Title

Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector

Authors

Koomey, Jonathan G

Mahler, Susan A

Webber, Carrie A

et al.

Publication Date

1998-02-01

LBNL-39511

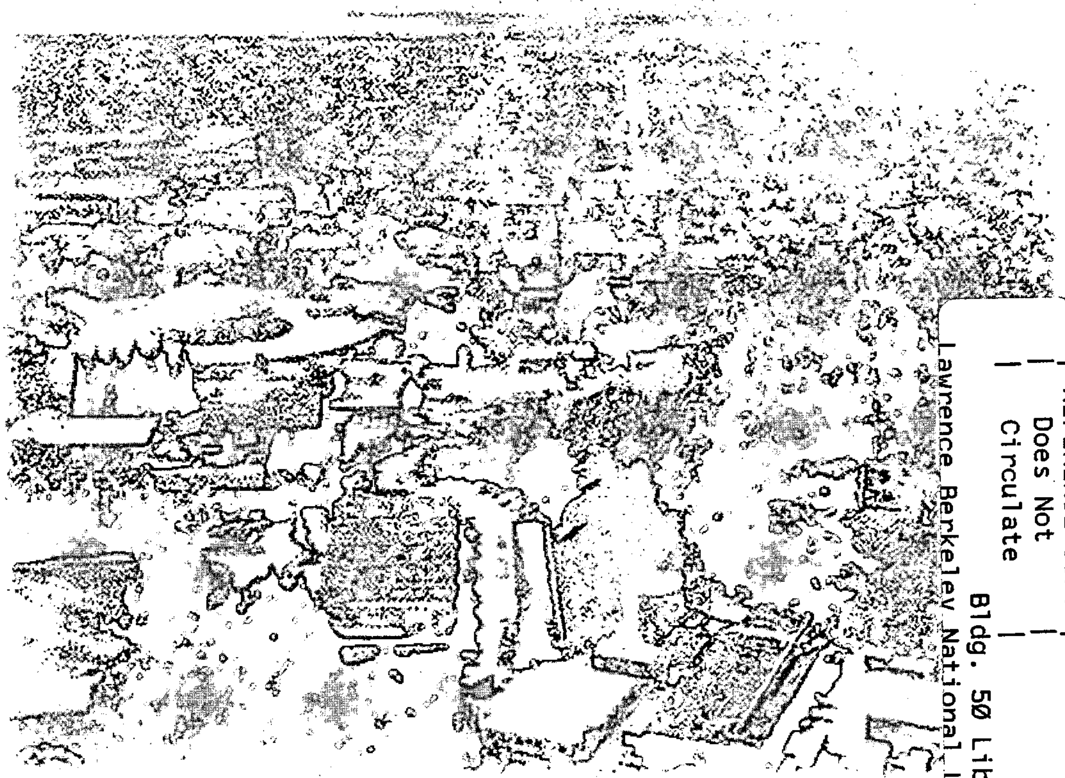
ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector

Jonathan G. Koomey, Susan A. Mahler, Carrie A. Webber, and James E. McMahon

Environmental Energy Technologies Division

February 1998



DISCLAIMER

LBNL-39511
UC-1600

PROJECTED REGIONAL IMPACTS OF APPLIANCE EFFICIENCY STANDARDS FOR THE U.S. RESIDENTIAL SECTOR

Jonathan G. Koomey, Susan A. Mahler, Carrie A. Webber, and James E. McMahon

Energy Analysis Program
Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720, USA

http://enduse.lbl.gov/projects/standards.html

February 1998

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies, State and Community Programs of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

ABSTRACT

Minimum efficiency standards for residential appliances have been implemented in the U.S. for a large number of residential end-uses. This analysis assesses the potential energy, dollar, and carbon impacts of those standards at the state and national levels. In this assessment, we use historical and projected shipments of equipment, a detailed stock accounting model, measured and estimated unit energy savings associated with the standards, estimated incremental capital costs, demographic data, and fuel price data at the finest level of geographic disaggregation available. We explicitly account for improvements in efficiency likely to occur in the absence of standards, but because our method for characterizing these exogenous improvements probably overestimates them, both the energy and cost savings presented in this report represent lower bounds to the true benefits.

Energy savings from the standards are substantial. Total primary energy savings will peak in 2004 at about 0.7 exajoules/year (1 exajoule = 10^{18} joules ≈ 1 quadrillion Btu = 10^{15} Btus). Cumulative primary energy savings during the 1990 to 2010 period total 10.6 exajoules.

Efficiency standards in the residential sector have been a highly cost-effective policy instrument for promoting energy efficiency. Projected cumulative present-valued dollar savings after subtracting out the additional cost of the more efficient equipment are about $33 billion from 1990 to 2010. Even if fuel and electricity prices decline substantially by 2010, as some industry observers predict, the standards remain robustly cost effective, with net savings still totaling $29 billion in this case. Each dollar of federal expenditure on implementing the standards will contribute $165 of net present-valued savings to the US economy over the 1990 to 2010 period. Average benefit/cost ratios for these standards are about 3.5 for the U.S. as a whole.

Projected carbon reductions are approximately 9 million metric tons of carbon/year from 2000 through 2010, an amount roughly equal to 4% of carbon emissions in 1990. Because these standards save energy at a cost less than the price of that energy, the resulting carbon emission reductions are achieved at *negative net cost* to society. Minimum efficiency standards reduce pollution and save money at the same time.

TABLE OF CONTENTS

ABSTRACT I

I. INTRODUCTION 1

II. METHODOLOGY AND DATA 1
- Shipment data and calculations 4
- Number of appliances meeting standards 4
- Initial unit energy consumption and savings 4
- Initial incremental costs 5
- Efficiency trends in the absence of standards 5
- Prices of fuels and electricity 7
- Carbon emissions factors 7
- Other data 7
- Calculation of annual and cumulative energy savings for the US 7
- Distribution of savings to the state level 8
- Net savings calculations 9

III. RESULTS 10
- National energy savings 10
- Time trends in energy savings 12
- Net national economic impact 14
- Economic results by state 17
- Carbon reductions due to standards 20
- Uncertainty in future energy prices 20

IV. DISCUSSION 20
- Engineering costs versus market data 20
- Cost-effectiveness of federal spending on minimum efficiency standards 21
- Comparison to other studies 21
- Policy implications 21

V. FUTURE WORK 22

VI. CONCLUSIONS 22

ACKNOWLEDGMENTS 22

REFERENCES 23

APPENDIX A: NOTES TO TABLE 1 26

APPENDIX B: RETIREMENT FUNCTION 28

APPENDIX C: EXAMPLE CALCULATION–CENTRAL AIR CONDITIONERS 29
- Initial unit energy savings 29
- Retirement and stock 29
- Energy savings 29
- Value of energy savings 30
- New and replacement shipments 30
- Regional disaggregation 30
- Appendix C notes 30

APPENDIX D: INPUT TABLES 31

APPENDIX E: RESULTS TABLES 42

LIST OF TABLES

Table 1a: Minimum efficiency standards included in this analysis 2

Table 1b: Minimum efficiency standards not included in this analysis....................... 2

Table 2: Inputs to the analysis.. 3

Table 3: Summary of effects of residential efficiency standards in 2010 11

Table C-1: Central Air Conditioner Data for Year 2000 Calculations 29

Table D-1: Historical and projected equipment shipments (millions of units per year)... 32

Table D-2: Scaling factors that account for baseline efficiency trends...................... 33

Table D-3: State population projections.. 34

Table D-4: State energy prices in 1995.. 35

Table D-5: State heating and cooling load hours... 36

Table D-6: Carbon emissions factors by region... 37

Table D-7: Saturations of existing equipment by Census division......................... 38

Table D-8: Saturations of new equipment by Census division............................. 39

Table D-9: Fed. government expenditures to implement appliance efficiency standards. 40

Table D-10: First page of county data on number of households and housing starts..... 41

Table E-1: Summary of national effects of residential efficiency standards in 1995...... 43

Table E-2: Summary of national effects of residential efficiency standards in 2000...... 44

Table E-3: Summary of national effects of residential efficiency standards in 2010...... 45

Table E-4: Summary of state-level effects of residential efficiency standards in 1995... 46

Table E-5: Summary of state-level effects of residential efficiency standards in 2000... 47

Table E-6: Summary of state-level effects of residential efficiency standards in 2010... 48

LIST OF FIGURES

Figure 1: Unit energy consumption for refrigerators–baseline and standards.............6

Figure 2: Primary energy savings from residential appliance efficiency standards.......13

Figure 3: Net annual dollar savings and annualized incremental costs......................15

Figure 4: Net annual dollar savings and incremental costs (not annualized)..............15

Figure 5: Baseline residential energy bills and bill savings from standards...............16

Figure 6: Annual bill savings by state in 2010..18

Figure 7: Bill savings per household by state in 2010.......................................19

Figure B-1: Appliance survival curve used in this analysis.................................28

I. INTRODUCTION

There has been an ongoing debate in the economics and policy analysis communities over whether carbon emissions can be reduced at zero or negative net costs. On the one side, arguing that carbon emissions reductions must always cost something, are economists convinced that the economy is currently at a more or less optimal equilibrium, and that any deviations must introduce inefficiency and hence societal costs. On the other side, arguing that there are many cost effective technologies and policies to reduce energy use and hence carbon emissions, are technologists, students of end-use markets, and some economists (Krause et al. 1993).

These two contrasting views collide most forcefully in the context of the minimum efficiency standards enacted by the National Appliance Energy Conservation Act of 1987 (NAECA). The first nation-wide U.S. appliance standards went into force in 1988. Since then, national standards have been put into place for several more appliances both through updates to NAECA and through the Energy Policy Act of 1992 (EPAct 1992). Most standard levels were determined by a consensus among manufacturers and environmental advocates. Until 1994, these regulations had broad political support, but some proposed changes to the standards have led to public criticism of the regulations and the process by which they are developed. Some have even called for the abolition of the enabling legislation related to the standards (Thorpe 1995).

This analysis assesses in a comprehensive, transparent, and well-documented fashion, the energy, environmental, and economic effects of current minimum efficiency standards for residential appliances. We calculate energy savings, bill savings, net dollar savings, and carbon emissions reductions at the national and state levels.

The results of these calculations give insights into the debate over the costs of reducing carbon emissions. If the appliance standards save money for society and reduce pollution at the same time, they result in carbon emissions reductions at negative net cost. If the standards impose costs on society that exceed the benefits, the cost of reducing carbon emissions using this policy mechanism is greater than zero, lending credence to the economists' claims.

This report first discusses the methodology and data used in the analysis and summarizes results. It then discusses the key issues raised by the results and proposes future work for improving the analysis.

II. METHODOLOGY AND DATA

Table 1a shows the standards being analyzed, the year each standard was enacted, and the fuel types affected by each standard. **Table 1b** shows the standards that are not analyzed here, which consist primarily of those in the Energy Policy Act of 1992 (EPACT) that affected commercial and industrial sector equipment. Building standards are also not analyzed in this report.

Table 2 shows the primary data inputs. For the purpose of this analysis, it was necessary to divide the standards by fuel type. This means that a single standard may be treated as several different products in our analysis. For example, water heating end-uses, such as clothes washers, dishwashers, showers, and faucets, were divided between the fuel types according to the type of water heater used in the home. Since dishwashers affected by the standards achieve some electricity savings from motor improvements, it was necessary to treat those savings separately from water heating savings. Thus, dishwasher motors appear as a separate product. The 30 "products" shown actually represent only 19 standards.

Table 1a: Minimum efficiency standards included in this analysis

End-use	*Technology type*	*Date* of Standard*	*Fuel types affected Electricity*	*Natural Gas*	*Distillate Oil*	*Comments*
Central heat		1992	HP	Furnace	Furnace	
Room heat		1990		X	X	
Air conditioning	Room	1990	X			
	Central	1992	X			
	HP	1992	X			
Water heat	Water heater	1990	X	X	X	
	Showers	1994	X	X	X	
	Faucets	1994	X	X	X	
Refrigerators		1990	X			
Freezers		1990	X			
Refrigerators		1993	X			
Freezers		1993	X			
Ranges and ovens		1990	X			
Dryer		1988		X		No pilot lights for gas dryers
Dishwasher		1988	X	X	X	Must allow drying without heat
Clothes washer		1988	X	X	X	Must have cold rinse cycle
Dryer		1994	X	X		May 14
Dishwasher		1994	X	X	X	May 14
Clothes washer		1994	X	X	X	May 14
Pool heater		1990				

Table 1b: Minimum efficiency standards not included in this analysis

End-use	*Sector*	*Date* of Standard*	*Fuel types affected Electricity*	*Natural Gas*	*Distillate Oil*	*Comments*
Refrigerators & freezers	Residential	2001	X			July 1
Room air conditioners	Residential	2000	X			October 1
Fluorescent lamps	All	1994+	X			
Fluorescent lamp ballasts	All	1990	X			
HID lamps	Indust./comml	1994+	X			
Incandescent reflectors	All	1994+	X			
Motors	All	1994	X			
Distribution transformers	Electricity	1994	X			
Packaged AC & htg	Commercial	1994	X	X	X	
Packaged terminal AC & HP	Commercial	1994	X	X	X	
Warm air furnaces	Commercial	1994		X	X	
Packaged boilers	Commercial	1994		X	X	
Storage water heaters	Commercial	1994	X	X	X	
Instantaneous water heaters	Commercial	1994	X	X	X	
Toilets	All	1994				Affects water use only

*All standards enter into effect on January 1st of the year indicated, unless otherwise noted.

We estimated unit energy savings for each of the standards after reviewing a variety of sources (see Appendix A). These savings per appliance or per household were multiplied by the number of appliances in the U.S. that were affected by the standards existing in any year. The annual energy savings is a function of business-as-usual efficiency trends, historical and projected equipment shipments, and the retirement rate for each appliance. These annual savings are then distributed to the state level based on regional equipment saturations, state level housing starts or stocks, and climatic variations (for heating and cooling equipment). A more detailed description of the methodology follows below, and a specific example (Central Air Conditioners) is contained in Appendix C.

Table 2: Inputs to the analysis

End-Uses	Year Standard Enacted	Life	Life Notes	Baseline Energy Consumption	Standards Energy Consumption	Initial UES	UES Notes	Initial Incremental cost / unit	Cost Notes	CCE In Base Year
Electric		years		kWh/yr	kWh/yr	kWh/yr		1995$/unit		$/kWh
HP	1992	14	1	5912	5669	243	5	90.34	5	0.0425
RAC	1990	15	1	763	666	96.4	7	8.11	17	0.0092
CAC	1992	12	1	1962	1857	105	5	50.96	5	0.0611
Refrigerator	1990	19	1	978	903	75	8	27.68	18	0.0357
Freezer	1990	21	1	687	621	66	8	15.93	19	0.0223
Refrigerator	1993	19	1	893	690	203	6	86.35	6	0.0412
Freezer	1993	21	1	568	468	100	6	58.45	6	0.0539
Clothes Dryer	1994	17	1	880	807	73	6	37.02	6	0.0519
Dishwasher (WH)	1994	13	1	537	429	108	9	22.69	20	0.0251
Clothes Washer	1994	14	1	767	521	246	9	2.32	15	0.0011
Water Heater	1990	13	1	5035	4773	262	10	33.47	21	0.0153
Showers	1994	20	2	1849	1360	489	9	49.11	15	0.0095
Faucets	1994	20	2	299	220	79	9	12.28	15	0.0147
Dishwasher Motors	1994	13	1	167	133	34	6	10.00	20	0.0352
Natural Gas		years		MMBtu/yr	MMBtu/yr	MMBtu/yr		1995$/unit		$/MMBtu
Central Heat	1992	19	3	61.00	59.45	1.55	11	28.96	11	1.81
Room heat	1990	15	3	38.50	36.35	2.15	13	1.16	17	0.06
Range	1990	19	4	3.40	1.30	2.1	14	55.60	14	2.56
Oven	1990	19	4	3.00	1.40	1.6	14	54.44	14	3.29
Clothes Dryer	1994	17	1	3.70	3.19	0.51	12	31.27	12	6.28
Dishwasher (WH)	1994	13	1	2.40	1.92	0.48	9	22.69	20	5.66
Clothes Washer	1994	14	1	3.40	2.32	1.08	9	2.32	15	0.25
Water Heater	1990	13	1	36.16	31.73	4.43	10	41.25	22	1.11
Showers	1994	20	2	8.13	5.98	2.15	9	49.11	15	2.16
Faucets	1994	20	2	1.32	0.97	0.35	9	12.28	15	3.33
Oil		years		MMBtu/yr	MMBtu/yr	MMBtu/yr		1995$/unit		$/MMBtu
Central Heat	1992	20	3	67.84	66.97	0.87	16	34.51	23	3.74
Dishwasher (WH)	1994	13	1	2.40	1.92	0.48	9	22.69	20	5.66
Clothes Washer	1994	14	1	3.40	2.32	1.08	9	2.32	15	0.25
Water Heater	1990	13	1	36.16	31.73	4.43	10	41.25	24	1.11
Showers	1994	20	2	8.13	5.98	2.15	9	49.11	15	2.16
Faucets	1994	20	2	1.32	0.97	0.35	9	12.28	15	3.33

UES = Unit Energy Savings; CCE = Cost of Conserved Energy, calculated using the lifetimes in Column 3 and a real discount rate of 7%.

Other notes to Table 2 are contained in Appendix A.

Shipment data and calculations

Shipment data for 1990 through 1994 are from Appliance Manufacturer Magazine (1995) (except for faucets, showers, and oil water heaters for which published shipment data were not available). All shipment data (1990-2010) for oil water heaters are from the LBNL Residential Energy Model (LBNL REM 1995). Shipments for faucets and showers are based on new housing starts and retrofits, assuming a 20 year lifetime for these fixtures (Koomey et al. 1994).

Shipments for 1995 through 2010 are estimated by applying forecasted average annual shipment growth rates projected by LBNL REM (1995) to the 1994 shipment data. The breakdown of shipments to new and existing households is estimated using LBNL REM (1995). Historical and projected shipments for all end-uses are shown in *Table D-1* in Appendix D.

Number of appliances meeting standards

The savings from appliance standards accrue gradually due to the large stock of appliances and their long lifetimes (ranging from 13 to 21 years for the appliances analyzed). In a particular year, energy savings accrue on all high efficiency units in houses in that year, including both new units and the accumulated stock of units meeting standards. As described above, we used historical appliance shipments and shipment forecasts to estimate the growing stock of appliances affected by standards. The stock of appliances meeting standards in a given year is the total accumulated shipments of post-standards appliances, less the number of those appliances expected to be already retired from use by that year.

A retirement function is used to estimate the retirement rate of appliances. In this linear function no appliances retire in the first 2/3 of their average life, and all units are retired by 4/3 of their average life. This retirement function is an approximation taken from work by McMahon, and it is described in Appendix B and shown in *Figure B-1*. This function is applied to the projected shipments to determine the number of devices purchased in a given year still existing in 1995, 2000, or 2010. Those devices still existing in a given year that were affected by efficiency standards are termed the "Applicable Stock".

Initial unit energy consumption and savings

The initial unit energy savings (UES) is the difference between the annual unit energy consumption (UEC) of a unit meeting the standards and the UEC of the average unit that would have been shipped in the absence of standards. The UECs used in the analysis are shipment-weighted average energy consumption for new units purchased in the first year of the standard. Actual energy use for a particular appliance will depend on the capacity of the appliance and the usage pattern. Baseline UECs were collected from a variety of sources for the appliances analyzed. UECs of appliances meeting standards were calculated from the efficiency level required by the standards, using the same capacity and usage data as the baseline. The Unit Energy Savings (UES) for faucets and showers is per household, while for all other appliances the UES is per unit.

The initial UESs were adjusted downward in years after the standard is implemented using the efficiency trends scaling factors discussed below. These factors account for the natural progress in efficiency expected in the baseline case.

We separated the energy savings from efficiency standards on dishwashers into motor savings and hot water savings. Current standards on clothes washers only affect hot water use, so no motor savings are specified for this end-use. We estimated the fuel breakdown of hot water supplied to dishwashers and clothes washers by using water heater saturation data from EIA (US DOE 1995a), and split the expected hot water savings into electricity, gas, and oil based on the saturations of each of the water heating fuels.

Initial incremental costs

Initial incremental costs were collected from a variety of sources. These are the estimated difference in the purchase price between a unit just meeting standards and the average unit sold before standards went into effect. For some appliances there was considerable variance between costs collected from different sources. In such cases, information about engineering costs provided the basis for our estimate. Incremental costs affect the calculation of net benefits and cash flows.

The initial incremental costs were adjusted downward in years after the standard is implemented using the efficiency trends scaling factors discussed below.

Efficiency trends in the absence of standards

Even in the absence of standards, the energy efficiency of appliances tends to improve gradually over time due to technological advances. For some products, this natural rate of technological improvement would have eventually reduced unit energy consumption to the level imposed by standards. The unit energy savings will be lower for units purchased in the future than for units purchased today, because the baseline for future units is lower. We approximated this effect by comparing historical annual trends in energy efficiency (%/year) to the percent efficiency improvement due to each standard in the first year that it was effective (%), then dividing one by the other to calculate the number of years it would take for the baseline to overtake the improvement due to the standard. These trends are shown by end-use in Appendix D, *Table D-2.*

Based on these calculations, we created Scaling Factors that would linearly scale down the unit energy savings and incremental cost to zero over the effective lifetime of the standard.[1] **Figure 1** shows the baseline UEC and standards levels over time for the 1990 and 1993 refrigerator standards. *Table D-2* in Appendix D shows the Scaling factors for all the end-uses in every year.

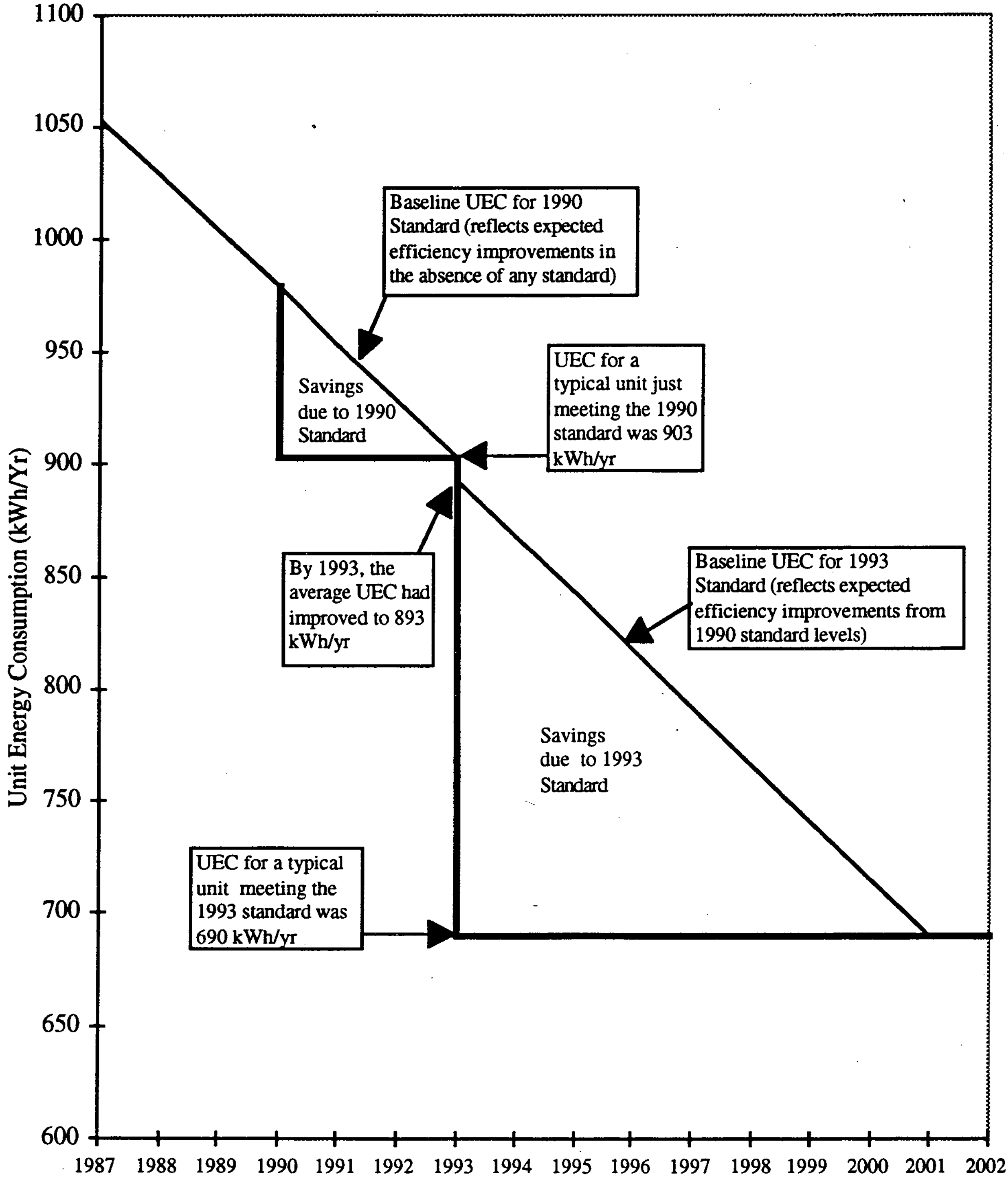
These scaling factors are a crude characterization of a complex process. The historical data upon which we relied to derive the annual rates of improvements in efficiency are based on years in the mid-1980s that are not entirely free of confounding factors. In particular, the imposition of state efficiency standards for certain end uses, as well as the prospect of federal standards that seemed likely to be enacted as early as 1986, may have influenced the more forward-looking manufacturers to accelerate adoption of efficiency technologies beyond those that would have been adopted in the absence of standards. State standards were implemented in California in the 1970s and early 1980s, and in Florida, Kansas, New York, and Massachusetts in the early to mid-1980s (Nadel and Pye 1996). Utility efficiency programs may also have influenced these trends for certain end uses.

State standards and utility programs both affected the historical efficiency data in ways that would likely lead to overestimates of the efficiency improvements to be expected from market forces in the absence of standards. We believe therefore that our method of incorporating these factors make our estimates of total energy and net dollar savings *lower bounds* instead of *best estimates.*

---

[1]Incremental costs are also affected by these efficiency trends because if the baseline unit is more efficient than the standard, the cost of achieving the standard level compared to the baseline is zero.

Figure 1: Unit energy consumption for refrigerators–baseline and standards



Prices of fuels and electricity

The value of regional energy savings is calculated using energy price data at the state level. National fuel price data are for 1995 from the Energy Information Administration's (EIA) 1996 Annual Energy Outlook (AEO) (US DOE 1996a). National fuel prices are converted to state fuel prices assuming the same relationships between state and national fuel prices as existed in 1993, taken from US DOE (1995b). Fuel prices are assumed for simplicity to remain constant over the analysis period. Electricity and natural gas prices are expected to remain flat through 2015 (0% annual increase for electricity, and 0.1% natural gas), while oil prices are expected to rise (1.2% annually). We decided that the virtue of simplicity in the calculations outweighed the slight disadvantage of underestimating the net benefits of standards on oil-fired equipment (which is only a small fraction of the total, in any case). See Appendix D, *Table D-4* for the fuel prices used in this analysis. We also create a sensitivity case with declining fuel prices that is described below.

Carbon emissions factors

Natural gas and distillate oil carbon emissions factors, which do not vary regionally or over time, are taken from US DOE (1996d). *National* carbon emissions factors for electricity are taken from Koomey et al. (1993) in 1990 and from AEO 96 for 1995 to 2010 (US DOE 1996a). We estimate *regional* electricity emissions factors for Census Divisions in 1995 from the Electric Power Annual (US DOE 1996b, US DOE 1996c),[2] and we use the relationship between regional and national electricity carbon emissions factors from this source to estimate regional emissions in future years. Our approach assumes that the relationship between regional and national emissions remains constant over time. See Appendix D, *Table D-6* for the national and regional emissions factors.

We assume that the average electricity emissions factor calculated as described in the previous paragraph is an accurate representation of the carbon emissions that would be avoided if electricity demand is reduced by the standards. If the power plants avoided by standards are different than the average plants, then the carbon savings will be different than calculated here. There is currently no simple way to assess marginal carbon emissions factors for electricity, so for simplicity we use the average emissions factors to calculate carbon savings.

We include only direct emissions from the combustion of fuels. Emissions associated with the extraction, processing, and transportation of fuels are not included.

Other data

Additional data used for the disaggregate analysis were demographic data, housing stocks, new housing permits, appliance saturations, and heating and cooling load hours (US DOE 1983), all at the finest level of geographic resolution available (usually Census Divisions or states, sometimes counties). These data are presented in summary form in Appendix D.

Calculation of annual and cumulative energy savings for the US

The initial unit energy savings associated with each standard is multiplied by the scaling factor in any year to determine the unit energy savings for equipment purchased in that year. This unit energy savings is then multiplied by the number of devices purchased in that year that are still existing in either 1995, 2000, or 2010 to calculate the annual energy savings associated with that

---

[2]We split the Mountain and Pacific Census divisions into North and South because they cover a large geographic area with wide variation in generation technologies.

cohort of equipment in those years. Since the equipment existing in 2000 (for example) consists of devices purchased in multiple years before 2000, the preceding calculation is repeated for all devices purchased before 2000 that are still existing in 2000, and the results are summed across all devices existing in 2000. Equation 1 summarizes this calculation.

$$S_i^{G,A} = \sum_{i=s}^{T} \text{Applicable stock}_i^{G,A} \text{x} \, UES_0^{G,A} \, \text{x} \, SF_i^A \quad (1)$$

Where:

$S_i^{G,A}$ =	energy savings in year i for appliance A in region G;
T =	target year (e.g., 1995, 2000, 2010);
i =	years up to and including T;
s =	start date for standard;
G =	disaggregate geographic level (county, state, census division);
A =	appliance/end-use type;
Applicable $\text{stock}_i^{G,A}$ =	shipments minus retirements for appliance A in year i at geographic level G;
$UES_0^{G,A}$ =	initial unit energy savings for appliance A (regional variations only captured for heating and cooling end-uses); and
SF_i^A =	scaling factor in year i for appliance A.

Distribution of savings to the state level

Estimation of the geographic distribution of national appliance shipment data is based on the finest geographic disaggregation available. Residential Energy Consumption Survey (RECS) appliance saturations are used for the 9 Census divisions (US DOE 1995a) combined with new housing permit and total household data from the 1994 Census at the county level (US Bureau of the Census 1994). A ratio of RECS saturation data at the 9 Census divisions and the national level is used to estimate appliance stock in a geographic area. For county and state level calculations, the county or state is assumed to have the same saturation as the Census division in which it falls. National level shipments are divided to the county level by weighting the total shipments with the fraction of households and new housing permits within a county. Equation 2 is used to distribute applicable stock to counties and states.

$$\text{Applicable stock}_i^{G,A} = \text{Applicable stock}_i^{N,A} \left[F_i^{\text{Replacement}} \left(\frac{Sat_{\text{exist}}^G}{Sat_{\text{exist}}^N} \right) \left(\frac{HH^G}{HH^N} \right) + F_i^{\text{New}} \left(\frac{Sat_{\text{new}}^G}{Sat_{\text{new}}^N} \right) \left(\frac{NHP^G}{NHP^N} \right) \right] \quad (2)$$

where

Applicable $\text{stock}_i^{G,A}$ =	shipments minus retirements for appliance A in year i at geographic level G;
G =	disaggregate geographic level (county, state, census division);
A =	appliance/end-use type;
i =	year i;
N =	national level;
F =	fraction of appliances that are replacement or new (at the national level from LBNL REM);
Sat =	saturation of appliances (from the 1993 RECS at the census division and national level). Replacement saturations are those in homes built before 1987 and new saturations are those in homes built after 1986;
HH =	households (from the 1994 Census at the county and national level); and
NHP =	new housing permits (from the 1994 Census at the county and national level).

In the case of faucets and showers the saturation is not applied, since the estimated energy savings and costs for these end-uses are per average household.

Energy savings for space heating and cooling appliances are also adjusted by using the ratio of regional heating and cooling load hours (HLH, CLH) to the national averages (US DOE 1983). State level values for HLH and CLH are used to adjust the UES calculations, as shown in Equations 3a and 3b. Heat pump heating and water heating regional energy consumption variations have not been captured in this analysis.

$$UES_0^{G,A} = UES_0^{N,A}\left(\frac{CLH^G}{CLH^N}\right) \text{ for cooling equipment} \qquad (3a)$$

$$UES_0^{G,A} = UES_0^{N,A}\left(\frac{HLH^G}{HLH^N}\right) \text{ for heating equipment} \qquad (3b)$$

Net savings calculations

We used two methods to estimate economic impacts: annualized costs and cash flow. In the first method, we spread the incremental cost over the lifetime of the appliance so that the pattern of expenditures matches the flow of bill savings. It is as if the appliance is purchased using a loan, with loan payments being spread over the lifetime of the appliance. Each month, the purchaser of the appliance makes a payment, but receives savings on her energy bill. This method smoothes net savings over time.

Incremental costs of the appliances are annualized in 1995 dollars with a real discount rate of 7 percent. The annualized net dollar savings in year i ($ANS_i^{G,A}$), which is the main economic indicator used in this analysis, is calculated using Equation 4:

$$ANS_i^{G,A} = S_i^{G,A} \text{ x } P_f^G - \sum_{i=s}^{T} \text{Applicable stock}_i^{G,A} \text{ x CRF x } SF_i^A \text{ x } IIC^A \qquad (4)$$

where

$S_i^{G,A}$ = energy savings in year i for appliance A in region G;

P_f^G = price of fuel f (electricity, natural gas, or oil) in region G;

CRF = the capital recovery factor, calculated as shown in Appendix A;

IIC^A = initial incremental cost for the more efficient equipment($/unit);

and the other parameters are as described above.

Our method assumes, for simplicity that the average price of fuels or electricity is an accurate reflection of their true cost to society. We do not attempt to assess the marginal cost of electricity, because there is no widely accepted method to calculate marginal costs on a regional basis across the U.S.

The second method looks at the cash flow over the lifetime of the investment, assuming that the appliance is paid for in full when it is installed. Purchasers incur the incremental cost when the appliance is purchased, but the benefits of higher energy efficiency are spread over the lifetime of the appliance. This means that the year an appliance is purchased, costs generally exceed energy bill savings (i.e., the net benefit is negative in the first year), but in subsequent years the net benefit jumps up since no additional costs are incurred after the year of equipment installation.

To calculate net savings in year i ($NS_i^{G,A}$) in terms of actual cash flows, we used Equation 5:

$$NS_i^{G,A} = S_i^{G,A} \times P_f^G - Shipments_i^{G,A} \times SF_i^A \times IIC^A \quad (5)$$

where

$Shipments_i^{G,A}$ = shipments for appliance A in year i at geographic level G, and the other parameters are as described above.

Equation 4 calculates the costs spread over time as if they are paid as the savings accrue (i.e., the annualized costs approach), while Equation 5 calculates the costs (cash flows) as they are incurred by society.

Whenever we express cumulative dollar values, we calculate present-values to 1995 using a 7% real discount rate. For example, the cumulative present value of annualized net savings is calculated using Equation 6:

$$PV(ANS_i) = \sum_{i=1990}^{2010} \frac{ANS_i}{(1+d)^{(i-1995)}} \quad (6)$$

where d is the discount rate (7% real), and ANS_i is as defined above.

III. RESULTS

National energy savings

As summarized in **Table 3** and shown in *Tables E.1-E.6* in Appendix E, standards for the appliances analyzed are expected to save a total of 10.6 exajoules (10 quads) of primary energy between 1990 and 2010.[3] About 57% of this savings is electricity, 41.4% natural gas, and only 1.5% distillate oil. Annual energy savings will increase as energy efficient appliances replace the existing stock, peaking in 2004 at 0.69 EJ (0.65 quads). These savings represent more than 3% of the projected residential energy consumption in 2004.[4]

The largest cumulative savings for the analysis period come from the standard on showerheads, which saves roughly 2.2 EJ (2.1 quads) of electric, gas, and oil water heating energy from 1994 to 2010. Following close behind is the gas water heater standard, which saves a total of 2 EJ (1.9 quads) through 2010. The 1993 refrigerator standard saves 1.35 EJ (1.28 quads) of primary energy during the period, while the other standards individually each save less than 1 EJ.

Electrical appliances accounted for 56% of total annual primary energy savings in 1995, and are projected to grow to 60% of annual energy savings by 2010. Savings due to refrigerator and water heater standards dominate early in the analysis period, but savings from low-flow shower fixtures grow rapidly, and by 2004 represent the largest savings in the electrical appliance category. The largest cumulative savings in electric appliances during the analysis period are due to the

---

[3]Electricity is converted from site to primary energy using a factor of 3.165 kWh primary per 1 kWh site electricity, which corresponds to 10,800 Btu/kWh. 1 exajoule = 10^{18} joules. 1 quad = quadrillion Btus = 10^{15} Btus. 1 Btu = 1055.1 Joules.

[4] The Annual Energy Outlook (1996) forecast for total residential energy consumption is 20.6 EJ (19.54 quads) in 2004.

Table 3: Summary of national effects of residential efficiency standards in 2010

End-use	Fuel	Annual in 2010: Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr	Cumulative 1990-2010: Primary Energy Savings Petajoules	Carbon Savings MT-C	Bill Savings M 1995 $	Incremental Costs M 1995 $	Net PV Benefit M 1995 $
CAC	Electricity	0	0.00	0	0	0	112	1.70	536	379	157
Clothes Washer	Electricity	52	0.75	390	5	385	721	10.37	3239	40	3198
Clothes Dryer	Electricity	51	0.74	397	235	163	500	7.19	2148	1291	857
Dishwasher	Electricity	25	0.35	186	55	131	283	4.00	1238	360	878
Dishwasher Motors	Electricity	20	0.28	150	62	88	228	3.22	998	407	592
Freezer 1990	Electricity	1	0.02	9	2	7	39	0.58	213	55	158
Freezer 1993	Electricity	6	0.08	42	26	16	106	1.57	541	338	203
Faucets	Electricity	19	0.27	153	25	128	207	2.85	894	152	743
HP	Electricity	0	0.00	1	0	0	46	0.67	262	129	133
Refrigerator 1990	Electricity	5	0.07	39	15	24	220	3.01	1228	507	720
Refrigerator 1993	Electricity	69	0.94	542	247	295	1348	18.57	6780	3229	3551
RAC	Electricity	1	0.02	12	1	10	214	3.12	1147	123	1024
Showers	Electricity	120	1.65	943	99	843	1278	17.62	5529	606	4922
Water Heater	Electricity	6	0.08	43	8	36	724	10.32	4186	740	3446
Central Heat	Natural gas	5	0.07	28	8	19	132	1.81	532	158	374
Clothes Washer	Natural gas	31	0.42	181	7	174	427	5.85	1459	59	1400
Clothes Dryer	Natural gas	10	0.14	59	60	-1	100	1.38	330	340	-10
Dishwasher	Natural gas	15	0.20	86	79	7	169	2.32	564	524	40
Faucets	Natural gas	12	0.16	73	38	35	128	1.76	415	227	188
Oven	Natural gas	18	0.25	111	57	54	237	3.25	840	454	386
Room heat	Natural gas	0	0.00	0	0	0	19	0.25	92	1	91
Range	Natural gas	27	0.37	163	65	98	350	4.80	1243	523	720
Showers	Natural gas	74	1.02	451	151	299	792	10.86	2566	908	1658
Water Heater	Natural gas	42	0.58	250	45	205	2014	27.62	8268	1512	6756
Central Heat	Distillate oil	0	0.00	0	0	0	0	0.00	0	0	0
Clothes Washer	Distillate oil	2	0.04	15	0	15	31	0.59	123	4	118
Dishwasher	Distillate oil	1	0.02	7	6	2	12	0.23	47	38	9
Faucets	Distillate oil	1	0.02	7	4	4	12	0.23	45	21	23
Showers	Distillate oil	7	0.13	45	14	31	75	1.42	276	85	191
Water Heater	Distillate oil	1	0.01	4	1	3	25	0.47	117	19	99
Total	Electricity	374	5.24	2906	780	2125	6,026	84.8	28938	8355	20583
Total	Natural gas	234	3.21	1402	511	891	4,368	59.9	16309	4705	11603
Total	Distillate oil	12	0.23	79	25	54	156	3.0	609	168	441
Total	All	620	8.68	4387	1316	3071	10,550	147.7	45856	13229	32627

(1) 1 Petajoule = 10e15 joules.

(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).

(3) Cumulative carbon emissions calculated using electricity emissions factor for 2010. The error introduced is small because emissions factors change little over the analysis period.

(4) Incremental costs based on annualized method. Cumulative costs and benefits present valued to 1995 at a 7% real discount rate.

refrigerator standards, but as with gas appliances, shower fixtures have the greatest savings potential beyond 2010.

Gas appliances account for 43% of annual primary energy savings in 1995, declining to 38% by 2010. In the beginning of the period, the largest savings among gas appliances come from the water heater standard. Gas water heating savings decline sharply, however, from about 0.15 EJ in 2000 to only 0.042 EJ in 2010. In contrast, savings due to the shower standard continue to grow through 2010, overtaking water heating savings in 2008 and growing to 32% of annual gas appliance savings by 2010. The cumulative savings for gas water heaters are higher for the analysis period, but by 2010, most of their savings potential has already been realized. The energy savings from shower fixtures will continue to grow beyond 2010.

Oil accounts for only a small part of total savings from appliance standards due to the fuel's small market share. The share of total savings due to oil-fired appliances grows from less than 1% in 1995 to just under 2% in 2010. Oil is the only fuel for which total savings continue to grow throughout the analysis period. The growth in savings from shower, faucet and dishwasher standards through 2010 swamps the declines in savings from the other appliances. Shower fixtures save the largest amount of energy among oil-fired appliances.

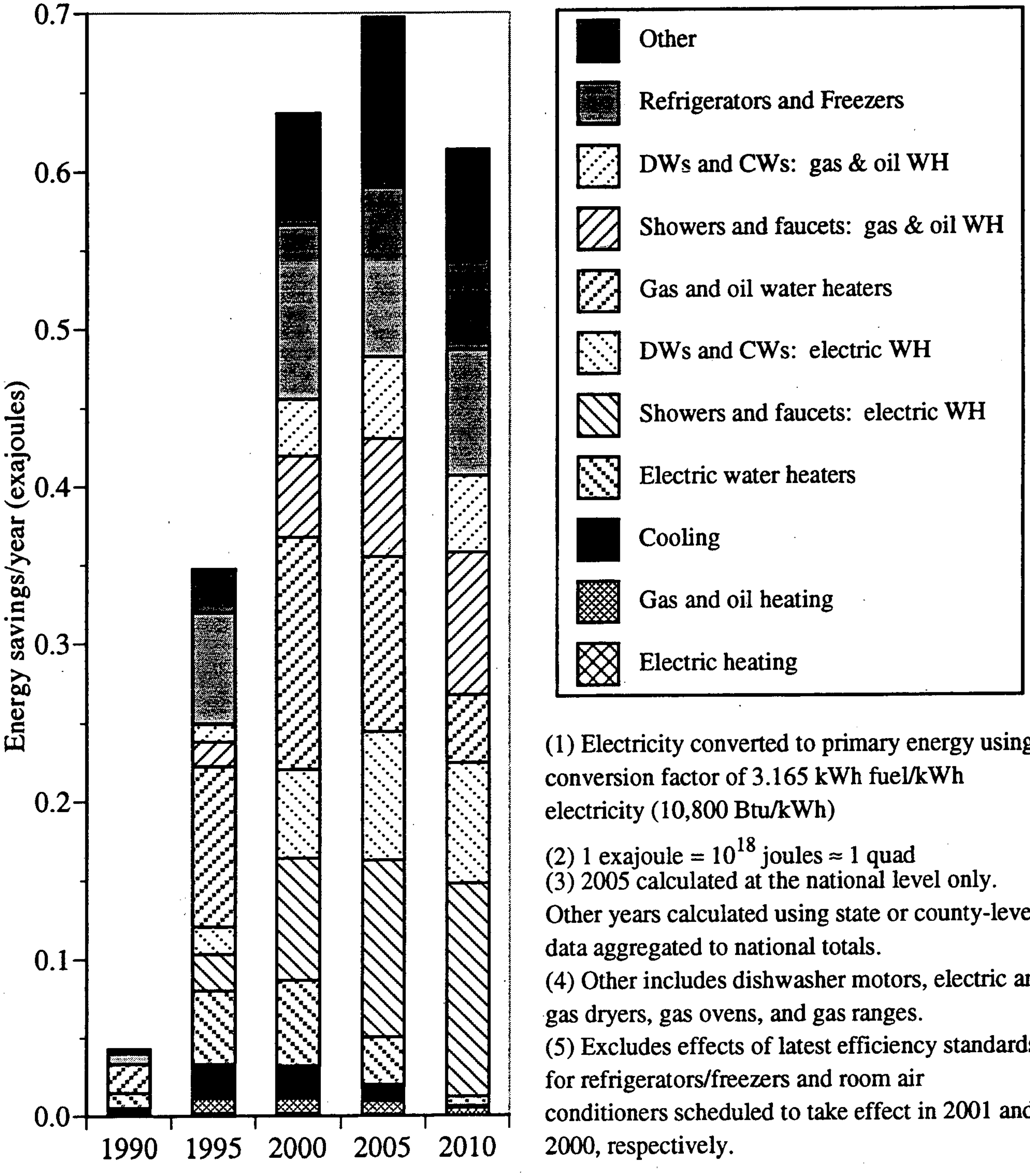
Time trends in energy savings

Annual savings from appliance standards increase sharply in the beginning of the analysis period. Each year, old, inefficient (pre-standards) appliances are replaced by new units meeting standards. Savings continue to accrue on these high efficiency units for as long as they remain in place. Over time, the projected technological improvement in the baseline begins to catch up to standards. Since the savings on each unit are calculated relative to the baseline unit in the year the unit was purchased, the savings on new units is lower in later years (since the baseline energy consumption has declined). Early in the period savings grow as the stock of high efficiency appliances increases, but they grow at a declining rate because the savings on the units purchased later have smaller energy savings. By 1999, appliances purchased after standards came into force are beginning to be retired and replaced. Although both the new unit and the unit being retired have the same unit energy consumption (they both meet standards) the new unit has lower savings because it is compared to a more efficient baseline.

Annual savings continue to increase through 2004, but in the absence of any new standards eventually the retirement effect begins to dominate and savings start to decline. By that time, the growth in the stock of appliances meeting standards has slowed considerably since most of the inefficient pre-standards appliances have already been replaced. Even more importantly, the energy savings for many appliances have been completely overtaken by baseline improvements.

This interaction between retirement patterns and natural rates of technological progress shapes the time trend of energy savings for different appliances. **Figure 2** shows that savings due to showers and faucets continue to grow through 2010. This result is primarily due to their long lifetimes (20 years), the large decrease in unit energy consumption due to the 1994 standards, and very slow progress in the baseline efficiency. Dishwasher water heating, dishwasher motor, clothes dryer, gas range and gas oven savings (the last four comprising much of the "Other" category in this Figure) also continue to increase throughout the period. The energy savings per unit for ranges and ovens are high, but the most important factor in the continued growth of savings is the persistence of those savings. The energy savings on each of these products persists through 2010, due primarily to slow improvements in the baseline efficiency. In contrast, energy savings due to heating and air-conditioning appliances are generally overtaken by baseline improvements early (by 1996). The savings due to standards for these end-uses begin to decline in 2000.

Figure 2: Primary energy savings from residential appliance efficiency standards



(1) Electricity converted to primary energy using a conversion factor of 3.165 kWh fuel/kWh electricity (10,800 Btu/kWh)

(2) 1 exajoule = 10^{18} joules ≈ 1 quad
(3) 2005 calculated at the national level only. Other years calculated using state or county-level data aggregated to national totals.
(4) Other includes dishwasher motors, electric and gas dryers, gas ovens, and gas ranges.
(5) Excludes effects of latest efficiency standards for refrigerators/freezers and room air conditioners scheduled to take effect in 2001 and 2000, respectively.

Net national economic impact

Figure 3 shows total bill savings, total expenditures and net savings for the annualized cost method and **Figure 4** shows the results for the cash flow method (in neither Figure are these results expressed in present-value terms). As expected, the net benefit from the cash flow calculation starts out lower than the net benefit from the annualized cost calculation, but by 2000 the cash flow net benefit is higher. Our annualized cost results imply that Americans will spend about $4.8 billion in 2005 less than they would have without appliance standards, while spending $1.4 billion on payments for the capital cost of the more efficient equipment, for a net annual savings of about $3.4 billion.

Figure 5 summarizes the economic effects of the standards in 2010. For reference, we show baseline energy expenditures for 1995 and 2010, normalized to 100%. In percentage terms, virtually all of the savings from standards come from the non-space conditioning end-uses, even though about 45% of total residential primary energy is projected to be consumed for heating and cooling in 2010.

Water heater measures (which also include flow control measures like dishwashers, clothes washers, showerheads, and faucets) dominate total energy savings from the standards. Water heating savings comprise about 65% of total bill savings and 75% of total net savings in 2010 (the net savings are larger in percentage terms because, on average, the water heating standards measures are cheaper to implement than many of the other measures). More than 85% of cumulative net present-valued savings come from water heating and refrigeration measures.

The total present-value of bill savings from the standards (1990 to 2010) is about $46 billion, and the present-value of annualized costs is about $13 billion, for a total net present-value savings of $33 billion. Savings will continue to accrue after 2010, but we do not account for those savings in this analysis. The overall benefit/cost ratio is about 3.5, and this ratio varies little when considering the savings and costs by fuel type. Benefit/cost ratios for specific end-uses range from just below 1.0 for the least cost-effective standard (natural gas dryers) to more than 100 for the most cost effective standard (natural gas room heating).

Figure 3: Net annual dollar savings and annualized incremental costs

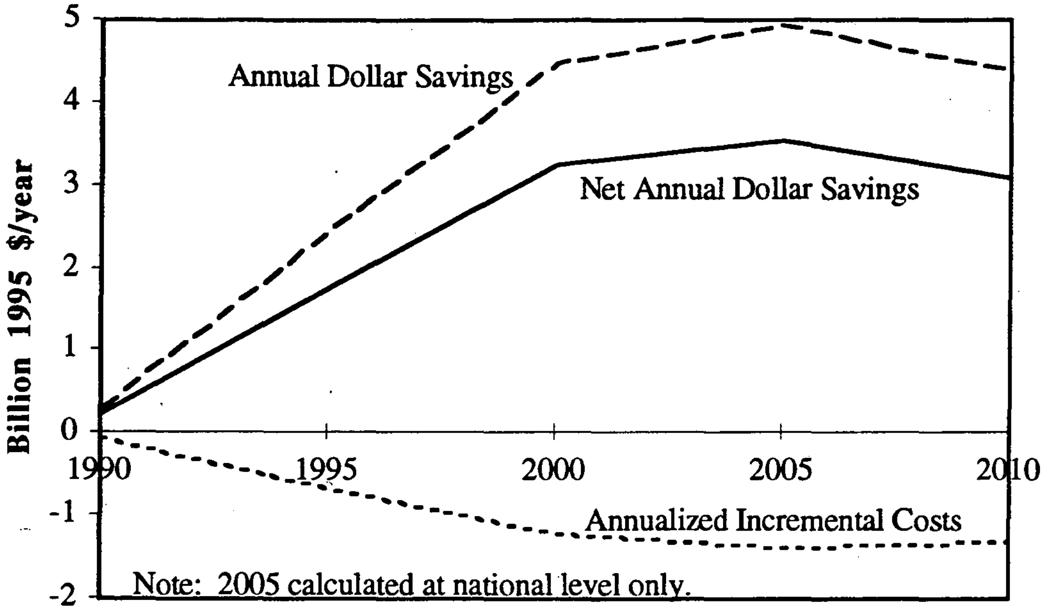


Figure 4: Net annual dollar savings and incremental costs (not annualized)

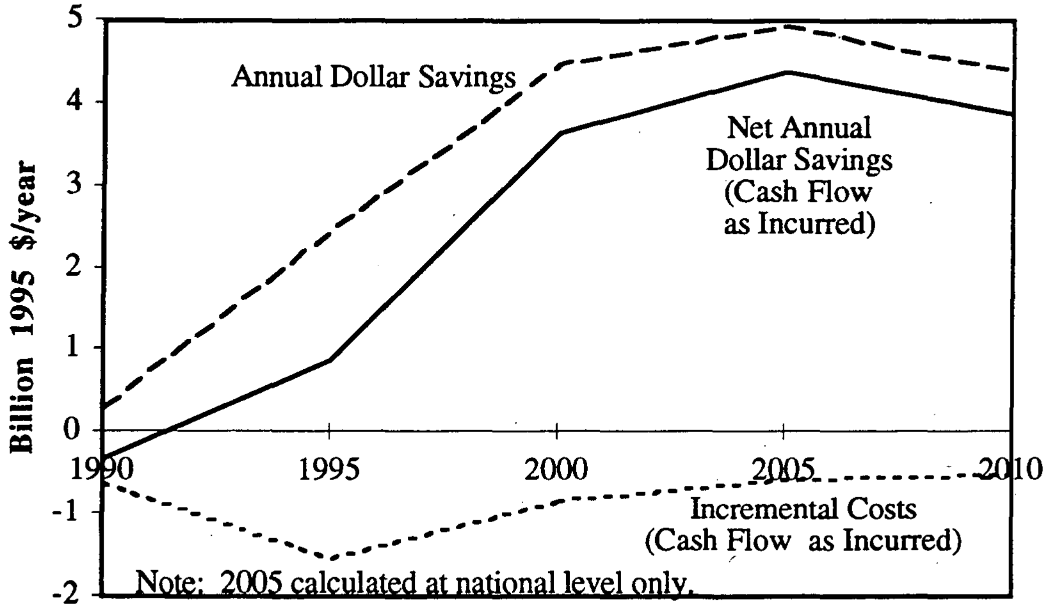
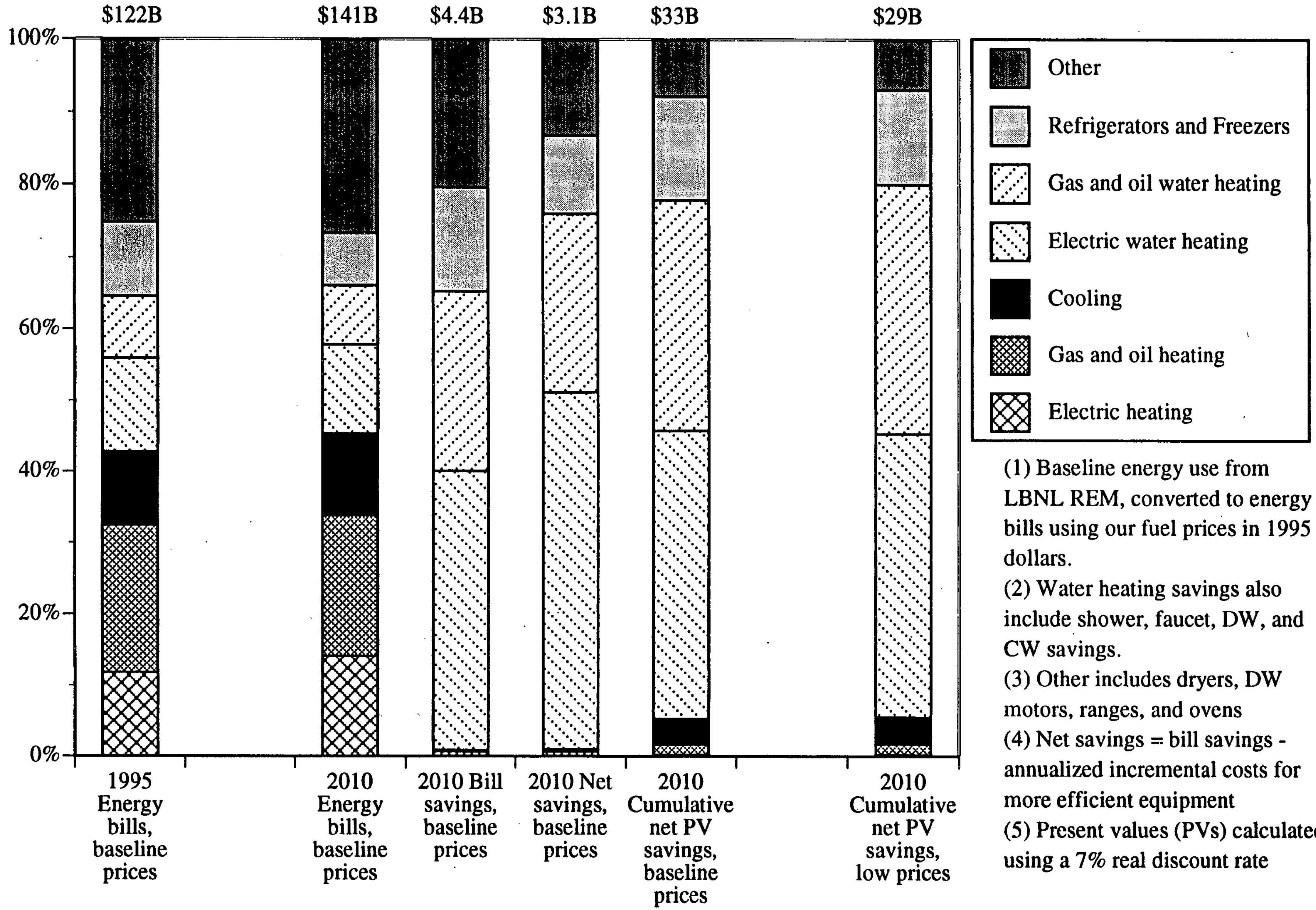


Figure 5: Baseline residential energy bills and bill savings from standards



(1) Baseline energy use from LBNL REM, converted to energy bills using our fuel prices in 1995 dollars.
(2) Water heating savings also include shower, faucet, DW, and CW savings.
(3) Other includes dryers, DW motors, ranges, and ovens
(4) Net savings = bill savings - annualized incremental costs for more efficient equipment
(5) Present values (PVs) calculated using a 7% real discount rate

Economic results by state

The results of the regional analysis are driven by population, climate, and energy prices. Heavily populated states have higher total energy savings because they have more appliances. Climate affects the usage, and thus the savings, of heating and cooling equipment. A homeowner in Florida runs her central air conditioner more hours per year than a homeowner in Maine, so she saves more on her electricity bill with a high efficiency unit. Finally, although energy prices do not directly affect energy savings in our calculations, they have a large effect on energy expenditures. The higher the cost of energy, the greater the monetary benefit of saving energy.

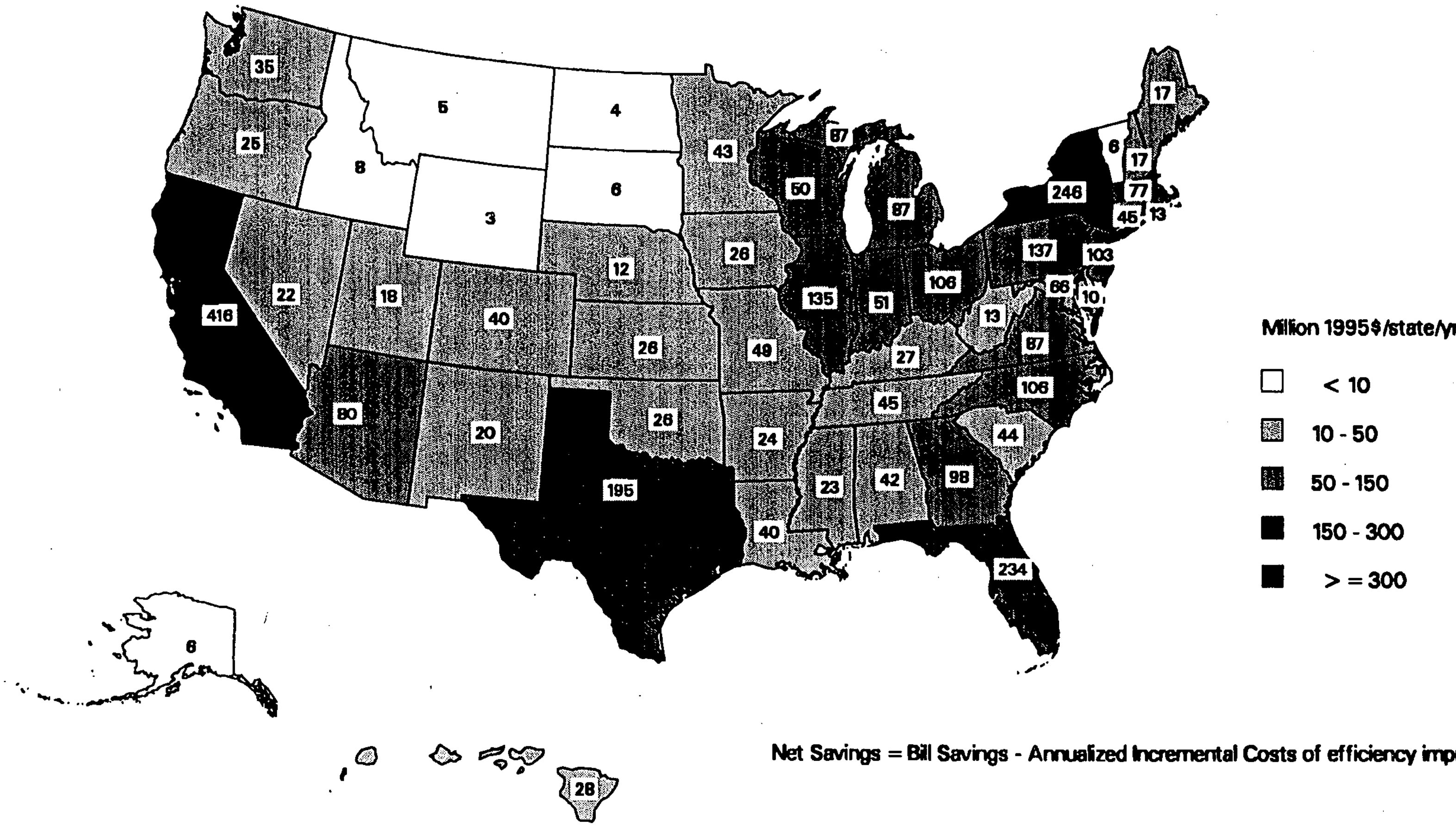
Figure 6 shows a map of state net dollar savings per year in 2010, as calculated in *Table E.6.* Population and fuel prices are the biggest determinants of state-level savings. Total net dollar savings in 2010 are highest in California ($0.42 B/year for 69 Petajoules [PJ]/year[5]), followed by New York ($0.25B/year for 32 PJ/yr), Florida ($0.23 B/yr for 43 PJ/yr), and Texas ($0.20 B/yr for 44 PJ/yr). Energy prices are much higher in New York than in Florida or Texas, which explains the different ranking of these two states in cumulative net benefits and energy savings.

Figure 7 shows annual state net savings on a per household basis, which average $24/year. The largest per household savings are in Hawaii ($54/year) and Arizona ($41/year), cooling-dominated states with relatively high energy prices. Other states with high per household savings are located in the Southeast and Northeast. Montana has the lowest per household bill savings ($13/year), largely because of low energy prices in that state.

[5]There are 1000 Petajoules in 1 Exajoule.

Figure 6: Annual Net Savings from Appliance Efficiency Standards by State in 2010

Total US Annual Net Savings = $3.1 Billion/yr



Net Savings = Bill Savings - Annualized Incremental Costs of efficiency improvements

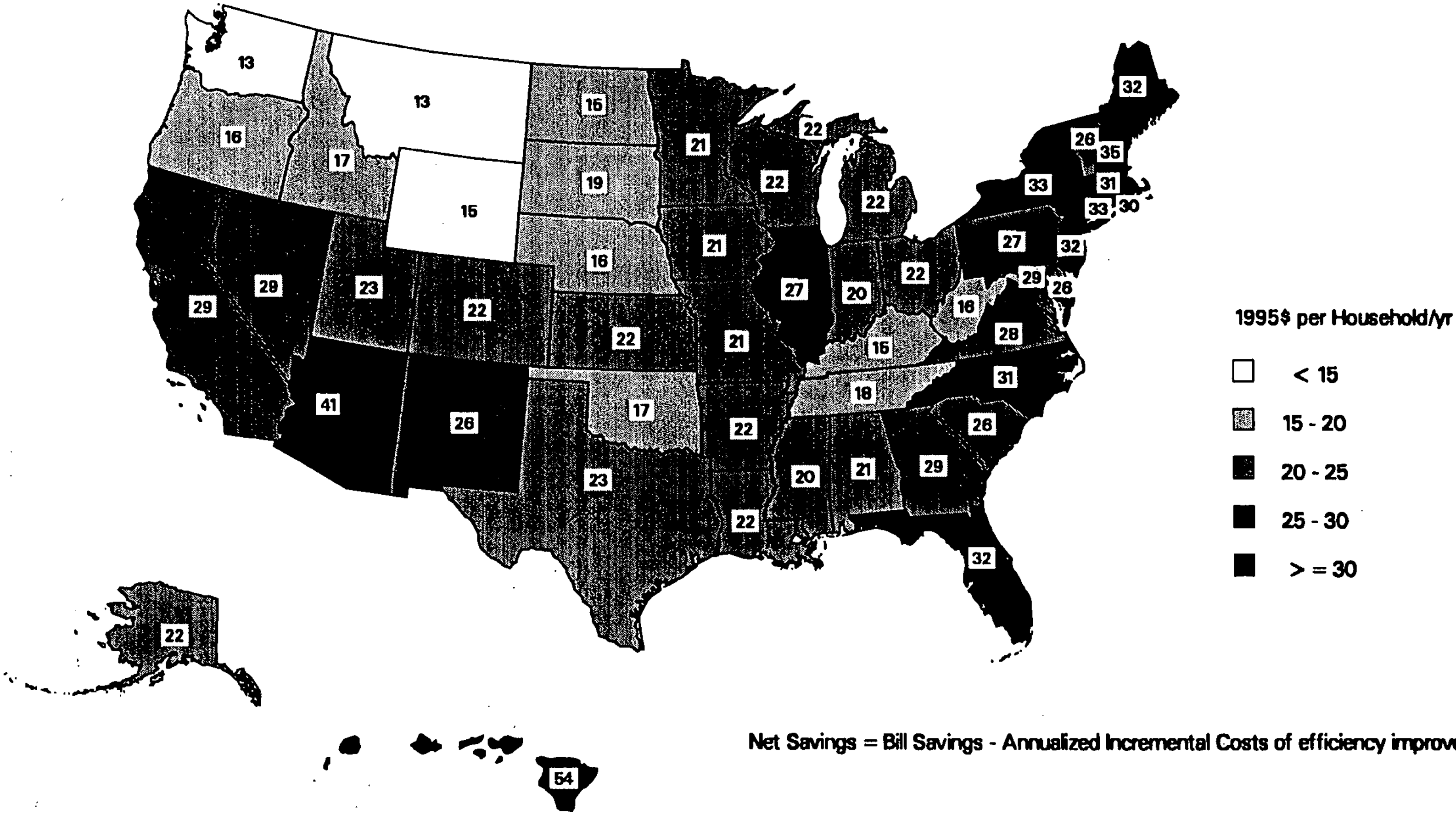
Lawrence Berkeley National Laboratory, Energy Analysis Department

18

stannnetsvg2010.aml 02/24/98

Figure 7: Net Savings per Household from Residential Appliance Efficiency Standards by State in 2010

Total US Net Savings = $3.1 Billion/yr, $24/household/yr



Net Savings = Bill Savings - Annualized Incremental Costs of efficiency improvements

Lawrence Berkeley National Laboratory, Energy Analysis Department

stannethhsvg2010bw2.aml 02/24/98

Carbon reductions due to standards

Annual carbon emissions reductions due to residential equipment efficiency standards are about 5 million metric tons (Mt-C) per year by 1995, and rise to about 9 Mt-C/year throughout the 2000 to 2010 period. Total residential carbon emissions for residences were about 253 Mt-C in 1990, so these savings are 2 to 4% of 1990 emissions (1990 is the baseline against which carbon emissions reductions are commonly benchmarked in the current climate negotiations). Cumulative carbon savings from 1990 to 2010 are about 148 Mt-C, of which 57% is attributable to electricity, 41% to natural gas, and 2% to oil.

The states with the largest carbon savings in 2010 are Texas (0.69 Mt-C/year), followed by California (0.63 Mt-C/year), Florida (0.60 Mt-C/year), and New York (0.41 Mt-C/year). California's electricity sector is much less carbon intensive than that of Texas or Florida, which explains why the Golden State's emissions savings are comparable to those of states with much lower energy savings attributable to the standards.

Uncertainty in future energy prices

The Energy Information Administration's 1996 Annual Energy Outlook forecasts virtually flat electricity and gas prices over the analysis period. For simplicity, we used 1995 prices throughout the analysis period for all fuel types. The Gas Research Institute (GRI), however, forecasts significant changes in electricity and gas prices through 2010 (GRI 1996). They project that electricity prices will decline 19% in real terms by 2010. Gas prices are expected to be slightly higher in 2000 than 1995, but fall to 11% below 1995 levels by 2010, while oil prices are expected to rise 5% in real terms over the period. We ran the model using the GRI forecasts in order to test the sensitivity of the results to fuel price changes.

The lower price forecasts reduce cumulative present-valued energy bill savings in 2010 about 10% (from $46 billion to $42 billion). However, all of the standards on electric end-uses remain cost-effective measures, in spite of lower bill savings, while all gas and oil measures remain cost effective, with the exception of gas clothes dryers (where the CCE is 18% higher than the gas price in 2010). The total net present-value of savings (after subtracting out the additional cost of the more efficient equipment) is still $29B, and the benefit cost ratio falls to 3.2. Given the uncertainty in these fuel price forecasts, and the likelihood that the actual cost of improving the efficiency of equipment is lower than estimated here (see below), our analysis shows the efficiency standards to be robustly cost effective in the face of possible declines in energy prices.

IV. DISCUSSION

Engineering costs versus market data

There has been considerable controversy over whether engineering-based estimates of price increases for more efficient appliances accurately reflect changes in consumer prices and the total cost to society. Recent work by Greening et al. (1997) shows that there was no statistically significant increase in quality-adjusted market prices for refrigerators and freezers from 1987 to 1993, even though efficiency standards went into effect in 1990 and 1993. The observed historical declines in prices continued unabated after the standards, and both the number of models and the number of available features increased during the analysis period. This result is particularly surprising for the 1993 standards, which forced the manufacturers to change nearly all their models to meet the standards.

This work does not allow us to conclude that standards were costless, because the appliance manufacturers may have been forced to absorb the costs of re-engineering their production lines in the face of increasing global competition and the monopsony power of the large retailers of such appliances. It does indicate that consumers did not face increased prices because of the standards, and they reaped large benefits in reduced energy bills because of the increased energy efficiency of these products, without sacrificing size or features.

We used incremental engineering costs as the basis for projected price for many of the appliances analyzed here. In the absence of further information, it is reasonable to conclude that the engineering-based costs are a sensible approximation for the total societal cost of improving the efficiency of appliances affected by the standards. Further research is necessary on whether these engineering-based costs accurately reflect the cost to society of improving technology once "learning-by-doing" effects are properly taken into account.

Cost-effectiveness of federal spending on minimum efficiency standards

As shown in Appendix D, *Table D-9*, total cumulative federal government expenditures to enforce all equipment standards are roughly $200 million (also present-valued to 1995 using a 7% real discount rate), while total cumulative net present-value savings are $33 billion. Every dollar of federal money spent on standards will therefore result in $165 of net savings for U.S. consumers through 2010. This assessment of cost-effectiveness is a conservative one, because our estimate of total present-value savings is a lower bound, because in many cases the savings will continue past 2010, and because the costs are for both residential and commercial equipment standards while the benefits are for the residential standards alone (although this latter effect is not likely to lead to a large correction, since the bulk of federal funding has been allocated to residential standards).

Comparison to other studies

There have been several analyses of the potential impacts of standards in the past decade. One of the more recent analyses is that by Geller (1995), who estimates impacts of all national equipment standards, including commercial and industrial sector end-uses. Geller finds total annual energy savings for residential standards in 2000 that are comparable to ours, but his savings exceeds ours by a significant margin in 2010. The main reason for this difference in savings over time is our explicit treatment of baseline efficiency trends, which are not treated in the Geller report, and which reduce our total savings by about a factor of two in the later years of the forecast.

The correction for the baseline efficiency trends does not affect the overall societal benefit/cost results. The benefit/cost ratio for the NAECA standards is calculated by Geller to be 2.4, while for the NAECA updates (refrigerators and freezers in 1993, clothes washers, dishwashers, and dryers) the benefit/cost ratio in their report is 3.2. Our benefit/cost ratios for the same two groups of appliances are 3.9 and 2.3, respectively. Our calculations therefore show the NAECA standards to be more cost effective than does Geller, and the NAECA updates for refrigerators and freezers to be less cost effective.

Policy implications

The results above show that standards save society money, which implies that they are also reducing carbon emissions at negative net cost to society. We believe that our analysis includes the relevant costs and is an accurate assessment of the costs and benefits. It is the obligation of those who argue that there are hidden costs omitted from the calculations to identify those hidden costs and suggest practical methods to quantify them. Until empirical work demonstrates the existence of these hypothesized hidden costs, our results must be taken as an indication that negative net cost carbon reductions are both possible and achievable in practice. The ultimate size of such carbon reductions is of course a function of the characteristics of buildings and equipment, the available technology to improve energy efficiency, and the rate of improvement in that technology over time.

V. FUTURE WORK

When this analysis was undertaken, the new standards on residential refrigerators, freezers, and room air conditioners had not yet been finalized. Since that time, the U.S. Department of Energy has finalized these rules, which take effect on July 1, 2001 for refrigerator/freezers and October 1, 2000 for room air conditioners. The standards should save an additional 200 kWh/year for the average refrigerator, will save 60 kWh/year for the average freezer, and will increase room air conditioner efficiency by 4% to 20% (Wenzel et al. 1997). These savings should be added to those calculated above.

The analysis should be extended to standards for commercial appliances, including the NAECA standard for magnetic ballasts, and EPACT standards for lamps, electric motors, and commercial heating and cooling equipment. Regional data on commercial end-uses and building characteristics are currently far more limited than in the residential sector, so the geographic component of such work would of necessity be less detailed.

In addition, field studies of energy savings for different end-uses should be conducted, to verify that the projected energy savings are actually being achieved. State level data on sales-weighted efficiency should also be collected, to determine how much each state's efficiency deviates from the national averages used in this analysis. Finally, empirical analyses of actual prices for equipment before and after the imposition of standards should be conducted for end-uses other than refrigerators (which were treated in Greening et al.). As experience with efficiency standards spreads throughout the world (Energy in Buildings 1997), more data of this type should become available.

VI. CONCLUSIONS

This analysis demonstrates that efficiency standards in the residential sector have been a highly cost effective policy instrument for promoting energy efficiency and carbon reductions. Cumulative present-valued dollar savings after subtracting out the additional cost of the more efficient equipment are about $33 billion from 1990 to 2010, while cumulative primary energy savings during this period total 10.6 exajoules. Even if fuel and electricity prices decline substantially by 2010, as some industry observers predict, the standards remain robustly cost effective, with net savings still totaling $29 billion in this case. Because our method for incorporating improvements in efficiency in the absence of standards probably overestimates these improvements, our energy and cost savings estimates are probably lower bounds to the true values.

Average benefit/cost ratios for these standards are about 3.5 for the U.S. as a whole. Each dollar of federal expenditure on implementing the standards will contribute $165 of net present-value savings to the US economy over the 1990 to 2010 period (accounting for savings accruing after 2010 would increase the size of the net benefits). Projected annual carbon reductions are approximately 9 million metric tons of carbon/year from 2000 through 2010, an amount roughly equal to 4% of carbon emissions in 1990. Because these standards save energy at a cost less than the prices of that energy, the resulting carbon emission reductions are achieved at *negative net cost* to society.

ACKNOWLEDGMENTS

We are grateful to Richard Jones and Bill Raup of the Office of Building Technologies, State and Community Programs, US Department of Energy, for funding this work. This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies, State and Community Programs of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

REFERENCES

Appliance Manufacturer Magazine. 1995. "Shipments". In *Appliance Manufacturer Magazine*. March.

Energy in Buildings. 1997. "Special Issue Devoted to Energy Efficiency Standards for Appliances". *Energy in Buildings*. vol. 26, no. 1.

EPAct. 1992. *Energy Policy Act of 1992*. Washington, DC: US House of Representatives. Conference Report 102-1018 to accompany H.R. 776. US Government Printing Office. October 5th.

Geller, Howard. 1995. *National Appliance Efficiency Standards: Cost-Effective Federal Regulations*. Washington, DC: American Council for an Energy Efficient Economy. November.

Geller, Howard S. 1986. *Energy and Economic Savings Potential from National Appliance Efficiency Standards*. American Council for an Energy-Efficient Economy. August.

Greening, Lorna A., Alan H. Sanstad, and James E. McMahon. 1997. "Effects of Appliance Standards on Product Price and Attributes: An Hedonic Pricing Model". vol. 11, no. 2, March.

GRI. 1996. *GRI Baseline Projection of U.S. Energy Supply and Demand: 1997 Edition (The Contribution of Technology)*. Washington, DC: Gas Research Institute. August.

Hanford, James W., Jonathan G. Koomey, Lisa E. Stewart, Matthew E. Lecar, Richard E. Brown, Francis X. Johnson, Roland J. Hwang, and Lynn Price. 1994. *Baseline Data for the Residential Sector and Development of a Residential Forecasting Database*. Lawrence Berkeley Laboratory. LBL-33717. May.

Johnson, Francis X., James W. Hanford, Richard E. Brown, Alan H. Sanstad, and Jonathan G. Koomey. 1994. *Residential HVAC Data, Assumptions and Methodology for End-Use Forecasting with EPRI-REEPS 2.1*. Lawrence Berkeley Laboratory. LBL-34045. June.

Koomey, Jonathan, Francis X. Johnson, James E. McMahon, Mary Orland, Mark Levine, Peter Chan, and Florentin Krause. 1993. *An Assessment of Future Energy Use and Carbon Emissions from U.S. Residences*. Berkeley, CA: Lawrence Berkeley Laboratory. LBL-32183. December.

Koomey, Jonathan G., Camilla Dunham, and James D. Lutz. 1994. *The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-use Treatment*. Berkeley, CA: Lawrence Berkeley Laboratory. LBL-35475. May.

Koomey, Jonathan G., Marla C. Sanchez, Diana Vorsatz, Richard E. Brown, and Celina S. Atkinson. 1997a. *The Potential for Natural Gas Efficiency Improvements in the U.S. Residential Sector*. Lawrence Berkeley Laboratory. DRAFT LBNL-38893. in process.

Koomey, Jonathan G., Diana Vorsatz, Richard E. Brown, Celina S. Atkinson, and Marla C. Sanchez. 1997b. *Updated Potential for Electricity Efficiency Improvements in the U.S. Residential Sector*. Lawrence Berkeley Laboratory. DRAFT LBNL-38894. in process.

Krause, Florentin, Eric Haites, Richard Howarth, and Jonathan Koomey. 1993.*Cutting Carbon Emissions–Burden or Benefit?: The Economics of Energy-Tax and Non-Price Policies* in Energy Policy in the Greenhouse, Volume II, Part 1 . El Cèrrito, CA: International Project for Sustainable Energy Paths.

LBNL REM. 1995. *The LBNL Residential Energy Model.* Berkeley, CA: E. O. Lawrence Berkeley National Laboratory. December.

Nadel, Steven, and Miriam Pye. 1996. *Appliance and Equipment Efficiency Standards: Impacts by State.* Washington, DC: American Council for an Energy Efficient Economy.

Rosenquist, Gregory. 1996. *Opportunities for Improving the Energy Efficiency of Window-type Room Air Conditioners.* Asilomar, CA: American Council for an Energy Efficient Economy, Washington DC, (also LBL-34835).

Thorpe, Sheldon G. 1995. "Wanted: Less Government Interference in the Name of Energy-Efficient Appliances". In *Appliance Manufacturer.* June.

US Bureau of the Census. 1994. *USA Counties 1994.* Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. CD94-CTY-02.

US DOE. 1983. *Supplement to: March 1982 Consumer Products Efficiency Standards Engineering Analysis and Economic Analysis Documents.* Washington, DC: U.S. Department of Energy. DOE/CE-0045. July.

US DOE. 1990. *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers.* U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Building Equipment Division. DOE/CE-0299P. December.

US DOE. 1993. *Technical Support Document: Energy Conservation 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, Assistant Secretary, Energy Efficiency and Renewable Energy, Building Equipment Division. Volume 2: Fluorescent Lamp Ballasts, Television Sets Room Air Conditioners, and Kitchen Ranges and Ovens; DOE/EE-0009. November.

US DOE. 1995a. *Residential Energy Consumption Survey (RECS): Housing Characteristics 1993.* EIA, Energy Information Administration, U.S. Department of Energy, Washington, DC. DOE/EIA-0314(93). June.

US DOE. 1995b. *State Energy Price and Expenditure Report 1993.* Washington, DC: Energy Information Administration, U.S. Department of Energy. DOE/EIA-0376(93). December.

US DOE. 1996a. *Annual Energy Outlook 1996, with Projections to 2015.* Washington, DC: Energy Information Administration, U.S. Department of Energy. DOE/EIA-0383(96). January.

US DOE. 1996b. *Electric Power Annual 1995, Volume I.* Washington, DC: Energy Information Administration, U.S. Department of Energy. DOE/EIA-0348(95)/1. July.

US DOE. 1996c. *Electric Power Annual 1995, Volume II.* Washington, DC: Energy Information Administration, U.S. Department of Energy. DOE/EIA-0348(95)/2. December.

US DOE. 1996d. *Emissions of Greenhouse Gases in the United States 1995.* Washington, DC: Energy Information Administration, U.S. Department of Energy. DOE/EIA-0573 (95). October.

US DOE, U.S. Department of Energy. 1982a. *Consumer Products Efficiency Standards Economic Analysis Document.* U.S. Department of Energy. DOE/CE-0029. March.

US DOE, U.S. Department of Energy. 1982b. *Consumer Products Efficiency Standards Engineering Analysis Document.* U.S. Department of Energy. DOE/CE-0030. March.

Wenzel, Tom P., Jonathan G. Koomey, Gregory J. Rosenquist, Marla C. Sanchez, and James W. Hanford. 1997. *Energy Data Sourcebook for the U.S. Residential Sector.* Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-40297. September.

APPENDIX A: NOTES TO TABLE 2

1) Hanford et al. (1994), using the average lifetime from the LBL REM.

2) Koomey et al. (1994).

3) LBNL REM (8/96).

4) Technical support documents supporting efficiency standards rulemakings (US DOE 1993a, US DOE 1993b).

5) UES, baseline UEC, and incremental costs for heat pumps and central air conditioners are taken from Koomey et al. (1997b). Data for different regions were weighted by the applicable stock to obtain a national average.

6) UES, baseline UEC, and incremental costs are taken from Koomey et al. (1997b).

7) Shipment weighted average EER in 1984 (baseline) = 7.48 from Geller (1986). Shipment weighted average capacity = 10.7 kBtu/hr from Johnson et al. (1994). Hours of operation are 533 hours/yr from Rosenquist (1996). Shipment weighted average EER under standards is 8.53 based on market shares from US DOE (1993a).

8) UES and average UEC under standards are from Geller (1986). Baseline UEC was calculated from UES and the expected average UEC under standards (7.5% below ceilings).

9) UECs and UES are from unpublished intermediate spreadsheets used to produce the results in Koomey et al. (1994). UECs are weighted by home vintage. Showers and faucet UECs are weighted 2/3 to existing (pre-1994) homes, 1/3 to new (post-1993) homes. Clothes washers and dishwashers UECs are weighted half to existing homes and half to new homes. See that paper for documentation of the calculations.

10) UECs and UES are from Koomey et al. (1994).

11) Baseline UEC, UES, and incremental cost are from Koomey et al. (1997a). Data for different regions were weighted by the applicable stock to obtain a national average.

12) Baseline UEC, UES, and incremental cost are from Koomey et al. (1997a).

13) UES is from LBNL REM (10/95). Baseline UEC is a weighted average of UECs from Johnson et al. (1994).

14) Baseline UEC, UES, and incremental cost used are from Koomey et al. (1997a) for adding electronic ignition (glo-bar type for ovens) to units without power cords. The 1990 standard applied these measures only to units with power cords. This incremental cost may be high, since adding electronic ignition to a unit with no power cord is more expensive than for units with a power cord.

15) Incremental cost for aerators/showerheads are from Koomey et al. (1997a) and total $60/unit. 80% is showers and 20% is aerators.

16) From Johnson et al. (1994), we found that the shipment-weighted AFUE of oil furnaces prior to standards was about 81% (higher than the minimum standard of 78%). Also the stock-weighted average UEC was 64.5 MMBtu/yr. We estimated that the average AFUE of units not meeting

standards was 77%. UECs corresponding to 77 (baseline) and 78 (standards) AFUE were calculated by scaling the stock-weighted average UEC by the ratio of the AFUEs. The baseline UEC given is the average of units not meeting standards.

17) From US DOE (1993b). Incremental cost is the difference between 1981 average price and 1990 average price, adjusted to 1995 dollars.

18) Based on incremental cost of $0.26/kWh of first year savings (1985$) from Geller (1986).

19) Based on incremental cost of $0.17/kWh of first year savings (1985$) from Geller (1986).

20) The total incremental cost for dishwashers (motors and water heating) is $32.69 from US DOE (1990). The incremental cost was allocated $10 to the motor and $22.69 to water heating savings.

21) Based on incremental cost of $0.09/kWh of first year savings (1985$) from Geller (1986).

22) Based on incremental cost of $6.56/MMBtu of first year savings (1985$) from Geller (1986).

23) From US DOE (1982a). Incremental costs for the two classes of oil furnaces were linearly scaled to reflect a lower standard (78 rather than 80 AFUE for indoor furnaces) and the improvement in the baseline from 1982 to 1992. The shipment weighted average was calculated (96% indoor, 4% outdoor). A markup of 1.6 from US DOE (1982b) was applied.

24) Incremental cost for oil-fired water heaters is assumed to be the same as for gas-fired units.

25) Dishwashers and clothes washers shipments are divided between water heating fuels based on 1993 EIA water heater saturations (shipments separated by water heating fuel were not available). Water heater saturations 38.4% electric, 53.0% natural gas, 4.1% oil, 2.9% LPG (US DOE 1995a).

26) Shipments for faucets and showers were not available; new home starts and retrofits based on 20 year lifetimes are used instead. The UES is per household.

27) 1990 through 1994 appliance shipments are from Appliance Manufacturer Magazine (1995), excluding faucets, showers, and oil water heaters.

28) 1995 through 2010 shipments are calculated from adding the forecasted average annual increase (from LBNL REM) to the 1994 historical shipment data.

29) All shipments for oil water heaters are from LBNL REM (no historical data was available).

30) The cost of conserved energy is calculated using the formula

$$CCE = \frac{\text{incremental cost (\$)*CRF}}{\text{UES (kWh/year)}}$$

where CRF is the capital recovery factor, used to annualize the incremental cost

($CRF = \frac{d}{(1-(1+d)^{-n})}$), d is the real discount rate (7%), and n is the equipment lifetime from Table 2.

31) State HLH and CLH estimated from national level maps summarized in US DOE (1983).

APPENDIX B: RETIREMENT FUNCTION

A retirement function ("survival curve") is used to estimate the retirement rate of appliances. In this linear function no appliances retire in the first 2/3 of their average life, and all units are retired by 4/3 of their average life. Expressed as equations, this function is as follows:

if Age < {2/3 * (Average Life)} then 100% survive

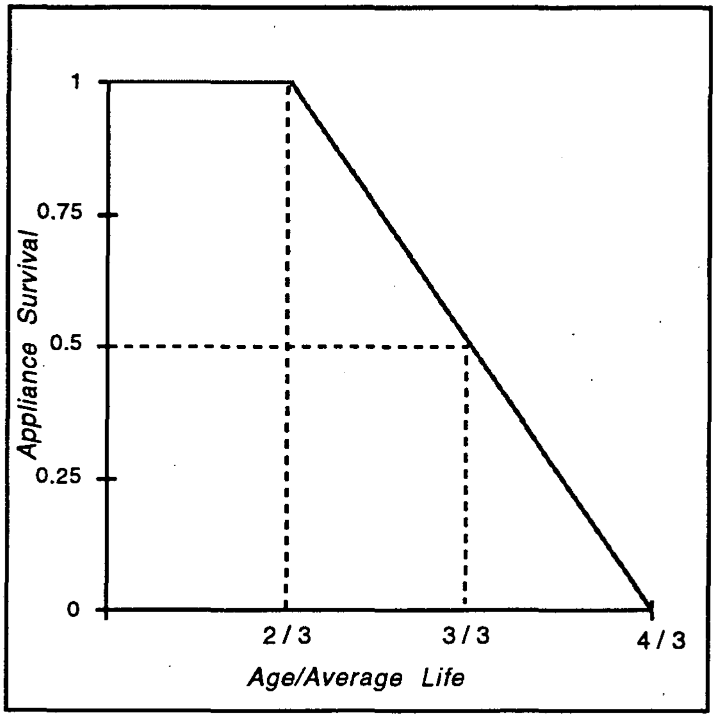
if Age > {2/3 * (Average Life)} and Age < {4/3 * (Average Life)}

then {2- AGE * 1.5/(Average Life)} survive

if Age > {4/3 * (Average Life)} then 0% survive

This retirement function is an approximation taken from work by McMahon, and it is shown in **Figure B-1**.

Figure B-1: Appliance survival curve used in this analysis



APPENDIX C: EXAMPLE CALCULATION–CENTRAL AIR CONDITIONERS

This section goes through a step by step example of the calculation method using data for central air conditioners. Table C-1 contains data used in this section.

Table C-1: Central Air Conditioner Data for Year 2000 Calculations

Year Sold	Shipments millions	Scaling Factor	Adjusted Unit Energy Savings kWh/year	Shipment Survival Factor Year 2000	Stock In Place Year 2000 affected by standards millions	Energy Savings Year 2000 Million kWh	Adjusted Incremental Cost 1995$/unit
1992	2.91	1.00	105	0.875	2.55	268	$51
1993	3.19	0.67	70.4	1.00	3.19	224	$34
1994	3.89	0.33	34.7	1.00	3.89	135	$17
1995	NA	0.00	0.0	1.00	0	0	0

Shipments for 1992 through 1994 are from historical data (1). The forecasted shipments are based on annual shipment growth rates from LBNL REM (2); CAC shipments are forecasted to increase by 48,900 units per year.

Initial unit energy savings

Initial Unit Energy Savings equals pre-standards baseline unit energy consumption minus maximum unit energy consumption permitted by the standards, which are 1962 kWh/yr and 1857 kWh/yr respectively. The resulting UES is 105 kWh/yr. As discussed earlier, baseline scaling factors are used for both the UES and the incremental costs in this model to simulate the effect of baseline efficiency improvements in the absence of standards. These scaling factors reduce the UES and incremental costs over time. For CACs, the scaling factor declines at a rate of 33 percent per year, reaching zero in three years. This is based on a historical average manufacturing energy efficiency improvement of 2 percent per year and a percentage improvement in efficiency due to standards of 5.4 percent, which yields 2.7 years (we round this to three years for ease of computation).

Retirement and stock

The number of functioning appliances each year is calculated from historical shipments and a survival probability as a function of age. The average life of CACs is 12 years, and they last from 8 to 16 years (2/3 and 4/3 of average life, respectively, as in Figure B-1). For CACs, the annual retirement rate is 1/((4/3-2/3)*12) or 1/8. Shipments are multiplied by a survival factor to get survivors by vintage for a given year. For example, if we are interested in savings forecasts for the year 2000, then the retirement factors are derived by applying the survival function to shipments through 2000. In the year 2000, 1992 shipments are 9 years old and the survival rate of these 1992 shipments is 0.875 (0.875=1-[(9-8)x(0.125)]). CAC shipments in 1992 were 2.9 million units, and applying the survival factor for the year 2000 results in 2.6 million appliances shipped in the year 1992 still existing in 2000. The analogous calculation is made for each year, 1992-2000.

Energy savings

Energy savings are calculated for the year 2000 by multiplying by the UES and stock for each year from 1992 through 2000 and summing these values. For CACs purchased in 1992, the energy savings are: (2.9 million shipments) x (0.875 survival rate) x (105 kWh UES) = 268 million kWhs. The annual value represents the energy savings for all appliances still in place (the appliance stock) since the particular appliance standard was enacted. The total energy savings for central air conditioners in the year 2000 is 627 Million kWh.

Value of energy savings

The national average electricity price used in the model is 8.6 ¢/kWh in 1995 dollars. At this price, the bill savings in 2000 for appliances sold in the year 1993 is $19.3 million. The incremental annualized cost in any year is the product of the Cost of Conserved Energy ($0.061/kWh, from Table 2) and the annual energy savings. In order to calculate net savings, we subtract the annualized cost from the bill savings in each year. Then the values for each year are totaled to get the year 2000 value.

New and replacement shipments

Shipments are divided between new and replacement units. The fraction of central air conditioning units that are allocated to new homes fluctuates between 25 and 30 percent from 1990 through 2010. The remaining units are allocated to existing homes, as replacement units.

Regional disaggregation

Disaggregated calculations are made at the county level. For this portion of the example, we focus on San Francisco county which is in the state of California and the Pacific census division.

Housing units are divided into two types: new and existing. New homes are considered to be those which were constructed after 1987 while existing homes are those constructed before 1987. This distinction is accounted for in the national level calculations. The national level energy savings estimates are distributed to the county level using the percent of new and existing homes that reside in the county. San Francisco had 305,984 households in 1995 which represented 0.33 percent of the 91,991,514 U.S. households. In 1994, San Francisco had 107 new housing permits, representing 0.01 percent of the 1,064,251 U.S. new home permits in that year.

Next, these county level energy savings data are adjusted for regional variation in appliance saturation using a ratio of census division and national level appliance saturation (we assume that all counties within a particular Census Division are assigned the saturation for that division). The Pacific census division saturation of CACs in new homes is 46 percent and the national saturation is 58 percent, resulting in a saturation ratio of 0.79.

Cooling appliances are adjusted for regional variation in cooling demand using the ratio of state and national level cooling load hours. These data are 1000 and 915, respectively, resulting in an adjustment factor of 1.09 for California.

The value of energy savings is calculated using state level average fuel prices. In California, the electricity price is $0.117/kWh, higher than the national average of $0.086.

Appendix C notes

(1) Appliance Manufacturer Magazine. 1995. "Shipments". *Appliance Manufacturer Magazine*. March. p. 19.

(2) P. Chan, 1996. LBNL. Personal Communication.

APPENDIX D: INPUT TABLES

This Appendix contains tables summarizing key inputs for the analysis:

Table D-1: Historical and projected equipment shipments (millions of units per year)

Table D-2: Scaling factors that account for baseline efficiency trends

Table D-3: State population projections

Table D-4: State energy prices in 1995

Table D-5: State heating and cooling load hours

Table D-6: Carbon emissions factors by region

Table D-7: Saturations of existing equipment by Census division

Table D-8: Saturations of new equipment by Census division

Table D-9: Fed. government expenditures to implement appliance efficiency standards

Table D-10: First page of county data on number of households and housing starts

Table D-1: Historical and projected equipment shipments (millions of units per year)

		Year	Historical					Forecasted															
End-use	*Fuel*	*standard enacted*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
CAC	Electricity	1992			2.91	3.19	3.89	3.94	3.99	4.03	4.08	4.13	4.18	4.23	4.28	4.33	4.38	4.43	4.47	4.52	4.57	4.62	4.67
Clothes Washer	Electricity	1994					2.40	2.43	2.46	2.49	2.52	2.55	2.58	2.61	2.64	2.67	2.70	2.73	2.76	2.79	2.82	2.85	2.89
Clothes Dryer	Electricity	1994					4.03	4.08	4.13	4.17	4.22	4.26	4.31	4.36	4.40	4.45	4.50	4.54	4.59	4.63	4.68	4.73	4.77
Dishwasher	Electricity	1994					1.76	1.78	1.81	1.83	1.85	1.88	1.90	1.93	1.95	1.98	2.00	2.03	2.05	2.08	2.10	2.13	2.15
Dishwasher Motor	Electricity	1994					4.50	4.56	4.63	4.69	4.75	4.82	4.88	4.94	5.01	5.07	5.13	5.20	5.26	5.32	5.39	5.45	5.51
Freezer 1990	Electricity	1990	1.30	1.41	1.64																		
Freezer 1993	Electricity	1993				1.61	1.69	1.69	1.69	1.69	1.69	1.69	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Faucets	Electricity	1994					1.80	1.82	1.82	1.82	1.82	1.82	1.82	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
HP	Electricity	1992			0.80	0.88	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.14	1.15	1.16	1.17	1.18
Refrigerator 1990	Electricity	1990	7.10	7.27	7.76																		
Refrigerator 1993	Electricity	1993				8.11	8.61	8.70	8.80	8.89	8.99	9.08	9.17	9.27	9.36	9.46	9.55	9.64	9.74	9.83	9.93	10.02	10.11
RAC	Electricity	1990	4.15	2.83	2.91	3.08	4.12	4.17	4.23	4.29	4.34	4.40	4.46	4.51	4.57	4.63	4.68	4.74	4.80	4.85	4.91	4.96	5.02
Showers	Electricity	1994					1.80	1.82	1.82	1.82	1.82	1.82	1.82	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Water Heater	Electricity	1990	3.23	3.17	3.40	3.61	3.90	3.92	3.94	3.96	3.98	4.00	4.02	4.05	4.07	4.09	4.11	4.13	4.15	4.17	4.19	4.22	4.24
Central Heat	Natural gas	1992			2.11	2.58	2.70	2.73	2.77	2.81	2.85	2.88	2.92	2.96	3.00	3.03	3.07	3.11	3.15	3.18	3.22	3.26	3.29
Clothes Washer	Natural gas	1994					3.49	3.53	3.58	3.62	3.66	3.71	3.75	3.80	3.84	3.89	3.93	3.98	4.02	4.07	4.11	4.16	4.20
Clothes Dryer	Natural gas	1994					1.30	1.31	1.32	1.33	1.34	1.35	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.42	1.43	1.44	1.45
Dishwasher	Natural gas	1994					2.56	2.59	2.63	2.66	2.70	2.74	2.77	2.81	2.84	2.88	2.92	2.95	2.99	3.02	3.06	3.10	3.13
Faucets	Natural gas	1994					2.70	2.72	2.72	2.72	2.72	2.72	2.72	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
Oven	Natural gas	1990	2.06	2.04	2.22	2.34	2.53	2.55	2.57	2.59	2.61	2.63	2.64	2.66	2.68	2.70	2.72	2.74	2.76	2.78	2.80	2.81	2.83
Room heat	Natural gas	1990	0.26	0.23	0.24	0.25	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	0.26	0.26	0.26
Range	Natural gas	1990	2.32	2.31	2.52	2.67	2.86	2.88	2.90	2.91	2.93	2.95	2.97	2.98	3.00	3.02	3.04	3.06	3.07	3.09	3.11	3.13	3.14
Showers	Natural gas	1994					2.70	2.72	2.72	2.72	2.72	2.72	2.72	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
Water Heater	Natural gas	1990	3.91	3.94	4.24	4.47	4.75	4.78	4.82	4.85	4.88	4.91	4.94	4.98	5.01	5.04	5.07	5.11	5.14	5.17	5.20	5.24	5.27
Central Heat	Distillate oil	1992			0.14	0.12	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.20
Clothes Washer	Distillate oil	1994					0.26	0.26	0.26	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.31
Dishwasher	Distillate oil	1994					0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.23	0.23
Faucets	Distillate oil	1994					0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Showers	Distillate oil	1994					0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Water Heater	Distillate oil	1990	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

(1) Historical shipments from Appliance Manufacturer (1995).

(2) Forecasted shipment from LBNL REM, except for showers and faucets, which were derived independently.

(3) Blank cells indicate that the standard either is not yet in force or has been superceded by a later standard (for refrigerators)

Table D-2: Scaling factors that account for baseline efficiency trends																								Historical annual efficiency improvement without standards	Total % efficiency improvement from baseline to standard
End-use	*Fuel*	Year *standard enacted*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*		
CAC	Electricity	1992			1.00	0.67	0.33	**0**																2.0%	5.4%
Clothes Washer	Electricity	1994					1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	1.0%	32.1%
Clothes Dryer	Electricity	1994					1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.1%	8.3%
Dishwasher	Electricity	1994					1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.68	0.5%	20.1%
Dishwasher Motors	Electricity	1994					1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.68	0.5%	12.5%
Freezer 1990	Electricity	1990	1.00	0.67	0.33	**0**																		3.0%	9.6%
Freezer 1993	Electricity	1993				1.00	0.83	0.67	0.50	0.33	0.17	**0**												3.0%	17.6%
Faucets	Electricity	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.5%
HP	Electricity	1992			1.00	0.50	**0**																	2.0%	4.1%
Refrigerator 1990	Electricity	1990	1.00	0.67	0.33	**0**																		3.0%	7.7%
Refrigerator 1993	Electricity	1993					0.88	0.75	0.63	0.50	0.38	0.25	0.13	**0**										3.0%	22.7%
RAC	Electricity	1990	1.00	0.83	0.67	0.50	0.33	0.17	**0**															2.0%	12.6%
Showers	Electricity	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.4%
Water Heater	Electricity	1990	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	**0**											0.5%	5.2%
Central Heat	Natural gas	1992			1.00	0.67	0.33	**0**																0.9%	2.5%
Clothes Washer	Natural gas	1994					1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	1.0%	31.8%
Clothes Dryer	Natural gas	1994					1.00	0.99	0.98	0.96	0.95	0.94	0.93	0.91	0.90	0.89	0.88	0.86	0.85	0.84	0.83	0.81	0.80	0.1%	13.9%
Dishwasher	Natural gas	1994					1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.68	0.5%	20.0%
Faucets	Natural gas	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.5%
Oven	Natural gas	1990	0.30	0.29	0.29	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.24	0.23	0.23	0.22	0.22	0.21	0.20	0.20	0.19	0.19	0.18	1.0%	53.3%
Room heat	Natural gas	1990	1.00	0.75	0.50	0.25	**0**																	1.5%	5.6%
Range	Natural gas	1990	0.30	0.29	0.29	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.24	0.23	0.23	0.22	0.22	0.21	0.20	0.20	0.19	0.19	0.18	1.0%	70.0%
Showers	Natural gas	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.4%
Water Heater	Natural gas	1990	1.00	0.93	0.87	0.80	0.73	0.67	0.60	0.53	0.47	0.40	0.33	0.27	0.20	0.13	0.07	**0**						0.8%	12.3%
Central Heat	Distillate oil	1992			0.03	0.02	**0**																	0.8%	1.3%
Clothes Washer	Distillate oil	1994					1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	1.0%	31.8%
Dishwasher	Distillate oil	1994					1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.68	0.5%	20.0%
Faucets	Distillate oil	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.5%
Showers	Distillate oil	1994					1.00	0.98	0.96	0.94	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.72	0.70	NA	26.4%
Water Heater	Distillate oil	1990	1.00	0.94	0.88	0.81	0.75	0.69	0.63	0.56	0.50	0.44	0.38	0.31	0.25	0.19	0.13	0.06	**0**					0.8%	12.3%

(1) Factors are to be multiplied by the total shipments in a given year to determine the "applicable shipments" that are actually affected by standards. Blanks are the equivalent of a scaling factor of zero.

(2) Time of phaseout determined by ratio of percentage efficiency improvement by the standards to the annual percentage change in efficiency in the "No standards case".

(3) Factors are always 1.0 in the first year, declining to the end year (bold face) in a linear fashion, except for gas ranges/ovens and oil furnaces.

Gas ranges and ovens begin at 30% because the standard applied only to units shipped with a power cord. According to Geller (1986), only 30% of total shipments HAD a power cord AND a pilot light. 95% of all shipments HAD a power cord, suggesting that 65% of shipments had a power cord but NO pilot light (so the std had no impact), and 5% had no power cord so that the standard didn't apply to them.

For oil-fired furnaces, only a small fraction of the products on the market (3%) did not meet the standard.

We believe that the standard was set at 78% solely for consistency with the standard on gas furnaces, not because it would save significant energy.

(4) Showers and faucet impacts assumed to decline to 70% of 1st year levels because of state and local water conservation measures and consumer education.

Table D-3: State Population Projections

State		*Population (thousands)* 1995	2000	2010	*Ratios* 2000/1995	2010/2000	2010/1995	*Annual percentage growth* 1995-2000	2000-2010	1995-2010
Alaska	AK	634	699	781	1.10	1.12	1.23	2.0%	1.1%	1.4%
Alabama	AL	4274	4485	4856	1.05	1.08	1.14	1.0%	0.8%	0.9%
Arkansas	AR	2468	2578	2782	1.04	1.08	1.13	0.9%	0.8%	0.8%
Arizona	AZ	4072	4437	5074	1.09	1.14	1.25	1.7%	1.4%	1.5%
California	CA	32398	34888	41085	1.08	1.18	1.27	1.5%	1.6%	1.6%
Colorado	CO	3710	4059	4494	1.09	1.11	1.21	1.8%	1.0%	1.3%
Connecticut	CT	3274	3271	3412	1.00	1.04	1.04	0.0%	0.4%	0.3%
District Of Columbia	DC	559	537	577	0.96	1.07	1.03	-0.8%	0.7%	0.2%
Delaware	DE	718	759	815	1.06	1.07	1.14	1.1%	0.7%	0.8%
Florida	FL	14210	15313	17372	1.08	1.13	1.22	1.5%	1.3%	1.3%
Georgia	GA	7102	7637	8553	1.08	1.12	1.20	1.5%	1.1%	1.2%
Hawaii	HI	1221	1327	1551	1.09	1.17	1.27	1.7%	1.6%	1.6%
Iowa	IA	2861	2930	2981	1.02	1.02	1.04	0.5%	0.2%	0.3%
Idaho	ID	1156	1290	1454	1.12	1.13	1.26	2.2%	1.2%	1.5%
Illinois	IL	11853	12168	12652	1.03	1.04	1.07	0.5%	0.4%	0.4%
Indiana	IN	5820	6045	6286	1.04	1.04	1.08	0.8%	0.4%	0.5%
Kansas	KS	2601	2722	2922	1.05	1.07	1.12	0.9%	0.7%	0.8%
Kentucky	KY	3851	3989	4160	1.04	1.04	1.08	0.7%	0.4%	0.5%
Louisiana	LA	4359	4478	4808	1.03	1.07	1.10	0.5%	0.7%	0.7%
Massachusetts	MA	5976	5950	6097	1.00	1.02	1.02	-0.1%	0.2%	0.1%
Maryland	MD	5078	5322	5782	1.05	1.09	1.14	0.9%	0.8%	0.9%
Maine	ME	1236	1240	1309	1.00	1.06	1.06	0.1%	0.5%	0.4%
Michigan	MI	9575	9759	10033	1.02	1.03	1.05	0.4%	0.3%	0.3%
Minnesota	MN	4619	4824	5127	1.04	1.06	1.11	0.9%	0.6%	0.7%
Missouri	MO	5286	5437	5760	1.03	1.06	1.09	0.6%	0.6%	0.6%
Mississippi	MS	2666	2750	2918	1.03	1.06	1.09	0.6%	0.6%	0.6%
Montana	MT	862	920	996	1.07	1.08	1.16	1.3%	0.8%	1.0%
North Carolina	NC	7150	7617	8341	1.07	1.10	1.17	1.3%	0.9%	1.0%
North Dakota	ND	637	643	676	1.01	1.05	1.06	0.2%	0.5%	0.4%
Nebraska	NE	1644	1704	1793	1.04	1.05	1.09	0.7%	0.5%	0.6%
New Hampshire	NH	1132	1165	1280	1.03	1.10	1.13	0.6%	0.9%	0.8%
New Jersey	NJ	7931	8135	8562	1.03	1.05	1.08	0.5%	0.5%	0.5%
New Mexico	NM	1676	1823	2082	1.09	1.14	1.24	1.7%	1.3%	1.5%
Nevada	NV	1477	1691	1935	1.14	1.14	1.31	2.7%	1.4%	1.8%
New York	NY	18178	18237	18546	1.00	1.02	1.02	0.1%	0.2%	0.1%
Ohio	OH	11203	11453	11659	1.02	1.02	1.04	0.4%	0.2%	0.3%
Oklahoma	OK	3271	3382	3683	1.03	1.09	1.13	0.7%	0.9%	0.8%
Oregon	OR	3141	3404	3876	1.08	1.14	1.23	1.6%	1.3%	1.4%
Pennsylvania	PA	12134	12296	12438	1.01	1.01	1.03	0.3%	0.1%	0.2%
Rhode Island	RI	1001	998	1034	1.00	1.04	1.03	-0.1%	0.4%	0.2%
South Carolina	SC	3732	3932	4311	1.05	1.10	1.16	1.0%	0.9%	1.0%
South Dakota	SD	735	770	815	1.05	1.06	1.11	0.9%	0.6%	0.7%
Tennessee	TN	5228	5538	6007	1.06	1.08	1.15	1.2%	0.8%	0.9%
Texas	TX	18592	20039	22850	1.08	1.14	1.23	1.5%	1.3%	1.4%
Utah	UT	1944	2148	2462	1.10	1.15	1.27	2.0%	1.4%	1.6%
Virginia	VA	6646	7048	7728	1.06	1.10	1.16	1.2%	0.9%	1.0%
Vermont	VT	579	592	623	1.02	1.05	1.08	0.4%	0.5%	0.5%
Washington	WA	5497	6070	7025	1.10	1.16	1.28	2.0%	1.5%	1.6%
Wisconsin	WI	5159	5381	5629	1.04	1.05	1.09	0.8%	0.5%	0.6%
West Virginia	WV	1824	1840	1842	1.01	1.00	1.01	0.2%	0.0%	0.1%
Wyoming	WY	487	522	596	1.07	1.14	1.22	1.4%	1.3%	1.4%
Total	US	263437	276242	300430	1.05	1.09	1.14	1.0%	0.8%	0.9%

(1) Source: US Bureau of Census, Current Population Reports, series P25-1111
Statistical Abstract of the US, 1995

Table D-4: State energy prices in 1995

State		Energy prices Electricity 1995 $/kWh	Natural gas 1995 $/MMBtu	Oil 1995 $/MMBtu	Index Electricity U.S. = 1.0	Natural gas U.S. = 1.0	Oil U.S. = 1.0
Alaska	AK	0.1160	4.06	7.07	1.34	0.67	1.01
Alabama	AL	0.0708	7.01	5.49	0.82	1.15	0.79
Arkansas	AR	0.0859	5.40	5.80	0.99	0.89	0.83
Arizona	AZ	0.1001	7.12	7.48	1.16	1.17	1.07
California	CA	0.1173	6.10	7.55	1.36	1.00	1.08
Colorado	CO	0.0751	4.55	4.85	0.87	0.75	0.69
Connecticut	CT	0.1182	9.34	7.17	1.37	1.53	1.03
District Of Columbia	DC	0.0743	8.42	8.16	0.86	1.38	1.17
Delaware	DE	0.0935	6.58	6.61	1.08	1.08	0.95
Florida	FL	0.0829	8.72	7.20	0.96	1.43	1.03
Georgia	GA	0.0809	6.17	6.76	0.94	1.01	0.97
Hawaii	HI	0.1274	16.77	7.41	1.47	2.75	1.06
Iowa	IA	0.0832	5.55	4.43	0.96	0.91	0.63
Idaho	ID	0.0519	5.27	6.67	0.60	0.86	0.95
Illinois	IL	0.1067	5.50	6.60	1.24	0.90	0.95
Indiana	IN	0.0692	5.79	6.26	0.80	0.95	0.90
Kansas	KS	0.0816	5.05	7.70	0.94	0.83	1.10
Kentucky	KY	0.0591	5.10	7.24	0.68	0.84	1.04
Louisiana	LA	0.0806	5.98	7.89	0.93	0.98	1.13
Massachusetts	MA	0.1142	8.16	6.93	1.32	1.34	0.99
Maryland	MD	0.0853	7.01	7.58	0.99	1.15	1.09
Maine	ME	0.1188	7.50	6.44	1.37	1.23	0.92
Michigan	MI	0.0847	4.95	6.68	0.98	0.81	0.96
Minnesota	MN	0.0735	5.34	6.49	0.85	0.88	0.93
Missouri	MO	0.0754	5.44	5.57	0.87	0.89	0.80
Mississippi	MS	0.0740	5.20	7.31	0.86	0.85	1.05
Montana	MT	0.0600	4.92	6.14	0.69	0.81	0.88
North Carolina	NC	0.0848	6.86	7.22	0.98	1.13	1.03
North Dakota	ND	0.0657	5.01	6.18	0.76	0.82	0.88
Nebraska	NE	0.0649	5.18	5.77	0.75	0.85	0.83
New Hampshire	NH	0.1278	7.71	6.09	1.48	1.27	0.87
New Jersey	NJ	0.1183	6.86	7.21	1.37	1.13	1.03
New Mexico	NM	0.0954	5.33	5.83	1.10	0.87	0.83
Nevada	NV	0.0675	5.58	7.10	0.78	0.92	1.02
New York	NY	0.1367	8.05	7.67	1.58	1.32	1.10
Ohio	OH	0.0868	5.59	6.49	1.00	0.92	0.93
Oklahoma	OK	0.0742	4.92	6.41	0.86	0.81	0.92
Oregon	OR	0.0521	6.28	6.76	0.60	1.03	0.97
Pennsylvania	PA	0.0992	6.71	6.74	1.15	1.10	0.96
Rhode Island	RI	0.1183	8.08	7.03	1.37	1.33	1.01
South Carolina	SC	0.0760	7.06	6.02	0.88	1.16	0.86
South Dakota	SD	0.0731	5.32	6.10	0.85	0.87	0.87
Tennessee	TN	0.0597	6.00	5.41	0.69	0.98	0.77
Texas	TX	0.0831	5.84	5.90	0.96	0.96	0.85
Utah	UT	0.0712	4.83	4.21	0.82	0.79	0.60
Virginia	VA	0.0786	7.31	6.80	0.91	1.20	0.97
Vermont	VT	0.1022	6.31	6.98	1.18	1.04	1.00
Washington	WA	0.0477	5.14	7.83	0.55	0.84	1.12
Wisconsin	WI	0.0730	6.38	6.36	0.85	1.05	0.91
West Virginia	WV	0.0654	6.16	6.68	0.76	1.01	0.96
Wyoming	WY	0.0620	4.60	6.14	0.72	0.75	0.88
Total	US	0.0864	6.09	6.98	1.00	1.00	1.00

(1) national prices for 1995 from AEO 96 are spread to the state level assuming that state prices have the same relationship to national prices that they had in 1993 (from US DOE 1995b).

Table D-5: State heating and cooling load hours

State		Heating load hours hours/year	Cooling load hours hours/year	*Index* *HLH* *U.S. = 1.0*	*CLH* *U.S. = 1.0*
Alaska	AK	3500	0	*1.63*	*0.00*
Alabama	AL	1500	1600	*0.70*	*1.75*
Arkansas	AR	1500	1600	*0.70*	*1.75*
Arizona	AZ	1700	1600	*0.79*	*1.75*
California	CA	2500	1000	*1.17*	*1.09*
Colorado	CO	2500	600	*1.17*	*0.66*
Connecticut	CT	2500	600	*1.17*	*0.66*
District Of Columbia	DC	2100	800	*0.98*	*0.87*
Delaware	DE	2200	600	*1.03*	*0.66*
Florida	FL	500	2400	*0.23*	*2.62*
Georgia	GA	1500	1500	*0.70*	*1.64*
Hawaii	HI	0	2300	*0.00*	*2.51*
Iowa	IA	2400	800	*1.12*	*0.87*
Idaho	ID	2500	600	*1.17*	*0.66*
Illinois	IL	2200	1000	*1.03*	*1.09*
Indiana	IN	2250	900	*1.05*	*0.98*
Kansas	KS	2000	1000	*0.93*	*1.09*
Kentucky	KY	2000	1000	*0.93*	*1.09*
Louisiana	LA	1200	1800	*0.56*	*1.97*
Massachusetts	MA	2500	600	*1.17*	*0.66*
Maryland	MD	2200	600	*1.03*	*0.66*
Maine	ME	2700	400	*1.26*	*0.44*
Michigan	MI	2800	500	*1.31*	*0.55*
Minnesota	MN	2900	500	*1.35*	*0.55*
Missouri	MO	2000	1100	*0.93*	*1.20*
Mississippi	MS	1400	1400	*0.65*	*1.53*
Montana	MT	2500	500	*1.17*	*0.55*
North Carolina	NC	1750	1100	*0.82*	*1.20*
North Dakota	ND	2700	400	*1.26*	*0.44*
Nebraska	NE	2250	1000	*1.05*	*1.09*
New Hampshire	NH	2500	500	*1.17*	*0.55*
New Jersey	NJ	2250	700	*1.05*	*0.77*
New Mexico	NM	2000	1000	*0.93*	*1.09*
Nevada	NV	2250	1000	*1.05*	*1.09*
New York	NY	2500	600	*1.17*	*0.66*
Ohio	OH	2300	800	*1.07*	*0.87*
Oklahoma	OK	1700	1200	*0.79*	*1.31*
Oregon	OR	2500	500	*1.17*	*0.55*
Pennsylvania	PA	2500	700	*1.17*	*0.77*
Rhode Island	RI	2400	500	*1.12*	*0.55*
South Carolina	SC	1500	1300	*0.70*	*1.42*
South Dakota	SD	2500	500	*1.17*	*0.55*
Tennessee	TN	1900	1000	*0.89*	*1.09*
Texas	TX	1250	2000	*0.58*	*2.19*
Utah	UT	2300	800	*1.07*	*0.87*
Virginia	VA	2100	900	*0.98*	*0.98*
Vermont	VT	2600	500	*1.21*	*0.55*
Washington	WA	2500	400	*1.17*	*0.44*
Wisconsin	WI	2800	500	*1.31*	*0.55*
West Virginia	WV	2300	900	*1.07*	*0.98*
Wyoming	WY	2500	550	*1.17*	*0.60*
Total	US	2145	915	*1.00*	*1.00*

(1) Source: US DOE 1983.

Table D-6: Carbon emissions by region

	Census Division	*States represented*	*Units*	*Emission factors* 1990	1995	2000	2010
Electricity							
New England	1	CT, ME, MA, NH, RI, VT	g C/kWh.e	114	104	104	106
Middle Atlantic	2	NJ, NY, PA	g C/kWh.e	142	130	129	132
East North Central	3	IL, IN, MI, OH, WI	g C/kWh.e	214	196	195	199
West North Central	4	IA, KS, MN, MO, NE, ND, SD	g C/kWh.e	239	219	218	222
South Atlantic	5	DE, DC, FL, GA, MD, NC, SC, VA, WV	g C/kWh.e	174	160	159	162
East South Central	6	AL, KY, MS, TN	g C/kWh.e	211	194	193	197
West South Central	7	AR, LA, OK, TX	g C/kWh.e	204	187	186	190
Mountain-N	8	CO+ID+MT+NV+UT+WY	g C/kWh.e	248	228	226	231
Mountain-S	8	AZ+NM	g C/kWh.e	183	167	167	170
Pacific-N	9	OR+WA+AK	g C/kWh.e	29	26	26	27
Pacific-S	9	CA+HI	g C/kWh.e	60	55	55	56
US Total/avg	All	All	g C/kWh.e	182	167	166	169
Natural gas	All	All	g/MMBtu	14470	14470	14470	14470
Distillate oil	All	All	g/MMBtu	19950	19950	19950	19950

(1) Elect. emissions factors 95-2010 as implied in AEO 96. Elect emiss. factor 1990 from Koomey et al. 1993.
Ratio of regional to national emissions in 1995 is multiplied by national emissions in each year to get regional emissions in each year.
This approach assumes that the relationship between regional and national emissions remains constant over time.
(2) Natural gas and distillate oil taken from EIA Emissions of GHGs in the US 1987-92. p. 15
(3) Electricity emissions (g-C/kWh.e) are at the meter, and include T&D losses.
(4) All carbon emissions factors are from direct emissions, and do not include emissions from the extraction, processing, and transportation of fuels.

Table D-7: Saturations of equipment in existing homes by census division

End-use	*Fuel*	*New England*	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*US*
CAC	Electricity	0.081	0.17	0.37	0.48	0.38	0.40	0.61	0.25	0.21	0.33
CH	Natural gas	0.10	0.28	0.62	0.48	0.18	0.28	0.41	0.50	0.38	0.36
CH	Distillate oil	0.18	0.10	0.034	0.089	0.068	0.011	0	0.010	0.023	0.054
CW	Electricity	0.17	0.15	0.19	0.30	0.50	0.51	0.23	0.27	0.20	0.28
CW	Natural gas	0.27	0.44	0.55	0.45	0.20	0.27	0.52	0.47	0.48	0.41
CW	Distillate oil	0.23	0.16	0.002	0.002	0.011	0	0	0	0	0.039
DRY	Electricity	0.49	0.43	0.54	0.63	0.61	0.74	0.61	0.63	0.42	0.55
DRY	Natural gas	0.11	0.21	0.21	0.15	0.043	0.026	0.12	0.081	0.23	0.14
DW	Electricity	0.09	0.08	0.09	0.15	0.27	0.24	0.14	0.18	0.15	0.15
DW	Natural gas	0.15	0.23	0.25	0.22	0.11	0.12	0.31	0.30	0.34	0.23
DW	Distillate oil	0.13	0.087	0.001	0.001	0.006	0	0	0	0	0.021
F90	Electricity	0.23	0.30	0.44	0.61	0.42	0.54	0.41	0.46	0.27	0.39
F93	Electricity	0.23	0.30	0.44	0.61	0.42	0.54	0.41	0.46	0.27	0.39
FCT	Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FCT	Natural gas	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FCT	Distillate oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
HP	Electricity	0.017	0.017	0.011	0.051	0.15	0.11	0.13	0.036	0.015	0.061
OVN	Natural gas	0.33	0.54	0.41	0.32	0.16	0.14	0.39	0.21	0.39	0.34
R90	Electricity	1.11	1.15	1.20	1.23	1.11	1.19	1.13	1.16	1.17	1.16
R93	Electricity	1.11	1.15	1.20	1.23	1.11	1.19	1.13	1.16	1.17	1.16
RAC	Electricity	0.33	0.42	0.28	0.32	0.27	0.33	0.26	0.10	0.12	0.27
RH	Natural gas	0.020	0.015	0.018	0.028	0.068	0.11	0.19	0.060	0.21	0.082
RNG	Natural gas	0.42	0.58	0.45	0.40	0.23	0.24	0.46	0.26	0.42	0.40
RNG	Distillate oil	0.021	0.093	0.017	0.021	0.086	0.026	0.011	0.016	0.085	0.052
SHW	Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SHW	Natural gas	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SHW	Distillate oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WH	Electricity	0.25	0.20	0.26	0.37	0.66	0.62	0.29	0.35	0.29	0.36
WH	Natural gas	0.39	0.58	0.72	0.55	0.27	0.32	0.67	0.61	0.69	0.55
WH	Distillate oil	0	0.26	0	0.002	0	0	0	0.17	0.012	0.051
DWM	Electricity	0.095	0.079	0.090	0.15	0.27	0.24	0.14	0.18	0.15	0.15

(1) Source: US DOE 1995a.

(2) Existing homes defined as homes in the RECS 1993 sample built before 1987.

Table D-8: Saturations of equipment in new homes by census division

End-use	*Fuel*	*New England*	*Middle Atlantic*	*East North Central*	*West North Central*	*South Atlantic*	*East South Central*	*West South Central*	*Mountain*	*Pacific*	*US*
CAC	Electricity	0.31	0.57	0.74	0.88	0.51	0.54	0.81	0.45	0.46	0.58
CH	Natural gas	0.10	0.49	0.74	0.39	0.21	0.19	0.44	0.40	0.48	0.40
CH	Distillate oil	0.28	0.079	0	0	0.001	0	0	0	0.007	0.017
CW	Electricity	0.36	0.30	0.19	0.42	0.73	0.76	0.46	0.34	0.12	0.43
CW	Natural gas	0.14	0.43	0.64	0.33	0.19	0.16	0.41	0.44	0.49	0.37
CW	Distillate oil	0.33	0.083	0	0	0	0	0	0	0.005	0.019
DRY	Electricity	0.74	0.63	0.54	0.62	0.89	0.88	0.77	0.78	0.43	0.71
DRY	Natural gas	0.045	0.14	0.31	0.15	0.013	0.034	0.11	0.042	0.19	0.11
DW	Electricity	0.30	0.30	0.15	0.42	0.60	0.51	0.43	0.29	0.13	0.37
DW	Natural gas	0.11	0.41	0.49	0.32	0.15	0.10	0.36	0.36	0.50	0.32
DW	Distillate oil	0.26	0.079	0	0	0	0	0	0	0.005	0.016
F90	Electricity	0.18	0.23	0.42	0.33	0.40	0.37	0.42	0.43	0.18	0.35
F93	Electricity	0.18	0.23	0.42	0.33	0.40	0.37	0.42	0.43	0.18	0.35
FCT	Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FCT	Natural gas	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FCT	Distillate oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
HP	Electricity	0.012	0.11	0.008	0.072	0.50	0.29	0.19	0.07	0.13	0.21
OVN	Natural gas	0.056	0.21	0.33	0.11	0.11	0.047	0.18	0.29	0.37	0.21
R90	Electricity	1.16	1.14	1.17	1.20	1.08	1.09	1.06	1.14	1.13	1.12
R93	Electricity	1.16	1.14	1.17	1.20	1.08	1.09	1.06	1.14	1.13	1.12
RAC	Electricity	0.24	0.15	0.11	0.056	0.045	0.13	0.024	0.014	0.081	0.074
RH	Natural gas	0.011	0.000	0.015	0	0	0	0.007	0	0.011	0.005
RNG	Natural gas	0.13	0.30	0.38	0.17	0.17	0.11	0.20	0.38	0.42	0.26
RNG	Distillate oil	0.43	0.004	0	0.057	0.013	0.23	0.041	0.069	0.027	0.052
SHW	Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SHW	Natural gas	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SHW	Distillate oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WH	Electricity	0.46	0.38	0.22	0.54	0.81	0.83	0.54	0.41	0.20	0.51
WH	Natural gas	0.17	0.51	0.70	0.40	0.20	0.17	0.45	0.50	0.73	0.44
WH	Distillate oil	0.38	0.10	0	0	0	0	0	0	0.007	0.022
DWM	Electricity	0.30	0.30	0.15	0.42	0.60	0.51	0.43	0.29	0.13	0.37

(1) Source: US DOE 1995a.

(2) New homes defined as homes in the RECS 1993 sample built 1987 to 1993.

Table D-9: Federal government expenditures to implement appliance efficiency standards						
Fiscal year	*Program costs, contractors/other Million current $*	*DOE salaries Million current $*	*Program costs, contractors/other Million 1995 $*	*DOE salaries Million 1995 $*	*Total Million 1995 $*	*Total PV to 1995 Million 1995 $*
1978	3.7	0.5	8.6	1.2	9.7	30.8
1979	4.1	0.5	8.5	1.0	9.6	28.2
1980	5.0	0.5	9.2	0.9	10.2	28.1
1981	3.8	0.5	6.4	0.8	7.2	18.6
1982	1.8	0.5	2.8	0.8	3.6	8.8
1983	1.0	0.5	1.5	0.8	2.3	5.2
1984	1.7	0.5	2.5	0.7	3.2	6.8
1985	2.5	0.5	3.5	0.7	4.2	8.4
1986	1.9	0.5	2.6	0.7	3.3	6.1
1987	2.0	0.5	2.7	0.7	3.4	5.8
1988	1.8	0.5	2.3	0.6	3.0	4.8
1989	1.8	0.5	2.2	0.6	2.8	4.2
1990	1.7	0.8	2.0	0.9	3.0	4.1
1991	2.0	0.8	2.2	0.9	3.1	4.1
1992	2.5	0.8	2.7	0.9	3.6	4.4
1993	3.5	1.0	3.7	1.1	4.7	5.4
1994	8.1	1.0	8.3	1.0	9.4	10.0
1995	10.3	1.0	10.3	1.0	11.3	11.3
1996	5.3	1.4	5.2	1.4	6.5	6.1
Total					104	201

(1) U.S. government fiscal years (FY) run from October 1 through Sept. 30th. Fiscal year 1996 began October 1, 1995.
(2) DOE salaries estimated by DOE staff.
(3) Current dollars converted to constant 1995 dollars using the consumer price index.
(4) Present value (PV) to 1995 calculated at 7% real discount rate.
(5) Expenditures are for all standards, not just residential standards.

Table D-10: First page of county data on number of households and housing starts

State fips	*state*	*County fips*	*fips*	*County*	*Households*	*% US households*	*New permits*	*% US permits*
1	AL	1	1001	Autauga County	11826	0.01286%	215	0.02020%
1	AL	3	1003	Baldwin County	37126	0.04036%	1932	0.18154%
1	AL	5	1005	Barbour County	9234	0.01004%	47	0.00442%
1	AL	7	1007	Bibb County	5776	0.00628%	0	0.00000%
1	AL	9	1009	Blount County	14616	0.01589%	40	0.00376%
1	AL	11	1011	Bullock County	3755	0.00408%	25	0.00235%
1	AL	13	1013	Butler County	7894	0.00858%	19	0.00179%
1	AL	15	1015	Calhoun County	42806	0.04653%	200	0.01879%
1	AL	17	1017	Chambers County	13860	0.01507%	15	0.00141%
1	AL	19	1019	Cherokee County	7452	0.00810%	23	0.00216%
1	AL	21	1021	Chilton County	12075	0.01313%	47	0.00442%
1	AL	23	1023	Choctaw County	5800	0.00630%	5	0.00047%
1	AL	25	1025	Clarke County	9575	0.01041%	42	0.00395%
1	AL	27	1027	Clay County	4952	0.00538%	13	0.00122%
1	AL	29	1029	Cleburne County	4800	0.00522%	0	0.00000%
1	AL	31	1031	Coffee County	15400	0.01674%	132	0.01240%
1	AL	33	1033	Colbert County	20069	0.02182%	158	0.01485%
1	AL	35	1035	Conecuh County	5253	0.00571%	9	0.00085%
1	AL	37	1037	Coosa County	4010	0.00436%	3	0.00028%
1	AL	39	1039	Covington County	14425	0.01568%	34	0.00319%
1	AL	41	1041	Crenshaw County	5316	0.00578%	6	0.00056%
1	AL	43	1043	Cullman County	25659	0.02789%	91	0.00855%
1	AL	45	1045	Dale County	17521	0.01905%	80	0.00752%
1	AL	47	1047	Dallas County	16975	0.01845%	21	0.00197%
1	AL	49	1049	DeKalb County	21015	0.02284%	72	0.00677%
1	AL	51	1051	Elmore County	16585	0.01803%	281	0.02640%
1	AL	53	1053	Escambia County	12855	0.01397%	37	0.00348%
1	AL	55	1055	Etowah County	38453	0.04180%	239	0.02246%
1	AL	57	1057	Fayette County	6885	0.00748%	11	0.00103%
1	AL	59	1059	Franklin County	10792	0.01173%	29	0.00272%
1	AL	61	1061	Geneva County	9224	0.01003%	12	0.00113%
1	AL	63	1063	Greene County	3482	0.00379%	4	0.00038%
1	AL	65	1065	Hale County	5381	0.00585%	1	0.00009%
1	AL	67	1067	Henry County	5727	0.00623%	39	0.00366%
1	AL	69	1069	Houston County	30856	0.03354%	357	0.03354%
1	AL	71	1071	Jackson County	18099	0.01967%	73	0.00686%
1	AL	73	1073	Jefferson County	251258	0.27313%	2560	0.24054%
1	AL	75	1075	Lamar County	5994	0.00652%	19	0.00179%
1	AL	77	1077	Lauderdale County	30699	0.03337%	178	0.01673%
1	AL	79	1079	Lawrence County	11476	0.01248%	12	0.00113%
1	AL	81	1081	Lee County	32998	0.03587%	360	0.03383%
1	AL	83	1083	Limestone County	19755	0.02147%	104	0.00977%
1	AL	85	1085	Lowndes County	4075	0.00443%	8	0.00075%

(1) The full data set shown in Table D-10 is not included here, but is available in electronic form on request.

APPENDIX E: RESULTS TABLES

This Appendix contains tables summarizing key results from the analysis:

Table E-1: Summary of national effects of residential efficiency standards in 1995

Table E-2: Summary of national effects of residential efficiency standards in 2000

Table E-3: Summary of national effects of residential efficiency standards in 2010

Table E-4: Summary of state-level effects of residential efficiency standards in 1995

Table E-5: Summary of state-level effects of residential efficiency standards in 2000

Table E-6: Summary of state-level effects of residential efficiency standards in 2010

Table E-1: Summary of national effects of residential efficiency standards in 1995

End-use	Fuel	Annual in 1995: Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr	Cumulative 1990-1995: Primary Energy Savings Petajoules	Carbon Savings MT-C	Bill Savings M 1995 $	Incremental Costs M 1995 $	Net PV Benefit M 1995 $
CAC	Electricity	10	0.14	72	41	31	31	0.47	189	134	55
Clothes Washer	Electricity	13	0.19	99	1	98	20	0.28	329	4	325
Clothes Dryer	Electricity	7	0.10	52	31	21	10	0.14	168	101	67
Dishwasher	Electricity	4	0.06	33	9	23	6	0.09	108	31	76
Dishwasher Motors	Electricity	3	0.05	26	11	16	5	0.07	87	35	51
Freezer 1990	Electricity	2	0.03	16	4	12	11	0.16	81	21	60
Freezer 1993	Electricity	5	0.07	36	22	14	10	0.15	118	74	44
Faucets	Electricity	3	0.05	26	4	22	5	0.07	81	14	67
HP	Electricity	3	0.05	25	13	12	13	0.18	86	42	44
Refrigerator 1990	Electricity	12	0.17	99	39	60	66	0.90	488	202	286
Refrigerator 1993	Electricity	51	0.70	407	185	222	106	1.45	1282	610	671
RAC	Electricity	15	0.21	115	11	104	63	0.91	464	50	415
Showers	Electricity	20	0.28	161	17	144	31	0.42	499	55	444
Water Heater	Electricity	47	0.66	353	62	291	175	2.48	1447	256	1191
Central Heat	Natural gas	8	0.11	44	13	31	25	0.35	147	44	103
Clothes Washer	Natural gas	8	0.11	46	2	44	12	0.16	148	6	142
Clothes Dryer	Natural gas	1	0.02	8	8	0	2	0.03	27	27	-1
Dishwasher	Natural gas	3	0.04	15	14	1	4	0.05	49	46	4
Faucets	Natural gas	2	0.03	12	6	6	3	0.04	38	21	17
Oven	Natural gas	7	0.09	40	21	19	23	0.31	149	80	68
Room heat	Natural gas	1	0.02	7	0	7	6	0.09	40	0	39
Range	Natural gas	10	0.13	59	24	35	33	0.46	221	93	128
Showers	Natural gas	13	0.17	77	26	51	19	0.26	232	82	150
Water Heater	Natural gas	101	1.38	595	106	488	362	4.96	2319	424	1895
Central Heat	Distillate oil	0	0.00	0	0	0	0	0.00	0	0	0
Clothes Washer	Distillate oil	1	0.01	4	0	4	1	0.02	12	0	12
Dishwasher	Distillate oil	0	0.00	1	1	0	0	0.01	4	3	1
Faucets	Distillate oil	0	0.00	1	1	1	0	0.01	4	2	2
Showers	Distillate oil	1	0.02	8	2	5	2	0.03	25	8	17
Water Heater	Distillate oil	1	0.02	8	1	7	5	0.09	33	5	28
Total	Electricity	196	2.75	1520	450	1070	553	7.77	5427	1628	3799
Total	Natural gas	152	2.09	904	220	684	489	6.71	3368	823	2545
Total	Distillate oil	3	0.06	22	6	17	8	0.15	79	19	60
Total	All	352	4.90	2446	676	1770	1,050	14.63	8874	2470	6404

(1) 1 Petajoule = 10e15 joules.

(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).

(3) Cumulative carbon emissions calculated using electricity emissions factor for 1995. The error introduced is small because emissions factors change little over the analysis period.

(4) Incremental costs based on annualized method. Cumulative costs and benefits present valued to 1995 at a 7% real discount rate.

Table E-2: Summary of national effects of residential efficiency standards in 2000

		Annual in 2000					Cumulative 1990-2000				
End-use	Fuel	Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr	Primary Energy Savings Petajoules	Carbon Savings MT-C	Bill Savings M 1995 $	Incremental Costs M 1995 $	Net PV Benefit M 1995 $
CAC	Electricity	9	0.14	68	38	30	79	1.18	417	295	122
Clothes Washer	Electricity	41	0.59	311	4	307	173	2.45	1241	15	1226
Clothes Dryer	Electricity	24	0.33	182	107	74	94	1.33	677	407	270
Dishwasher	Electricity	15	0.21	112	33	79	60	0.83	429	125	304
Dishwasher Motors	Electricity	12	0.17	90	37	53	48	0.67	346	141	205
Freezer 1990	Electricity	2	0.03	16	4	12	22	0.31	146	38	108
Freezer 1993	Electricity	7	0.10	51	31	19	42	0.61	299	187	112
Faucets	Electricity	11	0.15	87	14	73	45	0.61	316	54	263
HP	Electricity	3	0.05	25	13	12	30	0.42	193	95	98
Refrigerator 1990	Electricity	12	0.17	99	39	60	128	1.74	874	361	513
Refrigerator 1993	Electricity	90	1.22	713	325	388	504	6.84	3566	1698	1868
RAC	Electricity	14	0.20	111	10	101	137	1.95	868	93	775
Showers	Electricity	68	0.93	539	57	482	278	3.78	1954	214	1740
Water Heater	Electricity	54	0.76	410	73	337	449	6.31	3033	537	2497
Central Heat	Natural gas	8	0.11	44	13	31	64	0.88	330	98	232
Clothes Washer	Natural gas	24	0.34	144	6	138	102	1.41	559	23	537
Clothes Dryer	Natural gas	5	0.07	28	29	0	19	0.27	106	109	-3
Dishwasher	Natural gas	9	0.12	52	48	5	36	0.49	195	181	14
Faucets	Natural gas	7	0.09	42	22	20	28	0.38	147	80	67
Oven	Natural gas	12	0.17	73	38	35	72	0.99	380	205	175
Room heat	Natural gas	1	0.02	7	0	7	13	0.17	72	1	71
Range	Natural gas	18	0.25	109	44	65	107	1.47	564	237	327
Showers	Natural gas	42	0.58	257	86	171	172	2.37	907	321	586
Water Heater	Natural gas	145	1.99	859	154	706	1026	14.07	5307	971	4337
Central Heat	Distillate oil	0	0.00	0	0	0	0	0.00	0	0	0
Clothes Washer	Distillate oil	2	0.03	12	0	12	8	0.14	47	2	45
Dishwasher	Distillate oil	1	0.01	4	3	1	3	0.05	16	13	3
Faucets	Distillate oil	1	0.01	4	2	2	3	0.05	16	8	8
Showers	Distillate oil	4	0.08	26	8	18	16	0.31	98	30	68
Water Heater	Distillate oil	2	0.03	12	2	10	13	0.24	75	12	63
Total	Electricity	363	5.04	2813	786	2027	2,089	29.05	14359	4258	10101
Total	Natural gas	272	3.73	1616	438	1177	1,640	22.49	8567	2226	6341
Total	Distillate oil	9	0.17	58	16	42	42	0.79	252	65	187
Total	All	644	8.93	4487	1240	3247	3,770	52.33	23178	6549	16629

(1) 1 Petajoule = 10e15 joules.

(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).

(3) Cumulative carbon emissions calculated using electricity emissions factor for 2000. The error introduced is small because emissions factors change little over the analysis period.

(4) Incremental costs based on annualized method. Cumulative costs and benefits present valued to 1995 at a 7% real discount rate.

Table E-3: Summary of national effects of residential efficiency standards in 2010

		Annual in 2010					Cumulative 1990-2010				
End-use	Fuel	Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr	Primary Energy Savings Petajoules	Carbon Savings MT-C	Bill Savings M 1995 $	Incremental Costs M 1995 $	Net PV Benefit M 1995 $
CAC	Electricity	0	0.00	0	0	0	112	1.70	536	379	157
Clothes Washer	Electricity	52	0.75	390	5	385	721	10.37	3239	40	3198
Clothes Dryer	Electricity	51	0.74	397	235	163	500	7.19	2148	1291	857
Dishwasher	Electricity	25	0.35	186	55	131	283	4.00	1238	360	878
Dishwasher Motors	Electricity	20	0.28	150	62	88	228	3.22	998	407	592
Freezer 1990	Electricity	1	0.02	9	2	7	39	0.58	213	55	158
Freezer 1993	Electricity	6	0.08	42	26	16	106	1.57	541	338	203
Faucets	Electricity	19	0.27	153	25	128	207	2.85	894	152	743
HP	Electricity	0	0.00	1	0	0	46	0.67	262	129	133
Refrigerator 1990	Electricity	5	0.07	39	15	24	220	3.01	1228	507	720
Refrigerator 1993	Electricity	69	0.94	542	247	295	1348	18.57	6780	3229	3551
RAC	Electricity	1	0.02	12	1	10	214	3.12	1147	123	1024
Showers	Electricity	120	1.65	943	99	843	1278	17.62	5529	606	4922
Water Heater	Electricity	6	0.08	43	8	36	724	10.32	4186	740	3446
Central Heat	Natural gas	5	0.07	28	8	19	132	1.81	532	158	374
Clothes Washer	Natural gas	31	0.42	181	7	174	427	5.85	1459	59	1400
Clothes Dryer	Natural gas	10	0.14	59	60	-1	100	1.38	330	340	-10
Dishwasher	Natural gas	15	0.20	86	79	7	169	2.32	564	524	40
Faucets	Natural gas	12	0.16	73	38	35	128	1.76	415	227	188
Oven	Natural gas	18	0.25	111	57	54	237	3.25	840	454	386
Room heat	Natural gas	0	0.00	0	0	0	19	0.25	92	1	91
Range	Natural gas	27	0.37	163	65	98	350	4.80	1243	523	720
Showers	Natural gas	74	1.02	451	151	299	792	10.86	2566	908	1658
Water Heater	Natural gas	42	0.58	250	45	205	2014	27.62	8268	1512	6756
Central Heat	Distillate oil	0	0.00	0	0	0	0	0.00	0	0	0
Clothes Washer	Distillate oil	2	0.04	15	0	15	31	0.59	123	4	118
Dishwasher	Distillate oil	1	0.02	7	6	2	12	0.23	47	38	9
Faucets	Distillate oil	1	0.02	7	4	4	12	0.23	45	21	23
Showers	Distillate oil	7	0.13	45	14	31	75	1.42	276	85	191
Water Heater	Distillate oil	1	0.01	4	1	3	25	0.47	117	19	99
Total	Electricity	374	5.24	2906	780	2125	6,026	84.8	28938	8355	20583
Total	Natural gas	234	3.21	1402	511	891	4,368	59.9	16309	4705	11603
Total	Distillate oil	12	0.23	79	25	54	156	3.0	609	168	441
Total	All	620	8.68	4387	1316	3071	10,550	147.7	45856	13229	32627

(1) 1 Petajoule = 10e15 joules.

(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).

(3) Cumulative carbon emissions calculated using electricity emissions factor for 2010. The error introduced is small because emissions factors change little over the analysis period.

(4) Incremental costs based on annualized method. Cumulative costs and benefits present valued to 1995 at a 7% real discount rate.

Table E-4: Summary of state-level effects of residential efficiency standards in 1995

End-use		Annual in 1995 Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr
Alaska	AK	0.7	0.01	4.3	1.2	3.0
Alabama	AL	5.7	0.09	36.0	10.6	25.4
Arkansas	AR	3.5	0.05	22.7	6.6	16.0
Arizona	AZ	7.0	0.10	55.0	13.6	41.4
California	CA	37.1	0.36	289.1	68.6	220.5
Colorado	CO	5.8	0.10	32.1	11.5	20.6
Connecticut	CT	3.3	0.04	32.0	6.6	25.4
District Of Columbia	DC	0.7	0.01	4.7	1.3	3.4
Delaware	DE	1.0	0.01	7.9	2.1	5.8
Florida	FL	23.0	0.32	172.4	42.8	129.6
Georgia	GA	10.7	0.15	73.1	21.0	52.1
Hawaii	HI	1.4	0.01	19.2	2.6	16.6
Iowa	IA	3.8	0.06	24.4	7.6	16.8
Idaho	ID	1.7	0.03	8.2	3.4	4.8
Illinois	IL	16.3	0.25	116.1	31.0	85.1
Indiana	IN	8.7	0.13	50.2	16.8	33.4
Kansas	KS	3.6	0.06	22.5	7.2	15.2
Kentucky	KY	5.1	0.08	25.8	9.9	16.0
Louisiana	LA	6.0	0.09	38.5	11.1	27.4
Massachusetts	MA	6.2	0.07	55.3	12.2	43.1
Maryland	MD	6.5	0.09	47.4	13.3	34.1
Maine	ME	1.3	0.01	11.7	2.7	9.1
Michigan	MI	13.5	0.21	79.7	26.4	53.3
Minnesota	MN	6.4	0.11	37.6	13.2	24.4
Missouri	MO	7.6	0.13	45.7	15.0	30.7
Mississippi	MS	3.3	0.05	20.3	6.3	14.0
Montana	MT	1.0	0.02	5.2	2.0	3.2
North Carolina	NC	10.7	0.15	76.9	21.3	55.6
North Dakota	ND	0.8	0.01	4.4	1.7	2.7
Nebraska	NE	2.3	0.04	12.1	4.4	7.6
New Hampshire	NH	1.2	0.01	11.2	2.4	8.8
New Jersey	NJ	9.6	0.12	79.4	18.4	61.1
New Mexico	NM	2.1	0.03	14.3	4.1	10.3
Nevada	NV	3.0	0.05	16.8	6.0	10.8
New York	NY	20.3	0.26	194.3	38.8	155.5
Ohio	OH	15.6	0.24	98.7	29.8	68.8
Oklahoma	OK	4.5	0.07	25.2	8.6	16.6
Oregon	OR	4.4	0.04	23.7	8.5	15.2
Pennsylvania	PA	15.5	0.20	115.2	29.7	85.5
Rhode Island	RI	1.0	0.01	9.1	2.0	7.1
South Carolina	SC	5.1	0.07	33.8	9.9	23.8
South Dakota	SD	0.9	0.02	5.5	1.9	3.6
Tennessee	TN	7.4	0.12	39.4	14.4	25.0
Texas	TX	26.0	0.40	169.5	48.0	121.4
Utah	UT	2.6	0.04	14.3	5.2	9.1
Virginia	VA	9.2	0.13	63.7	18.5	45.1
Vermont	VT	0.6	0.01	4.6	1.2	3.4
Washington	WA	7.8	0.07	35.7	15.0	20.7
Wisconsin	WI	7.4	0.11	45.9	14.5	31.4
West Virginia	WV	2.1	0.03	12.4	4.2	8.2
Wyoming	WY	0.6	0.01	3.0	1.2	1.9
Total	US	352	4.9	2446	676	1770

(1) 1 Petajoule = 10e15 joules.

(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).

(3) Incremental costs based on annualized method.

Table E-5: Summary of state-level effects of residential efficiency standards in 2000

		Annual in 2000				
End-use		Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr
Alaska	AK	1.3	0.01	8.5	2.4	6.1
Alabama	AL	10.3	0.17	65.0	19.2	45.9
Arkansas	AR	6.2	0.09	40.0	11.9	28.1
Arizona	AZ	13.5	0.19	106.3	26.3	80.0
California	CA	69.0	0.66	544.1	130.5	413.5
Colorado	CO	11.3	0.19	63.0	22.2	40.8
Connecticut	CT	6.1	0.07	58.7	12.1	46.6
District Of Columbia	DC	1.3	0.02	8.8	2.4	6.4
Delaware	DE	1.8	0.03	14.0	3.6	10.5
Florida	FL	42.6	0.59	319.3	79.4	239.9
Georgia	GA	20.3	0.28	137.9	39.0	98.8
Hawaii	HI	2.6	0.02	35.8	5.0	30.7
Iowa	IA	6.8	0.11	43.5	13.4	30.2
Idaho	ID	3.4	0.06	16.1	6.6	9.5
Illinois	IL	28.8	0.44	206.1	55.2	150.8
Indiana	IN	15.7	0.24	90.4	30.5	59.9
Kansas	KS	6.6	0.11	40.9	13.0	27.9
Kentucky	KY	9.3	0.15	47.2	17.7	29.6
Louisiana	LA	10.3	0.16	66.6	19.6	47.0
Massachusetts	MA	11.3	0.13	101.7	22.5	79.2
Maryland	MD	12.3	0.17	89.7	24.1	65.6
Maine	ME	2.5	0.03	22.0	4.9	17.0
Michigan	MI	24.1	0.37	143.4	47.0	96.4
Minnesota	MN	11.9	0.20	69.5	23.8	45.8
Missouri	MO	13.6	0.23	81.5	26.6	54.9
Mississippi	MS	6.0	0.10	36.3	11.2	25.1
Montana	MT	2.0	0.03	9.8	3.8	6.1
North Carolina	NC	20.2	0.28	145.7	39.2	106.5
North Dakota	ND	1.5	0.02	7.9	2.9	4.9
Nebraska	NE	4.0	0.07	21.7	7.9	13.8
New Hampshire	NH	2.3	0.03	21.4	4.5	16.9
New Jersey	NJ	17.3	0.22	144.1	33.5	110.6
New Mexico	NM	4.0	0.06	27.7	7.8	19.9
Nevada	NV	5.9	0.10	33.7	11.9	21.8
New York	NY	35.6	0.46	342.5	68.7	273.8
Ohio	OH	27.4	0.42	175.1	53.0	122.1
Oklahoma	OK	7.9	0.12	44.5	15.2	29.3
Oregon	OR	8.4	0.07	44.7	16.3	28.4
Pennsylvania	PA	27.6	0.35	206.5	53.7	152.8
Rhode Island	RI	1.8	0.02	16.8	3.7	13.1
South Carolina	SC	9.5	0.13	63.0	18.1	44.9
South Dakota	SD	1.7	0.03	10.1	3.5	6.7
Tennessee	TN	13.8	0.22	73.7	26.4	47.3
Texas	TX	46.8	0.71	304.1	88.3	215.7
Utah	UT	5.1	0.09	28.1	10.1	18.0
Virginia	VA	17.5	0.24	120.8	34.0	86.8
Vermont	VT	1.1	0.01	8.8	2.3	6.5
Washington	WA	15.0	0.13	68.6	29.2	39.4
Wisconsin	WI	13.4	0.21	83.3	26.2	57.1
West Virginia	WV	3.8	0.05	22.1	7.3	14.8
Wyoming	WY	1.2	0.02	5.8	2.2	3.5
Total	US	644	8.9	4487	1240	3247

(1) 1 Petajoule = 10e15 joules.
(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).
(3) Incremental costs based on annualized method.

Table E-6: Summary of state-level effects of residential efficiency standards in 2010

		Annual in 2010				
End-use		Primary Energy Savings Petajoules	Savings MT-C	Bill Savings M 1995 $/yr	Incremental Costs M 1995 $/yr	Net Benefit M 1995 $/yr
Alaska	AK	1.2	0.01	8.8	2.6	6.2
Alabama	AL	9.9	0.16	62.4	20.1	42.3
Arkansas	AR	5.7	0.09	37.2	12.3	24.9
Arizona	AZ	13.8	0.20	110.2	29.6	80.6
California	CA	68.8	0.63	564.4	148.2	416.2
Colorado	CO	11.4	0.20	65.1	24.4	40.7
Connecticut	CT	6.2	0.07	59.1	13.2	45.9
District Of Columbia	DC	1.2	0.02	8.5	2.4	6.0
Delaware	DE	1.9	0.03	14.2	3.8	10.5
Florida	FL	42.6	0.60	320.3	86.4	233.9
Georgia	GA	20.8	0.29	140.8	42.2	98.6
Hawaii	HI	2.6	0.02	34.5	5.7	28.8
Iowa	IA	6.2	0.11	40.0	13.2	26.8
Idaho	ID	3.4	0.06	16.4	7.4	9.0
Illinois	IL	25.8	0.41	191.3	56.0	135.3
Indiana	IN	14.4	0.23	83.3	31.3	52.0
Kansas	KS	6.3	0.11	39.6	13.5	26.0
Kentucky	KY	8.9	0.15	45.3	18.0	27.3
Louisiana	LA	9.4	0.14	60.8	20.1	40.7
Massachusetts	MA	11.3	0.13	101.7	24.2	77.5
Maryland	MD	12.6	0.18	91.4	25.4	66.0
Maine	ME	2.5	0.03	22.9	5.5	17.5
Michigan	MI	21.9	0.35	134.8	47.5	87.2
Minnesota	MN	11.5	0.20	68.0	24.6	43.4
Missouri	MO	12.7	0.22	77.2	27.3	49.8
Mississippi	MS	5.7	0.09	34.6	11.5	23.1
Montana	MT	1.9	0.03	9.4	4.0	5.5
North Carolina	NC	20.6	0.29	148.1	41.8	106.4
North Dakota	ND	1.4	0.02	7.5	3.0	4.5
Nebraska	NE	3.8	0.07	20.3	8.1	12.2
New Hampshire	NH	2.4	0.03	22.9	5.2	17.8
New Jersey	NJ	16.3	0.21	139.3	35.4	103.9
New Mexico	NM	4.1	0.06	28.8	8.7	20.1
Nevada	NV	6.2	0.11	35.5	13.4	22.1
New York	NY	32.2	0.41	316.6	69.5	247.1
Ohio	OH	24.3	0.38	158.8	52.8	106.1
Oklahoma	OK	7.3	0.11	42.1	15.7	26.3
Oregon	OR	8.3	0.06	43.5	18.0	25.5
Pennsylvania	PA	25.4	0.33	192.5	55.0	137.6
Rhode Island	RI	1.8	0.02	17.0	4.0	13.0
South Carolina	SC	9.5	0.13	63.4	19.3	44.2
South Dakota	SD	1.7	0.03	9.8	3.6	6.2
Tennessee	TN	13.7	0.22	73.2	27.9	45.3
Texas	TX	44.3	0.69	290.9	95.4	195.5
Utah	UT	5.3	0.09	29.5	11.3	18.2
Virginia	VA	17.9	0.25	123.3	36.2	87.1
Vermont	VT	1.2	0.01	9.2	2.5	6.6
Washington	WA	15.1	0.12	68.6	32.7	35.9
Wisconsin	WI	12.4	0.20	77.3	27.0	50.4
West Virginia	WV	3.5	0.05	20.4	7.1	13.3
Wyoming	WY	1.2	0.02	5.9	2.5	3.4
Total	US	620	8.7	4387	1316	3071

(1) 1 Petajoule = 10e15 joules.
(2) Electricity expressed as primary energy at 10,800 Btu/kWh (3.165 kWh.primary/kWh.electricity).
(3) Incremental costs based on annualized method.

Ernest Orlando Lawrence Berkeley National Laboratory
One Cyclotron Road | Berkeley, California 94720

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098