtu/sf)	(10^6 sf)	(GWh)	(million therms)
1994	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1995	4.31	3.08	1.89	1.32	0.42	11.02	20.47	1,400	0	81
1996	4.31	3.08	1.89	1.32	0.37	10.97	20.47	1,400	76	81
1997	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	227	81
1998	4.31	3.08	1.89	1.32	0.31	10.91	20.47	1,400	378	81
1999	3.45	2.62	1.80	1.22	0.31	9.39	17.40	1,400	2,653	123
2000	3.45	2.62	1.80	1.22	0.31	9.39	17.40	1,400	4,928	123
2001	3.42	2.62	1.80	1.22	0.31	9.37	17.40	1,400	7,244	123
2002	3.42	2.46	1.74	1.22	0.31	9.16	17.40	1,400	9,849	123
2003	3.42	2.10	1.57	1.22	0.31	8.62	17.40	1,500	13,457	132
2004	3.36	2.10	1.57	1.22	0.31	8.56	17.40	1,500	17,148	132
2005	2.69	1.78	1.41	1.22	0.31	7.42	14.79	1,500	22,554	171
2006	2.63	1.78	1.41	1.22	0.31	7.36	14.79	1,500	28,047	171
2007	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,500	34,286	171
2008	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	40,941	183
2009	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	47,595	183
2010	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	54,250	183
2011	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	60,905	183
2012	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	67,560	183
2013	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	74,215	183
2014	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	80,869	183
2015	2.14	1.78	1.41	1.22	0.31	6.86	14.79	1,600	87,524	183

Notes:
* See notes on Table J.